

**THE ROLE OF FACILITATION AND SOCIAL PROCESSES IN
COLLABORATIVE LEARNING: IMPLICATIONS FOR THE DESIGN OF AN
APPLIED SYSTEMS SCIENCE CURRICULUM**

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I hereby certify that this thesis is my own work, and I have not obtained a degree in this University, or elsewhere, on the basis of this work.

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a little help from others can be a great blessing.”

- Uncle Iroh

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“Then something Tookish woke up inside him, and he wished to go and see the great mountains, and hear the pine-trees and the waterfalls...”

- J.R.R. Tolkien

List of works

Below is a list of publications and conference presentations, which have stemmed from work relating to this thesis.

Publications

- Dwyer, C. P., Hogan, M. J., **Harney, O. M.**, & Kavanagh, C. (2017). Facilitating a student-educator conceptual model of dispositions towards critical thinking through interactive management. *Educational Technology Research and Development*, 65(1), 47-73.
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- Hogan, M., Hall, T., & **Harney, O.M.** (2017). Collective Intelligence Design and a New Politics of System Change. *Civitas Educationis. Education, Politics, and Culture*, 6(1), 51-78.
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- Dwyer, C. P., Hogan, M. J., **Harney, O. M.**, & O'Reilly, J. (2014). Using Interactive Management to facilitate a student-centred conceptualisation of critical thinking: A Case Study. *Educational Technology Research and Development*, 62, 687-709.
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- Hogan, M. J., **Harney, O. M.**, & Broome, B. (2014). Integrating Argument Mapping with Systems Thinking Tools – Advancing Applied Systems Science. In A. Okada, S. Buckingham Shum, & T. Sherborne (Eds.). *Knowledge Cartography: Software Tools and Mapping Techniques* (pp. 401-421). London: Springer.
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Abstract

Resolving complex scientific and social problems requires effective collaboration. In the absence of adequate facilitation and the use of a structured methodology, however, collaborative groups often fail to reach their potential. Recognising this, John Warfield developed Interactive Management (IM), a computer-supported systems science methodology designed to harness the collective intelligence of groups, specifically, in the design of collaborative systems models. Warfield also proposed the incorporation of this methodology into a systems science education curriculum to foster skill in the application of collaborative, systems science methodologies. This thesis advanced upon Warfield's vision by investigating key aspects of the integration of IM into university education. Over the course of three experimental studies, the IM facilitation process and collaborative learning process was modified in specific ways and effects on both learning and social-emotional outcomes and processes were examined. The findings of these studies were then used to inform the design and implementation of an applied systems science education curriculum, which was piloted with a group of 23 undergraduate students over the course of a semester.

Study 1 investigated the influence of dialogue on students' levels of perceived efficacy of the IM methodology, as well as levels of perceived consensus and objective consensus in relation to the topic which was the focus of the IM session. Study 1 revealed that restricting dialogue had a significant negative impact on students' perceptions of the IM process. More specifically, students who were not permitted to engage in dialogue reported significantly lower levels of perceived efficacy of the IM methodology, as well as significantly lower levels of perceived consensus with other students in their group.

Study 2 examined the effects of task-level versus process-level prompts on variety and complexity of argumentation during an IM systems model-building task, as well as students' levels of perceived efficacy of the IM methodology, perceived consensus, objective consensus, and team orientation. When compared with task-level prompting, process-level prompting resulted in students engaging in more varied and complex argumentation during the collaborative systems model-building task, as well as reporting higher levels of perceived consensus and higher levels of perceived efficacy of the IM methodology.

Study 3 investigated the effects of facilitator-driven prompting versus peer-to-peer prompting on the variety and complexity of argumentation during an IM systems model-building task, as well as students' levels of perceived efficacy of the IM methodology, perceived consensus, objective consensus, team orientation, and discomfort in group learning.

The results of this study revealed that peer-to-peer prompting had significant positive effects, resulting in more varied and complex argumentation during the collaborative systems model-building task, as well as significantly higher levels of perceived efficacy of the IM methodology, higher perceived consensus and team orientation, and significantly lower levels of discomfort in group learning.

The findings of these studies were then used to inform the design and implementation of an applied systems science education curriculum, which was piloted with a group of undergraduate students over the course of a semester, and evaluated based on reflections provided by the students and instructors. These reflections, addressing various aspects of the pilot module design and delivery, were predominantly positive, indicating the potential of applied systems science education at university level going forward.

The findings presented in this thesis, including their implications for teaching and learning, and contributions to the literature are discussed as well as considerations for the continued advancement of Warfield's vision for applied systems science education. Finally, limitations of the studies and proposed directions for future research are outlined.

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List of Abbreviations

AM: Argument Mapping
CACCS: Conversational Argument Coding Scheme
CSCL: Computer-Supported Collaborative Learning
ES: Effect Size
FTGW: Feelings Towards Group Work
GDSS: Group Decision Support Systems
HCTA: Halpern Critical Thinking Assessment
IM: Interactive Management
ISM: Interpretive Structural Modelling
MEPA: Multiple Episode Protocol Analysis
NGT: Nominal Group Technique
SAT: Scholastic Aptitude Test
SBD: Scenario-Based Design
TMX: Team Member Exchange

Preface

“If we teach today’s students as we taught yesterday’s, we rob them of tomorrow.”

— John Dewey

Background

Collaborative learning, or the ability to develop a shared understanding of an issue or problem in a group setting, is fundamental for human survival, adaptation, and flourishing in a dynamic and changeable environment. Problems vary across situations, and in some situations groups need to develop an understanding of complex problems that include many interacting elements that operate together as part of a system. In these situations, the group needs to collaborate using a method that supports some form of systems thinking in order to adequately understand and address the problem. Collaboration, however, is invariably hard work. It can be particularly difficult to establish cooperative dynamics in groups of individuals who come together for the first time - individuals who have not had a chance to engage in dialogue, establish a sense of shared trust, or who have no norms established for working together, or no methodology to support consensus-building and systems thinking in the group. Ultimately, our proclivity for collaboration and cooperation is simply that – a proclivity, a tendency, a potentiality – it needs to be supported and maintained by certain environmental conditions, specific patterns of behaviour, and methods of working together at the group level (Warfield, 1976; Wilson, Ostrom, & Cox, 2013).

John Dewey famously argued that a democratic society requires an educated population that can engage in inquiry on open-ended issues. Indeed, he argued that the best place to practice and develop the essential skills needed to support collaborative learning and democratic deliberation is in the classroom. Democracy has to be reborn anew in every generation and education, says Dewey, is its midwife. A collaborative, informed and reflective attitude among the world’s population is needed to address many pressing issues including promoting global peace, designing sustainable environments, and facilitating social and economic justice. The range of global and local problems that groups face is immense, and supporting collaborative learning and skill development in the population is increasingly being recognised as important.

The ability to collaborate and work effectively with others in a team-based setting is increasingly highlighted as an essential skill in business, education, science, and other domains (Hesse, Care, Buder, Sassenberg, & Griffin, 2015). From a sociological and systems

design perspective, collaboration is also seen as fundamental in our collective effort to resolve complex scientific and social issues (Warfield, 1976; 2006). In line with this growing awareness and appreciation of collaboration as a means to resolve collective problems, various forms of collaborative learning have been introduced, employed, and experimented with across all levels of education over the past few decades (Dillenbourg, Järvelä, & Fischer, 2009; Johnson & Johnson, 2009). While a variety of definitions of collaborative learning exist in the literature, Roschelle and Teasley's (1995) succinct definition is widely cited. Collaborative learning, they propose, involves the co-construction of shared understanding.

Roschelle and Teasley note that shared understanding is something that can emerge and be transformed over time as a group works together. However, developing any shared understanding of an issue or problem presents many challenges for a group, and requires the coordination of potentially complex social-emotional and cognitive features of group dynamics. Also, in efforts to establish a shared understanding of complex systems where multiple sub-problems are interrelated, key methodological issues designed to support groups in dealing with complexity need to be considered. Central to this thesis is the claim that collaborative learning can be aided by carefully structured and purposefully implemented learning methodologies. In the absence of a structured methodology, particularly in situations where the goal of collaboration is to achieve a shared understanding of complex systems, groups can experience difficulties in communication and in the coordination and integration of their individual perspectives and knowledge (Broome & Fulbright, 1995). This thesis pays homage in particular to the work of John Warfield, past president of the International Society for Systems Sciences, and describes how his methodology, Interactive Management (IM; Warfield 1976; 2006), can be used to support collaborative learning in an educational context.

John Warfield recognised the difficulties that groups experience in effectively tackling and resolving complex societal problems, and focused on developing computer-supported collaborative learning methods designed to support groups in catalysing their collective intelligence in response to complex problems. According to Warfield, resolving complex scientific and societal problems as a group involves learning and the development of a shared understanding, which the group can then use to bring about change in a problematic situation. Warfield's methodology, IM, supports groups in developing structural models (or problematiques) that provide a systems-based representation of the structure of complex problems. An overview of Warfield's methodology and a description of how it can be

integrated into a curriculum focused on applied systems science will be a central focus in Chapter 1 of this thesis.

Complimentary to Warfield's methodological innovation, is the empirical and theoretical work of Gerry Stahl, Rupert Wegerif and other scholars who emphasise the importance of dialogical interaction as a key driver of learning for both individuals and groups (Mercer, 2000; Mercer, Dawes, Wegerif, & Sams, 2004; Stahl, 2010; Wegerif, 2007, 2010). Importantly, this focus on dialogical interaction is central to the work of many scholars in the Learning Sciences field of computer-supported collaborative learning (CSCL). According to Stahl (2015), given the institutions of schooling which have been inherited from the industrial age, significant emphasis is needed on the development of curricula which, in design and delivery, incorporate a Learning Sciences emphasis on student-centred, collaborative, explorative, immersive, computer-supported problem-solving approaches.

Unfortunately, according to Stahl (2015), CSCL research is often carried out using technologies which were designed based on models of individual learning and knowledge transfer, rather than the more ideal scenario in which technologies are designed based on an understanding of meaning negotiation, collaborative knowledge building or dialogical interaction. Stahl notes that one of the reasons for this may be that it is generally easier, or more affordable, for researchers to employ existing commercial technologies to support communication and classroom learning, rather than developing software or programmes which are designed with the specific function of supporting collaboration and group cognition. Importantly, Stahl notes that commercial software is generally not designed to facilitate collaborative knowledge building, but rather is often designed to enhance personal productivity and exchange of individual opinions. In this programme of research, Warfield's IM methodology is imported into university education. Although not originally designed for educational purposes, Warfield's methodology was developed with the aim of supporting collaboration, meaning-making, problem-solving, and consensus-building, and it emphasises the design of an environment which facilitates open, constructive dialogue, with the added structure of a computer-supported tool to support the development of consensus-based structural models as a product of group work.

One potential outcome of CSCL is systems thinking at the group level. In one of his last published papers, Warfield argued that systems thinking needs to be cultivated in an educational context, specifically, using collaborative methodologies like IM (Warfield, 2010). In his seminal work on systems science, Warfield (1976) also noted the degree to which systems science practice emphasised an exclusive role of individual systems

modellers. For example, many of the systems models developed in economics and environmental science are developed by individuals, not teams. The systems science field has broadly failed to highlight the importance of collaborative systems thinking and the critical value of groups and teams working together to understand and resolve complex societal problems.

Facilitating collaborative learning

As outlined in Chapter 1, the methodologies and frameworks of Warfield, Stahl and others can serve to guide the design of educational environments that support collaborative learning and systems thinking. At the same time, a number of key challenges remain in the implementation of CSCL approaches in the classroom. Experimental and design-based research (DBR) is needed to further understand and address these challenges. Based on the literature described in Chapter 2, these challenges can be broadly divided into two categories: challenges associated with *facilitation* of collaborative student groups that seek to develop an understanding of complex problems; and challenges associated with the *empowerment* of students who seek to regulate and direct their own collaboration as part of a peer-to-peer learning process, in the absence of external facilitation and control. Students may be facilitated and empowered in a variety of different ways when using CSCL tools and related methodologies, and experimental work can shed light on the specific effects of different manipulations and contextual variables in this regard. Key experimental manipulations of relevance to the synthesis of systems science and CSCL which are addressed in this thesis include: the presence or absence of dialogue in a collaborative systems model-building process (Study 1), the use of task-level versus process-level prompts in the facilitation of group dialogue and argumentation during a systems model-building process (Study 2), and the comparison of facilitator-driven versus peer-to-peer prompts in a systems model-building process (Study 3). Understanding derived from analysis and synthesis of experimental findings can then be used to inform the broader design of an applied systems science curriculum. More specifically, such understanding can be used to inform the design of a specific strategy for taking students through the process of collaboration, and subsequently empowering student groups to monitor and guide their own collaboration through peer-to-peer interaction in an environment that promotes effective group dynamics, as described in Chapter 6.

Both within and outside of an educational context, a focus on collaborative learning and team-based systems thinking involves consideration of a range of social, emotional and

cognitive processes. Consistent with a large body of research in the Learning Sciences, central to the experimental studies presented in the current thesis is a focus on the quality of argumentation in collaborative learning settings, specifically, during the act of building consensus-based systems models. In addition to this core cognitive focus, a number of social-emotional variables of interest in the current thesis include trust, perceived consensus, perceived efficacy of the IM methodology, team orientation, and feelings of discomfort in the collaborative learning setting. In particular, Chapters 3-5 describe the results of three experimental studies, which sought to manipulate key aspects of facilitation, interaction, and empowerment in collaborative learning environments, with the aim of investigating both process-related and effect-oriented aspects of collaboration. Chapter 6 builds upon this work and provides an account of the design, implementation, and evaluation of a pilot applied systems science curriculum focused on the development of collaborative enquiry skills in a small group learning environment, and the application of Warfield's Interactive Management methodology to a range of real-world applied problems. A summary overview of the thesis chapters is provided below.

Overview of the chapters

Chapter 1 introduces the applied systems science vision of John Warfield, as well as the computer-supported methodology which he developed, Interactive Management. This methodology is central in the design of the three experimental studies, presented in Chapters 3, 4, and 5, and is also a core component of the pilot applied systems science education curriculum reported in Chapter 6. Chapter 1 also introduces a central thread running through the thesis, specifically, a focus on dialogue and the facilitation of dialogue in the service of developing a shared understand of complex problems. A focus on dialogue and theories of dialogue helps to shed light on a number of key social, emotional, and cognitive processes that can influence the quality and nature of shared understanding that develops in a group collaboration, and thus provides a useful context for understanding the types of experimental and contextual variables that can be examined in a CSCL educational context.

Chapter 2 begins with an overview of research in the area of collaborative learning. This is followed by a review of research focused on the cultivation, facilitation, and support of argumentation skills in the classroom. Chapter 2 also explores the benefits of peer learning, as well as the potential of peer learning as an approach to support greater student engagement in collaborative discourse and argumentation in the classroom. This chapter then examines key social-emotional processes which may have an impact on collaborative

learning processes and outcomes, including: consensus, team orientation, attitudes towards group learning, perceived efficacy, and trust. Last, Chapter 2 closes with a section detailing the rationale for each of the experimental studies presented in subsequent chapters.

Chapters 3, 4, and 5, report three interrelated, empirical studies. Each study builds upon the previous to assess key variations in the application of the IM methodology as an educational tool. Each study chapter includes a rationale for specific hypotheses grounded in the research literature, a description of the research methodology, presentation of results, and a discussion of key findings.

Chapter 3 presents the first empirical study, which introduces students to the IM systems model-building process. Study 1 explores the influence of dialogue on both objective and perceived consensus in response to a shared problem, and perceived efficacy of the IM methodology from a student perspective. This study highlights in particular the negative effects of inhibiting dialogue in the process of building a consensus-based systems model in an educational context. Initial levels of trust across group members are also identified as a significant factor positively influencing group outcomes.

Chapter 4 presents the results of Study 2. To further explore the importance of dialogue, this study investigates the influence of different IM facilitator prompting styles during a collaborative systems model-building session. In particular, Study 2 explores the influence of task-level versus process-level prompting on the variety and complexity of collaborative argumentation during an IM session. As in Study 1, consensus and efficacy are key outcomes of interest, alongside an additional focus on team orientation. Study 2 highlights the benefits of providing process-level prompts to students during an IM session, as opposed to task-level prompts. Again, initial levels of trust also positively influence group outcomes.

Chapter 5 builds upon the previous two chapters by integrating the concept of peer-to-peer prompting into the IM methodology. Although originally designed as a facilitator-driven process, facilitation of the IM process - in particular, the process of prompting reasoning during the systems model-building process - can be transferred directly to student groups. Study 3 compares the effects of facilitator-driven versus peer-to-peer prompts on a variety of cognitive and social-psychological outcomes in the group. In particular, Study 3 examines whether or not peer-to-peer prompting is more effective than facilitator-driven prompting in enhancing the quality of argumentation in a group context, as well as the levels of perceived and objective consensus, perceived efficacy, team orientation, and discomfort in group learning. Study 3 highlights a range of cognitive and social-emotional benefits associated

with empowering students to engage in peer-to-peer prompting during an IM systems model-building process.

Chapter 6 draws from each of the previous chapters, and describes a pilot applied systems science education curriculum. This curriculum was run over a 12-week period with a group of final year undergraduate university students. The course design incorporated a focus on capacity building in the areas of dialogue, argumentation, collaboration, CSCL tool use, peer prompting, and teamwork. Chapter 6 provides an account of the design, implementation, and evaluation of the pilot curriculum, as well as reflections from both the course facilitators and students.

Last, Chapter 7 provides a retrospective overview of each chapter of the thesis. This is followed by a summary of the findings from each experimental study, as well as a discussion of the implications of each for teaching and learning and the contributions made to the collaborative learning literature. This is followed by a discussion of key considerations in the context of advancing a vision for applied systems science education and broader implications for education into the future.

Chapter 1: Introduction

1.1. Chapter overview

Chapter 1 provides an overview of the theoretical, philosophical, and methodological approaches which are central to this thesis. This begins with an introduction to John Warfield's approach to systems science, including a detailed description of the systems science methodology which he developed, Interactive Management (IM), and his vision for the integration of his systems science methodology into university education. This is followed by a wider exploration of the concept of dialogue, including reference to the philosophical perspectives of key thinkers in the area of dialogue, as well as an overview of recent research and thinking on the role of dialogue in the collaborative learning classroom. Next, Chapter 1 discusses collaborative learning from the perspective of the Learning Sciences, including key lessons and considerations derived from this rapidly expanding field. Finally, Chapter 1 closes with a description of the approach taken to applied systems science education in the current thesis, with reference to key components and considerations derived from the aforementioned theoretical, philosophical, and methodological approaches.

1.2. John Warfield and applied systems science

In his classic book, *Societal Systems: Planning, Policy and Complexity*, John Warfield (1976) opens by documenting a range of complex societal problems (e.g., war, crime, poverty, environmental degradation, etc.) that need to be addressed by groups who recognise these societal problems as shared problems. One of the main reasons we find it difficult to tackle societal problems, says Warfield, is because we lack methodologies that support the development of shared understanding of complex issues. As such, in the absence of some shared understanding, we often fail to develop consensus-based action plans in response to problems. From Warfield's perspective, dealing with complex societal problems requires group learning, and the development of a shared understanding of the societal problem the group has identified as a focus of collective enquiry and action. This shared understanding becomes the basis for the group's efforts to bring about change in response to the societal problem, or problem situation. A complex societal problem, according to Warfield, generally includes many interacting elements, or sub-problems, that operate together in a system of interdependencies. Developing an understanding of a complex societal problem, or problem situation, involves an enquiry regarding ways in which these interacting elements operate

together as part of a system. To support group problem-solving and applied systems science focused on collective action in response to societal problems, Warfield focused on developing specific tools and group facilitation methods designed to provide a structured approach to tackling complexity and harnessing the collective power of groups (Warfield and Cardenas, 1994; Warfield 2006). In working towards this goal, two aspects of Warfield's overall approach can be distinguished: (a) the use of learning methodologies and tools to support systems thinking and, (b) the facilitation and empowerment of collaborative teams to collectively solve problems.

1.2.1 Methodologies and tools to support systems thinking

Warfield developed a unique applied systems science methodology IM. IM is a computer-supported thought and action mapping process which helps groups to develop outcomes that integrate contributions from individuals with diverse views, backgrounds, and perspectives. A detailed description of the key steps in the IM process is provided in Section 1.2.2. below, and a summary overview of the key steps is presented in Figure 1. As can be seen in Figure 1, central to IM is a matrix structuring process which facilitates groups in developing structural hypotheses describing interdependencies between elements in a system (i.e., sub-problems in a problem situation), based on the consensus-based logic of the group. Integrating ideas from formal logic and the mathematics of matrices, consensus-based decisions as regards key relations of influence among a set of elements in a system are translated into a graphical representation illustrating the logic of the group. These graphical representations act as systems models that inform the shared understanding of a group. Although the mathematics behind the process of transforming a completed matrix into a graphical representation is somewhat complex (see Warfield, 1976, Chapters 11 - 14), drawing in particular on the mathematics of matrices and graph theory, the application of the software for the purpose of generating a structural hypothesis in relation to any given problem situation is reasonably straightforward. In fact, Warfield emphasised the importance of separating the computational complexity of structuring from the process of dialogue, information search, deliberation, and voting in a group. The IM software is designed to alleviate the group of computational burden in the query-driven matrix completion process, and thus allows them the opportunity to maximise the processes of creative idea generation, dialogue, information search, critical thinking and voting in relation to key binary relations in the overall problem structure.



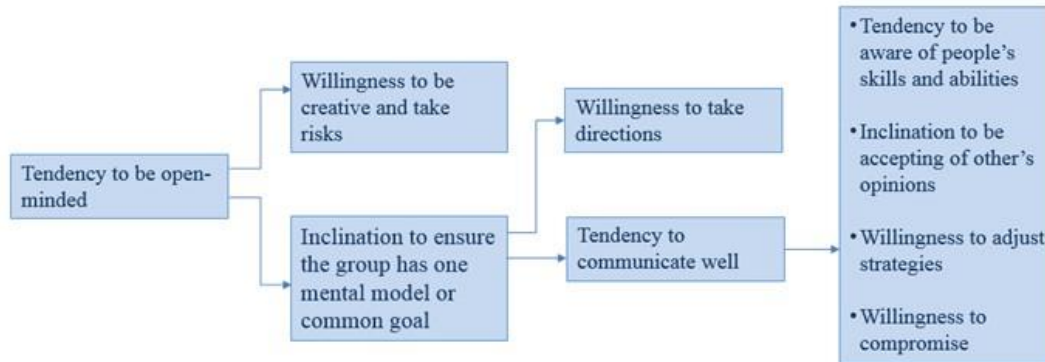
(1) Generate and Clarify Ideas using NGT or Ideawriting

1	2	3	4	5	6	7	8	9
1	1	0	0	0	1	0	1	0
1	1	0	0	0	1	0	1	0
0	0	1	0	0	0	0	1	0
0	0	0	1	0	0	0	1	0
1	1	1	0	1	1	1	1	0
1	1	0	0	0	1	0	1	0
0	0	1	0	0	0	1	1	0
0	0	0	0	0	0	0	1	0
1	1	1	0	0	1	0	1	1

(3) Structure Ideas using Matrix, based on Group Deliberation and Logic

ID	Idea
2	Willingness to cooperate
3	Willingness to learn
4	Tendency to be confident to put forward your argument
5	Motivation to be alert
1	Willingness to communicate
6	Willingness to be patient
9	Tendency to be open-minded
8	Willingness to be creative and take risks
7	Willingness to take directions

(2) Select Ideas for Structuring using Voting Process



(4) Generate Graphical Representation of Group Logic

Figure 1. A simple visual description of some of the key steps in the IM methodology

Warfield suggests that understanding societal problems always involves an effort to identify how problems in the problem situation interact. As such, the *problem situation*, as Warfield describes it, invariably involves a set of interrelated sub-problems. This requirement to understand the problem situation is the same for societal problems that operate on a large scale, such as conflict resolution between nations, and for societal problems that operate on an apparently smaller scale, such as improving mental health in a local school. Failure on the part of a group to recognise potential interactions between problems in the problem situation, and deriving action plans and policies from simple models that neglect these interactions, may result in undesirable outcomes and precludes action by the group that could be beneficial to resolving shared problems.

Although the mathematics of matrices supports the structuring of interdependencies in a system, in order for a group to be able to work with systems models, the models need to describe problems using language and graphics that are open to comprehension and that can form the basis for coherent action plans. Warfield critiques approaches to systems modelling that are exclusively mathematical, and not the result of collaborative dialogue and knowledge exchange. For example, Warfield (1976) was explicit in his critique of Forrester's (1973) approach to systems modelling, and the dominant school of thought at the Massachusetts Institute of Technology (MIT) at the time. Notably, a major catalyst for the emergence of Warfield's applied systems thinking approach was the publication of Forrester's World Model (1973). Forrester's original World Model, which focused on global dynamics including population growth, economic development, and environmental resources included 58 elements, 81 pair relations, and complex mathematical interdependencies. The model, and other models focused on national and regional dynamics, were emerging as increasingly influential in policy deliberations. However, as noted by Warfield (1976):

1. The model developed by Forrester was quantitative, but included many unstated qualitative assumptions.
2. The model was not the product of collaborative group work and it was not presented in a way that can be readily understood by the public.
3. Many solutions can be generated depending on what assumptions are entered in a particular computer run.

4. Any decisions and solutions anticipated as a consequence of belief in the validity of the model would involve many individuals, groups, and organisations to implement solutions.

Warfield notes that societal problems cannot be solved in the same sense as arithmetic problems are solved. Working to resolve societal problems, he argues, involves learning and the development of sufficient understanding as to the nature of a specific societal problem, and effectively using this understanding to bring about some change that diminishes the perceived intensity of the problem, without creating other problems in the process.

Mathematics and quantification can be useful in this process, says Warfield, but they need to be used in a way that promotes understanding and effective collective action within the group working collaboratively to address a specific societal problem.

The theoretical constructs that inform IM were developed by Warfield over the course of more than 20 years, and draw from both behavioural and cognitive sciences, with a strong basis in general systems thinking (see Ackoff, 1981; Argyris, 1982; Cleveland, 1973; Deal & Kennedy, 1982; Kemeny, 1980; Rittel & Webber, 1974; Simon, 1960). The IM methodology seeks to balance behavioural and technical demands of group work (Broome & Kever, 1989) while honouring design laws concerning variety, parsimony, and saliency (Ashby, 1958; Boulding, 1966; Miller, 1956). For example, drawing upon Ashby's Law of Requisite Variety (Ashby, 1958), Warfield argued that in order to resolve a complex societal issue, one must match up the dimensions of the solution with the dimensions of the problem situation. As an approach to applied systems science, the IM process seeks to support groups to address the Law of Requisite Variety by encouraging group members to identify a comprehensive set of component problems that characterise the problem situation they are addressing, and by facilitating group members in modelling interdependencies between these component problems. By virtue of this process, IM seeks to ensure that a requisite variety of problem components will be addressed in efforts to control or transform the problem situation.

Requisite variety implies that system complexity is addressed directly in a design process, and this in turn implies a need to manage the cognitive load that group members might experience when addressing many aspects of a problem situation. The Law of Requisite Parsimony (Miller, 1956) concerns the rate at which information is delivered to an individual or group of individuals, and is critical whenever groups seek to address complex systems problems. In efforts to minimise cognitive load, the rate at which information is presented to individuals and groups should not exceed their cognitive capacities. For

example, drawing upon Miller (1956), Warfield notes that people have limited short-term memory storage capacity and, thus, effective facilitation in an IM session involves limiting the focus of attention to a sub-set of system information. The structured and facilitated nature of the IM process ensures that cognitive load is minimised (e.g., only one pair of system relations is presented at a time during matrix structuring and systems model-building).

Finally, the Law of Requisite Saliency (Boulding, 1966) highlights that collaborative system design work must incorporate specific provisions for human learning that offer the strong possibility of diminishing the variability in perception of the relative saliency of ideas. In other words, each idea presented to a group needs to be equally salient during any system design process. By working through stages of idea clarification, voting, and structuring of ideas during the IM process, the issue of requisite saliency is addressed, as each component problem is discussed and clarified openly, as are relations between problems, such that a shared understanding of system elements and relations is achieved by the group.

As a team-based, collaborative approach to applied systems science, IM has been applied in a variety of situations, including assisting city councils in making budget cuts (Coke & Moore, 1981), developing instructional units (Sato, 1979), designing a national agenda for pediatric nursing (Feeg, 1988), creating computer-based information systems for organisations (Keever, 1989), improving the U.S. Department of Defense's acquisition process (Alberts, 1992), defining global challenges (Christakis, 1987), improving Tribal governance processes in Native American communities (Broome, 1995), managing cultural issues in the automotive industry (Staley & Broome, 1993), and promoting peacebuilding in divided societies (Broome, 2004; 2006). Participant testimonials at the end of workshops, together with changes in organisational and institutional policies and practices that have resulted from IM applications, provide evidence for the learning and system change that is possible through use of the IM process (Warfield, 2006). More recently, IM has been employed in a number of basic science applications, including: understanding how music listening enhances well-being (Groarke & Hogan, 2016), understanding the key dispositions of good critical thinkers (Dwyer, Hogan, Harney & Kavanagh, 2017), and understanding the key dispositions of successful entrepreneurs (Rezaei-Zadeh, Hogan, O'Reilly, Cleary, & Murphy, 2014). The IM process has also been used in a variety of recent European Union (EU) projects, for example, focused on mobilising stakeholders in efforts to promote marine sustainability (Domegan et al., 2016), the design of a technology platform for the access and use of open data (Ruijter et al., 2017), and for the design an ecosystem for authoring of ebooks for children (Thompson Long et al., 2017). In these recent applications (e.g. Ruijter et al.,

2017; Thompson Long et al., 2017) among others, IM has been combined with Scenario-Based Design (Rosson & Carroll, 2000). Scenario-Based Design (SBD) is a user-centred approach to the design of technological solutions to problems. SBD seeks to focus the design process on how the users will engage with the tool to achieve their aims, as opposed to focusing on the tool functionality in itself (Rosson & Carroll, 2000), and may be used effectively as a further step in the systems change and design thinking process.

1.2.2. Steps in the IM process

Typically, IM sessions progress through a series of steps. First, a group of people, usually ranging in size from 8-20, with an interest in resolving a problematic situation come together in a situation room and are asked to generate a set of ‘raw’ ideas (commonly 50-200) about what might potentially have a bearing on the problem at hand. This idea generation stage can take a number of forms, and most commonly will involve either (a) *ideawriting*, or (b) the *nominal group technique*.

Ideawriting (Warfield & Cardenas, 1994) is a method that utilises relatively small groups of 4-6 persons developing ideas and exploring the meaning of those ideas through open discussion. Ideawriting involves five steps: (a) presentation of a stimulus question to participants; (b) silent generation of ideas in writing by each participant working alone; (c) exchange of written sheets of ideas among all group members, with the opportunity for individuals to add ideas as they read through the ideas generated by other group members; (d) discussion and clarification of ideas; and (e) an oral report of the ideas generated by each working group in a plenary session. In this plenary session, duplicate ideas across the working groups are eliminated from the set and new ideas (if any) are added; the resulting set of ideas is then ready for use in the next stage of the group’s work.

The *nominal group technique* (NGT; Delbeq, Van De Ven, & Gustafson, 1975) is a method that allows individual ideas to be pooled, and is best used in situations in which uncertainty and disagreements exist about the nature of possible ideas. The NGT involves five steps: (a) presentation of a stimulus question to participants; (b) silent generation of ideas in writing by each participant working alone; (c) “round-robin” presentation of ideas by participants, with recording on a flipchart by the facilitator of these ideas and posting of the flipchart paper on walls surrounding the group; (d) serial discussion of the listed ideas by participants for the sole purpose of clarifying their meaning (i.e., no evaluation of ideas at this point); and (e) implementation of a closed voting process in which each participant is asked

to select and rank, in terms of perceived importance, five ideas from the list, with the results compiled and displayed for review by the group.

When using either *Ideawriting* or *NGT*, the processes of group discussion and voting help the group to clarify the sub-set of ideas that bear upon the most critical problem issues. Next, using the IM software matrix structuring methodology, each of the critical issues are compared systematically in pairs and the same question, using a common relational phrase, is asked of each in turn, for example, “Does problem A *significantly aggravate* problem B?”. Unless there is majority agreement that one issue impacts upon another, the relation does not appear in the final analysis. After all the critical issues have been compared in this way, IM software generates a problem structure (or *problematique*) showing how the issues are interrelated (see appendix A for sample *problematiques* and a brief description of associated project contexts). The *problematique* can be displayed for discussion by the group, and becomes the launch pad for planning of solutions to problems within the problem field. The logical structure of a problem is visible in the *problematique* and when generating solutions, action plans are aimed at resolving problems in a logical and orderly manner. When the group is happy that they have modelled both the problem field and the best possible set of solutions, the IM session closes and the group leaves with a detailed action plan, a specific set of goals to work on, and a roadmap and logic describing how all the various plans and goals of each member will work together to resolve the original problem. Notably, the IM methodology can be used to structure problems, objectives, options, competencies, and so on, using a variety of different relational statements (e.g., Does A aggravate/enhance/ promote/support B?).

1.2.3. Facilitating and empowering groups

Central to Warfield’s vision for applied systems science is the facilitation and empowerment of collaborative teams. Warfield’s approach to systems modelling is dialogue-based and collaborative, and seeks to empower groups to build consensus and shared understanding by facilitating structured dialogue and input from all stakeholders in the situation room. Warfield recognised the need to support a group’s collaborative efforts in this context. This is clearly seen in the design and implementation of IM. The IM methodology is a facilitated process and a key role of the group facilitator is to ensure that the steps in the IM process are implemented effectively. IM facilitation is designed to address certain pitfalls which commonly occur in group problem-solving situations. A number of the key pitfalls highlighted by Warfield are described below:

Underconceptualisation – Warfield suggests that, in the context of working groups, certain aspects of a problem may be deemed ‘obvious’ or highly salient and may be prioritised as part of a simple mental model generated by the group. This simple mental model may never be subjected to critical analysis or considered alongside other components of a problem situation, and the result is a potential underconceptualisation of the problem situation the group is addressing. To counter this, the IM methodology includes critical stages of idea generation and clarification (i.e., using either NGT or Ideawriting), where all ideas generated are treated as *equally salient* and are clarified prior to a phase of voting or selection of the most critical issues by each group member. This ensures that the problem or issue the group is addressing is not underconceptualised, but rather a more complete picture of all issues that have a potential bearing on the problem are considered by the group.

Lack of clear communication – By employing methodologies such as NGT or Ideawriting in which each group member has the opportunity to communicate their ideas, IM facilitation supports clear communication in the group. This approach stands in contrast to other common methods used in group situations, such as brainstorming, where turn-taking may not be facilitated and where interruptions in communication might occur as people generate ideas in a more spontaneous manner in an effort to be creative (Straus, Parker, Bruce, & Dembosky, 2009). While widely employed, research has found that brainstorming is prone to productivity losses, such as *production blocking* (Diehl & Stroebe, 1987) in which ideas are inhibited or lost, for example, as participants wait for others to speak during the idea production process. Importantly, research has also highlighted the importance of the facilitator during idea generation processes, with several studies reporting that some productivity losses can be eliminated when a trained facilitator is guiding the process (Kramer, Fleming, & Mannis, 2001; Offner, Kramer, & Winters, 1996; Oxley, Dzindolet, & Paulus, 1996).

In the case of idea generation during IM sessions, the role of the facilitator in these situations is not focused on simply gathering ideas but rather gathering and clarifying ideas at the group level, for example, by ensuring that all group members understand an idea before the next idea is introduced. Similarly, during IM structuring, it falls under the role of the facilitator to ensure that the rationales or arguments describing how ideas might be related (or not related) in a system are fully explained and thus become the focus of critical reflection for other members of the group. Furthermore, in addition to guiding the group through each stage of the IM process, the facilitator must also maintain a curious, reflective, and neutral stance throughout, prompting the collective intelligence and collaborative dynamic of the group,

without biasing the content of their thinking. This often requires the facilitator to provide explicit prompts and feedback to the group, supporting their communication and their collective reasoning (Hogan, Broome, & Harney, 2014). When IM is used in a classroom setting, the role of the facilitator, or teacher, needs to be considered carefully and the influence of facilitator behaviours on group dynamics and learning outcomes needs to be examined experimentally. As such, two experimental studies presented in this thesis seek to manipulate key aspects of facilitator behaviour, focusing in particular on the nature of prompts used by facilitators (i.e., task-level versus process-level prompts) and who is delivering those prompts in a group setting (i.e., a teacher or student peers).

Lack of informed choice-making – Warfield was aware that hidden or unstated assumptions within a group can negatively impact informed choice-making. By supporting the clarification of ideas and relations between ideas, and by avoiding underconceptualisation, Warfield sought to ensure that participants in an IM session were in a position to make informed choices. More generally, the IM environment is designed to promote open sharing of ideas, clear visual displays of ideas on idea walls, and sustained reflective deliberation throughout an IM session. This provides a context in which each group member could make decisions with the benefit of the collective knowledge input from their fellow group members.

Lack of positive group dynamics – closely linked to all of the above, IM was designed with the aim of promoting positive group dynamics, in order to support and facilitate the work of the group. Warfield placed considerable emphasis on supporting reflective thinking and the development of consensus within IM working groups. However, while Warfield considered positive group dynamics to be critical to the success of collaborative groups, he did not conduct any research investigating the influence of key aspects of the IM facilitation process on measurable aspects of the group dynamics. In seeking to build upon Warfield's work, with the goal of integrating IM into educational practice, this thesis seeks to investigate key factors supporting positive group dynamics – such as trust, perceived consensus, perceived efficacy of the IM methodology, team orientation, and attitudes towards group learning. The relevant literature relating to each of these factors is explored in Chapter 2.

1.2.4. Systems science education

While Warfield devoted most of his career to the task of building a viable and applied systems science that was open to use by a broad range of stakeholder groups across a variety of problem situations, his thinking in relation to how systems science could be integrated into

university education came much later in his career, and he died before any substantial progress could be made in this regard. He did, in one of his final papers however, describe his vision for system science education, describing in particular *The Horizon College*. In this paper, Warfield (2010) highlights the importance of developing systems thinking skills in third level education, and envisions that this will be done through “collaborative activity, assisted with extensively-tested computer software that amplifies (without biasing) human cognitive attributes” (p. 8). Here, of course, Warfield is referring to the IM matrix structuring software he designed, and the broader IM process he developed and applied in many projects. In providing a rationale for his vision, Warfield critiques the institutionalised modes of learning in higher education, and the inherent resistance to changing educational practices. He emphasises the need, in particular, to teach skills of systems thinking and system design, which he sees as complementary to a prominent goal in higher education, that of developing critical reasoning and analytical skills. Warfield questions the absence of a focus on systems design thinking, noting that “critical reasoning assumes the pinnacle of significance when it is applied in a design mode” (p. 8). Building on skills of critical reasoning and analysis, a focus on system design allows the learner to gain an insight into the nature of complex problems, how sub-problems in a problem situation are related, and which options may be available for dealing with interdependent problems in a problem situation. In developing his vision, Warfield was thinking beyond the scope of individual modules, courses, departments, and faculties, to the broader interdisciplinary and transdisciplinary training of students in generic system design skills, which may be readily applied to a variety of complex societal problems.

Warfield anticipated that the introduction of a systems design focus in education would be difficult to implement, however. While referring to “an urgent need for effective, science-based system design in society” (2006, p. 79), Warfield (2007) also noted significant barriers to initiating and sustaining systems design, or applied systems science, programmes in higher education. First, Warfield noted *the lack of systems scientists* as a barrier to the development of a systems science programme. Warfield refers to this as an example of a “chicken-egg” problem, as the lack of systems scientists available to teach new students emerges as a consequence of the lack of systems science education programmes. Notably, Warfield compiled his original list of barriers to systems science education in 2007 and, since then, a number of systems science degree programmes have emerged. However, they remain limited in number, and the majority adopt a heavily mathematical or computational approach to systems science, which, according to Warfield (1976) is problematic given the lack of focus on collaborative learning and collaborative system design.

Second, and related to the above obstacle, Warfield noted a *lack of external demand for systems scientists*. Warfield suggests that “higher education follows the money trail” (p. 85) and he concluded that the lack of external demand for systems scientists resulted in a lack of internal demand to create systems science courses. However, it should be noted that the skills which may be developed through systems science education are not only applicable to the vocation of *systems scientist*. In recent years, generic problem-solving skills, especially team-based, problem-solving skills, have been recognised as the skills which employers most desire in university graduates. For example, in 2015, the US National Association of Colleges and Employers collected survey responses from 260 employers, including large multinational companies such as Chevron, IBM, and Seagate Technology, to ascertain which skills were most sought after by employers. The results of the survey showed that *ability to work in a team structure* was the top-ranked skill sought by employers (Koc, Koncz, Tsang, & Longenberger, 2015). Furthermore, consistent with Warfield’s focus, the majority of the top-ranked skills identified in the survey of employers involved or implied some degree of collaboration. Examples of these included: *the ability to make decisions and solve problems; the ability to communicate verbally with people inside and outside an organization; the ability to plan, organise and prioritise work; and, the ability to obtain and process information*. The need for these skills, identified as important for working in modern multinational companies, suggests that while there may not be an external demand for systems scientists, there is a strong need for graduates with broadly applicable collaborative learning skills.

Similarly, the American Chamber of Commerce (2016) has raised concerns about the quality of education in the Republic of Ireland, highlighting the need for improved individual and collaborative problem-solving skills in graduates. Similarly, in their publication of the *Strategy for Research and Development, Science, Technology* (2016), the Irish government has recognised the need to significantly improve the teaching of science and reasoning in second and third level education. This, they argue, is critical in order to ensure national competitiveness in the knowledge economy. It has been noted that the existing higher education curriculum places a premium on teacher delivery of information and rote learning (Hay, Kinchin, & Lygo-Baker, 2008; Kinchin & Hay, 2007), coupled with forms of individual assessment which make it difficult to achieve high levels of collaborative problem-solving skills in students. A move towards cultivating collaborative learning and systems design skills requires a re-imagining of traditional modes of teaching and learning, moving towards a stronger emphasis on collaborative work in all aspects of the learning process. This

view is consistent with Castells (2001), who noted that while we have evolved toward a *Networked Society*, where individuals are inextricably linked through computers and the Internet, the parallel redesign of education systems to foster collaborative learning skills lags far behind.

Finally, as regards obstacles to systems science education, Warfield noted that systems science programmes do not have a natural prospective student base, in the same way that other undergraduate programmes do (e.g., physics, biology, chemistry, psychology, etc.), as systems science is so broad in scope. Warfield suggested that, for a certain category of student, the broad nature and applicability of systems science education may be an appealing factor. However, whether it is appealing enough to warrant registration on a full three-year degree programme was considered unlikely by Warfield. In line with this consideration, Chapter 6 of this thesis describes the experiences of final-year undergraduate students who signed up for an elective module (i.e., a single semester module run across 12 weeks) focused on collaborative learning and applied systems science. The experiences of students on this module were predominantly positive. Thus, it seems reasonable to assume that the introduction of elective undergraduate modules focused on systems science could offer a pathway to the design of broader and more widely applicable systems science education programmes that provide undergraduates with key skills that support lifelong learning and productive teamwork across a broad variety of project scenarios.

1.2.5. Building on Warfield's vision

Although Warfield's vision for integrating systems science into university education came late in his career, he became convinced that systems science education will be instrumental in enhancing our collective ability to address societal problems. Warfield's methodological approach to applied systems science serves as a guiding framework for systems science education, in particular, given its focus on learning in collaborative teams and the use of systems thinking tools. However, Warfield did not focus explicitly on the challenge of facilitating students in the use of systems science tools in an educational context. This thesis seeks to build upon Warfield's vision by examining key features of the collaborative environment which may influence the application of IM in a university education context. The investigation of key instructional and social components of learning (described in Chapters 3-5), and the subsequent design of a pilot applied systems science curriculum (described in Chapter 6), was informed by situating Warfield's vision within a Learning Sciences approach to educational research and design, as well as drawing upon research from

the domains of social and educational psychology. The basis for this investigation begins with an exploration of the philosophical and theoretical underpinnings of collaborative learning, which is discussed in the next section.

1.3. Philosophical and theoretical underpinnings of collaborative learning

According to Stahl (2013), there is no single unifying theory of collaborative learning, rather it is influenced by a number of theories of learning and human development. One theoretical approach builds on the work of Lev Vygotsky, who emphasised the social aspects of learning and human development (Vygotsky, 1978). This approach remains prominent as a foundational starting point for many scholars in the field of collaborative learning and computer-supported collaborative learning (CSCL), as many researchers recognise that social interaction plays a fundamental role in the development of cognition (Kearsley, 1994; Buchberger, 2000).

Vygotsky advanced a view that knowledge and understanding are socially constructed through interactions with others. For Vygotsky, the learner's interactions with other people, preferably more competent members of their social group (e.g., teachers and parents), initiate the learner into the social, linguistic practices and artefacts of the society. Through participating in the cultural life of the community, the learner is seen as engaging in a kind of cognitive apprenticeship, which helps them to acquire the cultural tools that support the development of more advanced levels of thinking and greater conscious control over their mental processes. According to Vygotsky, the processes of linguistic and tool-mediated interaction between the learner and others become internalised as the basis for reflection and logical reasoning.

Socio-cultural approaches to collaborative learning, building upon the work of Vygotsky, often refer to two overarching concepts – scaffolding and mediating artefacts (Ludvigsen & Mørch, 2010). Scaffolding, a term introduced by Wood, Bruner, and Ross (1976) is an instructional technique whereby a teacher models a learning task and provides instructional support to students, then gradually removes instructional supports and shifts responsibility for task completion to the students. For instance, in collaborative learning, teachers might model the use of 'question asking', including the use of open-ended questions to prompt thinking in students, and students might later take on the teacher's role, as they work to provide scaffolding for each other in the form of peer prompting and peer feedback. Scaffolds can also be technological, as commonly seen in the field of CSCL. Computers represent artefacts of culture that can be used to mediate learning experiences and offer

specific scaffolding or support for learners. Building upon the field of collaborative learning, CSCL is a branch of the Learning Sciences which has focused on the question of how people can learn together with the help of computers (Stahl et al., 2006). As a means of scaffolding, educational technologies can also perform similar functions to those typically provided by more advanced peers or instructors (e.g., providing prompts or instructions).

Related to scaffolding is the concept of mediation. Mediation generally refers to the use of tools, which may be employed to bridge the gap between learner and teacher, or between learner and the knowledge to be acquired. In the context of teaching and learning, technology can be seen as a mediating artefact or tool when it is used by a teacher to support learning. The computer-supported matrix structuring tool used as part of the IM process can thus act as a mediating artefact in the context of developing an understanding of a complex problem, by providing a focal point for a facilitated, collaborative discussion between students and a teacher or facilitator. For example, Figure 2 below presents an example of a student-centred model of critical thinking (CT) skills and dispositions, developed by a group of students who were tasked with identifying and structuring key components of good critical thinking. This model was then used to inform the design of activities to support student learning (Dwyer, Hogan, Harney, & O'Reilly, 2014).

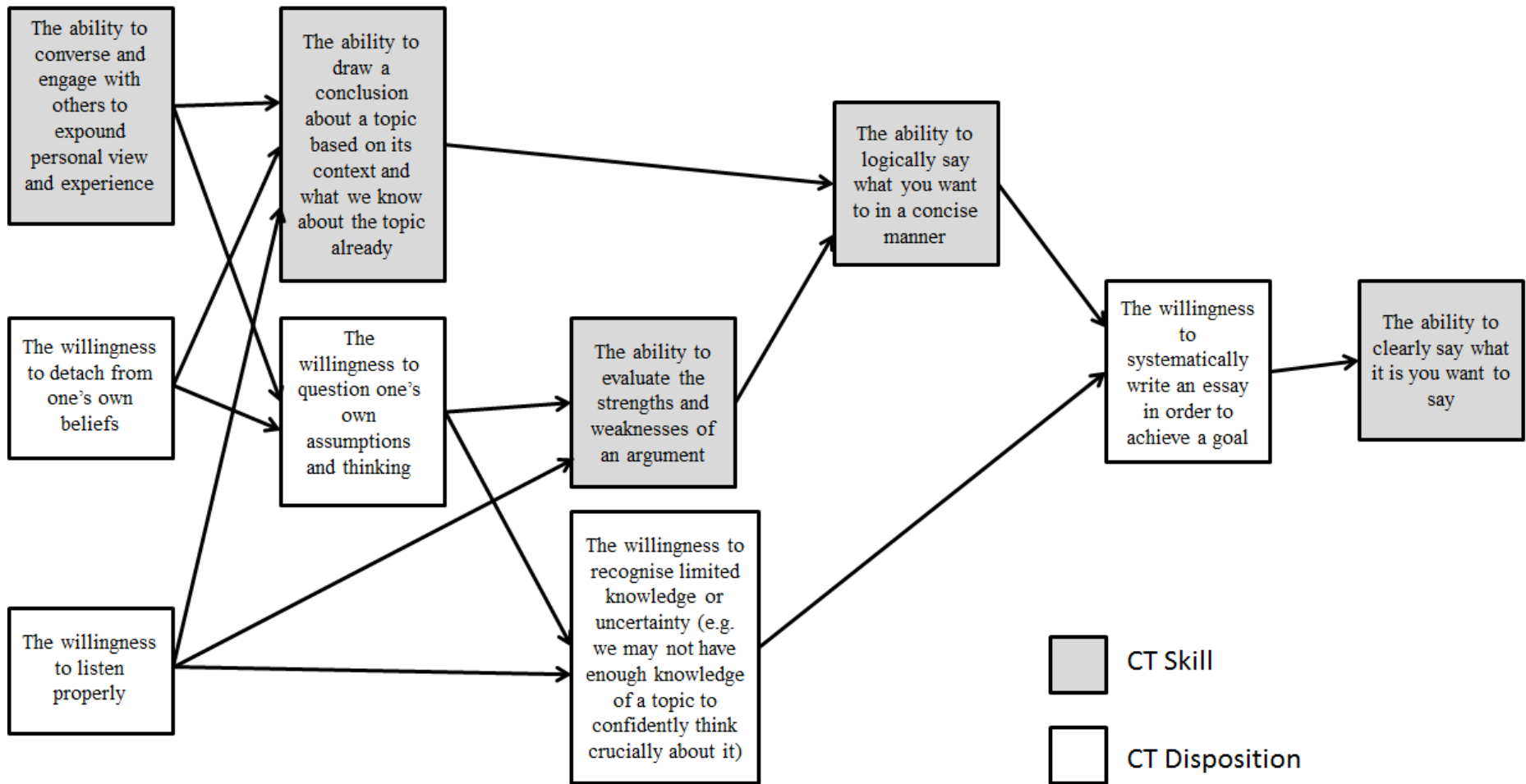


Figure 2. Student-centred model of critical thinking skills and dispositions (Dwyer et al., 2014)

Vygotsky's perspective has important implications for collaborative learning, and the Learning Sciences more broadly. Consistent with Vygotsky, for instance, Van Den Bossche, Gijsselaers, Segers, & Kirschner (2006) suggest that research on collaborative learning needs to focus on the sociocognitive processes through which a shared understanding is built. In line with this need, Chapter 2 highlights a number of processes which have been identified as important in the design of collaborative learning environments. These include: trust, consensus, team orientation, attitudes towards group learning, and, perceived efficacy of the IM methodology. A review of the literature on the significance of these variables in the context of collaboration is also provided in Chapter 2. The effects of these variables on learning processes and outcomes in the context of systems science education are subsequently investigated in Chapters 3-5.

1.3.1 Dialogue and collaboration

Vygotsky highlighted the importance of language as a tool of culture that mediates learning in a group context. Consistent with this view, a number of theories of dialogue are influential in shaping our understanding of collaborative learning and computer-supported collaborative learning. This section introduces the perspectives of key thinkers in the field of dialogue, including: Buber (1958), Gadamer (1960), and Bakhtin (1981), before moving on to discuss recent approaches to the use of dialogue in the classroom (Mercer, 2000; Wegerif, 2007, 2015). Theories of dialogue stress the linguistic nature of interaction, and the notion of dialogue partners coming from, and negotiating, multiple different perspectives during dialogic inquiry (Wells, 1999). Thus, theories of dialogue have particular relevance in the context of consensus-building and the development of shared understanding by student groups working together on applied systems science projects.

While direct empirical analysis on dialogue as a mechanism of collaborative learning has emerged recently as a prominent focus of enquiry in the field of Learning Sciences, the theoretical rationale for dialogue as a basis for collaboration has a much longer tradition in philosophy and in the field of communications. Given that Warfield's approach to systems science is dialogue-based in nature as opposed to purely mathematical, and given that the definition of collaborative learning as the co-construction of shared understanding (Roschelle & Teasley, 1995) implies a need for dialogue amongst members of a working group, an exploration of key theoretical perspectives on dialogue is valuable here.

The English word dialogue comes from the Greek word dialogos, and it implies that meaning (logos) is prefixed or arises through or across (dia) the communication at the group

level (Broome, 2009). As such, it implies a synthesis of meaning that emerges at the group level, and it implies that the group is somehow unified in this effort. In order to achieve this unity of effort and synthesis of meaning, the group needs to adopt a principled stance in relation to communication, focusing for example, on ensuring that everyone's voice is equally valued (Hogan, Hall, & Harney, 2017). Collaborative learning, by its very nature requires communication, and in particular, some form of dialogic learning (Wegerif, 2016). In thinking about dialogue, it is necessary to move beyond the everyday usage of the word, used to describe any level of exchange or discussion between two or more people. Rather, it refers to dialogue as a process, dialogue as a tool, dialogue as a means of exchanging ideas in a constructive manner - a process which offers the possibility of altering damaging communication patterns which groups may engage in, and supporting instead positive, open, and constructive patterns of communication that provide a means of effective collaboration (Bohm, 1996). However, this type of dialogue typically doesn't occur naturally in a classroom (Zheng & Warschauer, 2015). Effective dialogue and collaboration requires structure, support and guidance, and often, facilitation and instructional support prior to groups becoming more independent, and demonstrating a capacity for peer-to-peer facilitation, collaboration, and co-creation of learning outcomes (Gan & Hattie, 2014).

Broome (2009) provides an integrative overview of different perspectives on dialogue, outlining in particular the contribution of a number of key scholars in the field, beginning with philosopher Martin Buber. Central to Buber's theory of dialogue is the distinction between two types of human relationships, I-It and I-Thou. According to Buber, an I-It relationship is characterised by a situation whereby the communicator views the other as an object and seeks primarily to manipulate the other for the communicator's purpose. Conversely, an I-Thou relationship is characterised by honesty, directness, spontaneity, and mutual responsibility. Neither communicator is trying to impose their view on the other, but rather together they create an environment which encourages mutual growth and development.

Buber also introduced the concept of the *between* as a guiding metaphor of communication, suggesting that dialogue is rooted in the space that exists between communicators. Buber suggested that it is this common centre which brings people together in a dialogue, as opposed to what either communicator brings individually. As such, there is a shift in perspective whereby group members transcend the 'self' and the 'I', and meet in between to engage in dialogue. A key focus of collaborative learning then, must be to create and nurture this space between collaborators, that is, between both teacher-student and

student-student collaborative groups. The environment, classroom atmosphere, and methodology used in class, which encompasses and shapes the behaviour of the teacher/facilitator and students, must support I-Thou relationships characterised by honesty, directness, spontaneity, and mutual responsibility.

Hans-Georg Gadamer, in *Truth and Method*, suggested that, above all else, humans seek understanding, and that language is the means through which understanding is built. Gadamer refers to language and understanding as “living, dynamic processes, open to continual development and change” (Gadamer, 1960, p. 3), and suggests that the understandings and meaning that evolve between communicators are dependent on the context of the encounter, as well as the individual understandings and prejudices that each communicator brings, and which may inform their interpretation of what the other is communicating.

In this work, Gadamer talks of a *fusion of horizons*, where the process of developing a shared understanding involves the attainment of a *higher universality* that overcomes the limited horizons of each participant. It is a move from the separate positions of individuals to a synthesising position that includes relevant aspects of each person's views. This *fusion of horizons* seems to resemble Buber's concept of *the between*, which also moved the focal point of dialogue from each individual's horizons or perspectives, to a space between individuals where shared understanding can develop. Gadamer's fusion of horizons is also consistent with Warfield's approach to collaborative problem-solving. Warfield's approach takes a group of individuals through a process of structured dialogue and transforms their individual positions into something akin to a higher universality, in the form of a *problematique*.

Mikhail Bakhtin, a contemporary of Vygotsky, further reinforces this emphasis on respecting and building upon multiple perspectives, by suggesting that dialogue reflects both unity and difference, and that central to dialogue is this simultaneous fusion and differentiation of perspectives. Bakhtin believes that for dialogue to occur, communicators must work together to build a shared understanding, while also maintaining their unique individual perspectives. In this way, dialogue is characterised by what Bakhtin refers to as dialectical tensionality, which gives rise to a fluid and dynamic process, during which, as Broome (2009) notes: “there is a dynamic interplay of expression and non-expression, certainty and uncertainty, conventionality and uniqueness, integration and separation... an emergent process in which the interplay of contradictory forces creates a constant state of unrest and instability, while also bringing moments of unity and synthesis” (p. 3). Warfield's

methodology, however, which provides the context for dialogue in this programme of research, seeks to promote more than “moments” of unity and synthesis. It does so by producing a concrete graphical output, informed by the group’s collective intelligence, and built in the context of a sustained dialogue, during which time multiple systems relations describing a problem situation are considered by the group.

Other influential theories of dialogue also recognise the role of emotion in dialogic interactions. Freire, for example, suggested that effective dialogue, that which can lead to great change, is built on a foundation of humility, guided by trust, and driven forward by hope (Broome, 2009). Importantly in the context of collaborative learning, it is this trust, according to Freire, that allows us to let go of our own preconceived notions and beliefs “so as to be exposed to the dialogic exploration and creation of the world” (Vidovic, 2010, p. 28). Rogers, similarly, recognised the power of emotional connections and relationships in the context of dialogue, suggesting that concern for human feelings, human relationships, and human potential are central to effective communication. According to Broome (2009), Rogers believed the key to creating an environment for effective dialogue depends on a “willingness to listen and to enter into a meaningful relationship with the other, genuineness in sharing feelings and ideas with the other, respect and regard for the other, and empathic understanding” (p. 302).

More recently, Wegerif has introduced the concept of *Dialogic Education*, building upon the perspectives of some of the theorists mentioned earlier in this section. For Wegerif (2010), dialogic education means “teaching *for* dialogue as well as teaching *through* dialogue” (p. 18). Consistent with Rogers’ perspective, Wegerif (2010), in studies designed to evaluate the *Thinking Together* programme, found that the quality of relationships between peers was influential in promoting effective dialogue. For example, willingness to ask for help, openness to changing opinions, and willingness to admit one was wrong and another right, were highlighted as indicators of dialogic quality. This of course, raises an important distinction between philosophical and empirical analyses of dialogue. While influential, the perspectives on dialogue of Buber, Gadamer, Bakhtin, Freire, and Rogers are primarily philosophical. More recent investigations of the nature and influence of dialogue have been empirical, including the work of Wegerif (2006, 2010, 2015) referred to above. In an effort to further elucidate the role of dialogue in collaborative learning, the following section moves on to discuss and evaluate empirical research which has been carried out in an effort to understand the use of dialogue as a tool to support collaborative learning.

1.3.2. The role of dialogue in the classroom

Consideration of the various perspectives on dialogue highlighted above leads to a few key proposals in relation to dialogue and collaborative learning in classroom settings. First, dialogue involves much more than students simply speaking to one another; it is not merely conversation. Dialogue involves a complex interplay of exploration and deliberation between communicators, operating on both a cognitive and social-emotional level. Recognising this, Warfield noted that promoting and maintaining effective dialogue requires careful design of the collaborative environment, an environment in which a trained facilitator must lead a group through a series of steps that support collaborative learning.

Notably, dialogical forms of collaborative learning are quite far removed from the manner in which most classroom teaching occurs. The typical classroom scenario involves a teacher or lecturer at the top of the room, addressing the students in a predominantly monological fashion – a scenario which typically involves the primary communicator (teacher or lecturer) speaking about a certain topic at length, broken up by brief windows of, often shallow, questions and answer type discussions between the teacher and student(s). In fact, studies of discourse and dialogue in classrooms have consistently reported that teacher's talk dominates the conversation during lessons (Dillon, 1985; Edwards & Mercer, 2013; Lemke, 1990). A study by Newton, Driver, and Osbourne (1999) found that less than 5% of in-class time is allocated to group discussions, while less than 2% of teacher-student interactions involve meaningful discussion of ideas and productive exchange of views and opinions. Furthermore, the classic studies conducted by Rowe (1974a, 1974b) concluded that teachers rarely allow enough time for students to respond to a question before rephrasing, asking a different question, or asking another student. While classroom discourse is seen as an avenue for collaborative knowledge construction and meaning-making, recent studies have reported that teacher-dominated discourse continues to be prevalent in classrooms (Hardman & Abd-Kadir, 2010; Beauchamp & Kennewell, 2010) and, more crucially, that this approach often limits opportunities for student involvement, access to different modes of communication, and purposeful practice in the use of language (Strayer, 2012; Alexander, 2004; Cazden, 2001; Nystrand, Wu, Gamorgan, Zeiser, & Long, 2003).

This teacher-dominated approach is also prevalent in third level education, in many cases to an even greater extent, with 50-minute lectures consisting almost entirely of one-way communication remaining the standard practice across many disciplines. In addition, traditional and dominant approaches to teaching are often slow to change. The classic and

commonly used forms of discourse prevalent in education come in a variety of simple forms, and often involve teacher initiation, student response, and teacher evaluation, known as *IRE* (Mehan, 1979) or *IRF* when the third step involves follow-up or feedback (Sinclair & Coulthard, 1975; Chin, 2006). Overall, these dominant forms of interaction, *IRE* and *IRF* are widely regarded as teacher-dominated and are found in research studies to be ineffective in fostering students' collaborative dialogue (Alexander, 2004; Duschl & Osborne, 2002; Lemke, 1990, Mercer & Littleton, 2007). The study by Lemke (1990), for example, found that IRF exchanges result in limited learning outcomes as teachers typically focus on using classroom interactions to cue simple fact recall and assess declarative knowledge. Given the claim by Asterhan & Schwarz (2010, p.261) that, "the extent to which students learn from collaborative activities depends on the depth and the quality of the dialogue peers engage in", it is difficult to justify this over-reliance on teacher-driven discussion. Asterhan and Schwarz's claim is supported by numerous research studies which have highlighted examples of dialogue moves which add depth and quality to group discussions. These dialogue moves include: explaining ideas to others (Coleman, 1998), producing and receiving elaborated help (Webb, 2009; Webb & Palincsar, 1996), elaborating on each other's ideas and problem-solving (King & Rosenshine, 1993; van Boxtel, van der Linden, & Kansellar, 2000), and engaging in reasoned argumentation (Asterhan & Schwarz 2007, 2009; Chin & Osborne 2010; de Vries, Lund, & Baker, 2002; Schwarz, Neuman, & Biezunar, 2000).

Soter et al. (2008), in their discussion of classroom discourse, state that the "belief that language is a tool for thinking" (p. 376) is critical to the development of an environment of dialogic enquiry in the classroom. They also propose that, in order to cultivate productive discourse, the environment must be one which is structured and focused. However, it must not be structured in a way that is rigid and prohibitive to generative learning - finding a balance between structure and freedom is key. This involves maintaining the structure and focus required for the task at hand, while also remaining responsive to students' spontaneous contributions. In practice, Soter et al. (2008) suggest that this balance between structure and freedom requires a gradual shift in control of the discourse, from being predominantly teacher-driven, to predominately student-driven, echoing the idea of the teacher moving "from the sage on the stage to the guide on the side" (Dillenbourg et al., 2009, p.14). Essentially, the end result of a gradual shift in control from teacher to student involves a move towards peer learning as a pedagogical approach, whereby learning is driven by peer-to-peer dialogue and interaction, as opposed to a predominant teacher-student dialogue and interaction. Critically, the number of studies examining the dialogue which occurs between

peers in small group learning situations is increasing, with many reporting a richness in student contributions and engagement which is not as apparent in more traditional, teacher-dominated approaches such as *IRF* (Bleicher et al., 2003; Kim, Anderson, Nguyen-Jahiel, & Archididou, 2007; McIntyre et al., 2006; Olitsky, 2007). Ultimately, according to Soter and colleagues one of the primary goals of a dialogic classroom is to “achieve the goal of students taking responsibility for co-constructing their understandings together”, a process Mercer (2000) termed “interthinking” (p. 376).

Importantly, creating an environment supportive of dialogue in classrooms is likely to have wide-ranging benefits, including providing a grounding for the development of systems thinking skills as proposed by Warfield. For example, in a study conducted by Mercer, Dawes, Wegerif & Sams (2004), it was found that children can be taught to use dialogue more effectively as a tool for reasoning, and that talk-based activities can provide a means to scaffold the development of reasoning and scientific understanding. More specifically, Mercer and colleagues designed, implemented and evaluated the *Thinking Together* programme, which aimed to: (a) raise children’s awareness of the use of dialogue as a means of engaging in collaborative thinking; (b) enable children to develop their abilities to use dialogue as a tool for individual and collaborative thinking; and (c) enable children to apply this dialogic tool in their learning of science and mathematics.

In evaluating the *Thinking Together* programme, Mercer and colleagues (2004) observed seven classes of primary school students (aged 9-10), totalling 109 students, in the experimental (*Thinking Together*) condition, and a matched set of control classes, totalling 121 students. Following a training day for teachers, and pre-intervention observation and assessment of students, teachers in the experimental condition delivered five lessons to student groups focused on critical questioning, sharing of information, and negotiating a decision. Following the programme of lessons, changes in the quality of children’s talk and collective reasoning were analysed from video-recorded data using a mixed methods approach. From a qualitative perspective, the dialogue was analysed to gauge the extent to which the discussions in the target groups reflected Exploratory Talk. According to Mercer (2000, p. 98), Exploratory Talk refers to “discussion in which partners engage critically but constructively with each other’s ideas. Relevant information is offered for joint consideration. Proposals may be challenged and counter-challenged, but if so reasons are given, and alternatives are offered. Agreement is sought as a basis for joint progress. Knowledge is made publicly accountable and reasoning is visible in the talk”. Mercer and colleagues’ (2004) study also involved an examination of pre- and post-intervention transcripts, as students

engaged in science learning tasks. From a quantitative perspective, the analysis involved recording the frequency of indicator words such as “because”, “if”, “I think”, “would” and “could” which have been shown by previous research to be associated with quality reasoning. The relative mean duration of pre- versus post-intervention utterances was also analysed, as previous research has found that the more children explain and justify their views, the longer the utterances will be. Measures of understanding of the science curriculum (SATs questions) and changes in the quality of collective and individual reasoning (Raven’s Progressive Matrices Test; Raven, 2003) were also taken pre- and post-intervention.

Results of the study showed a significant increase in indicator words after the intervention in the target group. Mercer et al. argued that the increased use of these words reflected student’s “increased attempts to share each other’s thoughts before deciding on a course of action and moving on through the programme” (p. 370). As regards the measure of understanding of the science curriculum, the results showed increases in performance were significantly greater in the experimental condition than in the control condition, suggesting that the enhanced talk among students had a positive effect on their learning. Furthermore, students in the experimental condition performed significantly better on a concept mapping exercise which was designed to test the extent to which students became more able to perceive relationships between different scientific concepts. Last, as regards the Raven’s test, students in the experimental condition performed significantly better than the controls after the intervention, taking into account the pre-intervention performance levels of both groups. Overall, the researchers suggested that these results supported the hypothesis that a programme encouraging the use of Exploratory Talk had specific, predicted positive effects on the quality of children’s reasoning.

The results of Mercer et al.’s (2004) study have implications for the role of dialogue in collaborative learning. These findings, as the researchers suggest, extended the existing literature by providing additional evidence that “the development of scientific understanding is best assisted by a careful combination of peer group interaction and expert guidance, and provides an example of how that combination can be successfully achieved” (p. 375). In other words, providing an environment which is conducive to quality dialogic interaction between peers, as well as support from teachers or facilitators, is conducive to the development of knowledge and understanding. Such results provide empirical support for the perspectives of Vygotsky, Bakhtin and other proponents of the power of dialogue and social interaction for learning.

At the same time, the precise mechanism by which Exploratory Talk provides learning benefits is open to more than one interpretation (Wegerif, 2008). While explicit reasoning is generally considered central to Exploratory Talk (Wegerif, 1996), this association may be called into question by research showing desired educational outcomes following teaching of Exploratory Talk, without any corresponding increase in explicit reasoning skills. A study by Rojas-Drummond, Fernandez, Mazón, & Wegerif (2006) for example, compared the impact of teaching Exploratory Talk on a collaborative convergent reasoning task (consisting of a modified version of the Raven's test) and a collaborative, divergent writing task in which students had to read three short texts and jointly construct a summary which integrated the main ideas from each. In this study, there were two conditions: an experimental condition in which students were trained in the use of Exploratory Talk as part of the *Learning Together* programme, and a control condition in which students were taught in accordance with the regular curriculum. The results of this study revealed that children in the experimental condition improved significantly in the use of Exploratory Talk on the reasoning task, solving 76% of their problems using Exploratory Talk at post-test (versus 38% at pre-test). Conversely, children in the control condition showed no change from pre-test to post-test (i.e., 21% and 19% of problems solved at pre-test and post-test, respectively). Furthermore, students in the experimental group used a total of 106 arguments during the post-test task (up from 42 at pre-test) whereas students in the control group used 22 at post-test (up from 18 at pre-test). Thus, the authors reported that the use of explicit reasoning, including the provision of claims, challenges, and warrants, was beneficial in the context of this reasoning task.

As regards the divergent textual integration task, initial analysis of the dialogue showed no evidence of Exploratory Talk or explicit reasoning in either experimental or control conditions. However, the analysis did suggest that the experimental group became more coordinated and sophisticated in their post-test task performance. To explore this further, the authors employed ethnography of communication, which is a method of discourse analysis. This analysis revealed that the experimental group demonstrated an increase in the number and quality of communicative acts used during the post-test task. Furthermore, these changes were accompanied by a significant improvement in the quality of the summaries which they produced. As such, while improvements were made following the Exploratory Talk training, they were not associated with an increase in explicit reasoning in the context of the latter task.

Building upon such results, Wegerif (2008) notes that while numerous studies have demonstrated educational benefits following the implementation of Exploratory Talk, such as in mathematics (Monaghan, 2005), promoting children's discussion of text (Reninger & Rehark, 2009) and improved reasoning abilities (Mercer, Wegerif, & Dawes, 1999), the key mechanism at play may not be "the use of language as a tool for reasoning", as has been claimed (Mercer et al., 2004, p. 361). Wegerif (2008) suggests that this claim may have arisen due to the fact that reasoning tests are so commonly used to assess the quality of talk, but he offers an alternative mechanism by which the benefits of Exploratory Talk may be operating. This alternative explanation relates to the ground rules of Exploratory Talk, which focus on the importance of students asking each other open questions, and respectfully listening to each other. This mode of question-asking and listening, according to Wegerif, may serve to cultivate an open, dialogic space of reflection, which in turn may facilitate creativity and problem-solving. This interpretation highlights the importance of an open, supportive environment in which dialogue can take place, again implying a potentially important role for the group facilitator and the need for a supportive and productive collaborative working environment in promoting learning benefits which may arise through dialogic interaction.

More recently, it has been noted that investigating the effects of dialogue on the development of group thinking presents a methodological challenge. Wegerif et al. (2017) points out that while numerous studies have been designed to test the effects of dialogue on educational outcomes, many of these studies begin by proposing a model of good dialogue and then working to assess the impact of their educational intervention on key measurable aspects of this model. According to Wegerif and colleagues, many of these studies contain significant design flaws. One of these flaws relates to the fact that studies which exclusively use outcome measures derived from pre-defined conceptualisations of good dialogue lack a means to ascertain if there is any link between the 'effective talk' demonstrated, and a corresponding enhancement of group thinking, unless a separate group level performance outcome is also measured. While Wegerif and colleagues suggest that measurements of 'effective talk' can be useful in demonstrating the emergence of dialogue skills, "it does not, in itself, tell us if the dialogue itself is genuinely effective in supporting and enhancing group thinking" (p. 4). The issue here, according to the authors, is that such an approach, when used alone, amounts to "testing to a model" in the absence of any additional measure of the effectiveness of the group thinking.

Furthermore, Wegerif et al. (2017) highlights that many models of effective classroom dialogue are based on research which provides only indirect evidence for their impact on specific curriculum outcomes. This can pose a problem in efforts to establish clear causal relationships. For example, studies on dialogue do not always account for other processes which may have influenced the group's learning. This could include, for example, the confidence which students gain from participating in a dialogue education programme; the students' questioning and interaction; the explicit reasoning of students in the context; or the trusting relationships developed between group members.

Similarly, while dialogue in the classroom may have positive effects on individual learner outcomes, as indicated in a recent meta-analysis (Murphy, Wilkinson, Soter, Hennessey, & Alexander, 2009), these studies say nothing about the impact of dialogue on collective or group level thinking and performance outcomes (Davies & Meissel, 2016). Collective intelligence and group level thinking outcomes are unique products of group work. If one is focused on enhancing these collective outcomes, as opposed to individual learning outcomes, a specific lens of enquiry and unique group level performance measures are needed.

In the case of Warfield's methodology, it is possible to provide such a group level product, specifically, the problematique generated by a group and the associated group reasoning that underpins the logic presented in the problematique. Also, with Warfield's methods for quantifying the complexity of problematiques, based on the number of paths of influence, and the number of stages in the problematique, it is possible to make comparisons between groups that have been exposed to different experimental manipulations that may influence group level outcomes. The second and third empirical studies in this thesis adopt an experimental approach to the analysis of dialogue and combine both group level cognitive measures with individual level, social-emotional measures to provide a holistic view of the role of structured dialogue on collaborative learning processes and outcomes.

1.4. Advancing Learning Sciences approaches to collaborative learning: a focus on learning processes and orchestration

As an approach to applied systems science, Warfield's IM methodology is unique not only in its focus on teamwork and dialogue as a basis for systems thinking and collaborative problem-solving, it is unique in the sense that a very specific CSCL methodology is used to develop systems models designed to support collective action. Therefore, as noted above, in building on Warfield's vision for systems science education, it is necessary to situate his

methodology within the broader collaborative learning and Learning Sciences literature. The Learning Sciences is an interdisciplinary field which concerns the study of teaching and learning. According to Sawyer (2014), the ultimate goal of the field is to “better understand the cognitive and social processes that result in the most effective learning and to use this knowledge to redesign classrooms and other learning environments so that people learn more deeply and more effectively” (p. 1). A fundamental assumption of many learning scientists, according to Barab and Squire (2004), is “that cognition is not a thing located within the individual thinker but is a process that is distributed across the knower, the environment in which knowing occurs, and the activity in which the learner participates” (p. 1). Learning scientists have sought to develop technological tools, curricula, and theories that help them to systematically understand and predict how learning occurs. Research in this domain moves beyond simply observing and involves systematically engineering learning contexts in ways that allows the researcher to generate evidence-based claims about learning.

Following the emergence of the Learning Sciences, a change in the nature of collaborative learning research has been seen in recent years. The initial goal of collaborative learning research was to understand the circumstances under which collaborative learning was more effective than individual learning. This approach involved researchers controlling several kinds of variables, including: group size, group composition, the nature of the learning task, and so on. However, given the complexity of the learning environment in which research was taking place (i.e., the in-class context in which many variables are interacting to shape learning outcomes), establishing causal links between specific variables in these environments and learning outcomes was difficult. These methodological challenges resulted in many contrasting findings being reported in the literature. For example, research revealed cases in which significant variation in group work interaction and performance was reported between groups that did not differ in terms of their size, composition, or the nature of the assigned task (Barron, 2000). Such findings prompted deeper investigation of factors that influence group performance. Kreijns, Kirschner, and Jochems (2003), for example, noted that a key element that needs to be addressed in all group learning situations is the nature of the social interactions occurring within the group. In line with this, a study by Webb, Nemer, and Zuniga (2002) examined the effects of group-ability composition on student performance in the context of middle school collaborative science tasks. This study included (a) high-ability students working in homogenous groups (i.e., all high-ability students) or (b) heterogeneous groups (i.e., mixed ability students). Individual student performance was measured by both written and practical tasks associated with the topic of

discussion, and group performance was measured by researchers' coding of the levels of discussion, quality (or correctness) of answers, and justification of answers. The results of this study, which focused on outcomes for high-ability students, found that high-ability students in homogenous groups all performed highly, whereas high-ability students in some heterogeneous groups performed highly, while other high-ability students in other heterogeneous groups did not. Importantly, further analysis revealed that group functioning (including quality of discussion, and level of help given and received with the group) was the strongest predictor of performance, and explained much of the effect of group composition. These results suggest that while group composition may be influential, the mechanism by which it exerts its influence may be more complex, and may itself be influenced by the interactions and processes at the group level.

Similarly, Saleh, Lazonder, and De Jong (2005) conducted an investigation of the effects of group-ability composition on social interaction, achievement, and motivation. In their study (comprised of 104 elementary students) students of high, average, and low ability (based on test performance) were randomly assigned to either homogenous or heterogeneous groups for a series of collaborative learning sessions in biology. All students completed pre- and post- tests of content knowledge, as well as motivational beliefs about working in groups. Social interaction during the collaborative learning sessions was recorded and subsequently coded into episodes such as: reasoning episodes, conflict episodes, and question episodes. The results of the analyses following the sessions revealed that low-ability students achieved more and were more motivated in heterogeneous groups; average-ability students performed better in homogenous groups; and high-ability students performed equally well in either heterogeneous or homogenous groups. Further analysis revealed that patterns of differences in quality of social interaction explained some of the performance variation across groups. For example, dialogue in homogenous groups consisted of a higher proportion of collaborative elaborations than heterogeneous groups, whereas heterogeneous groups exhibited relatively more individual elaborations. In conclusion, Saleh et al. suggested that further research is needed to examine the use of supports for social interaction and how these may be applied in groups of different ability levels to enhance individual and group level performance.

In a large-scale study, Cheng, Lam, and Chan (2008) also found that group processes were a determining factor in student achievement in a group context, whereas group composition was not. In their study, which was comprised of 367 secondary school project-based learning groups ($N = 1921$), Cheng et al. conducted hierarchical linear modelling

analysis to examine associations between quality of group processes (based on a 16-item measure addressing positive interdependence, individual accountability, equal participation, and social skills), self- and collective efficacy (based on a 4-item measure based on Bandura's [1997] conceptualisation of efficacy), student achievement (determined by mid-term school exams), group heterogeneity (determined using within-group variance on exam scores), group gender composition, and group size. The results of their analysis found that when the quality of group processes was high, both high and low achieving students reported higher collective efficacy than self-efficacy. Again, these results suggest that understanding and supporting quality group processes may warrant more attention when it comes to promoting learning gains, rather than a more exclusive focus on individual characteristics or group composition.

1.4.1. Process-oriented research

As a result of such findings researchers have begun to adopt a more process-oriented approach to the study of collaborative learning, investigating the role of key variables in mediating learning interactions (Dillenbourg, et al., 2009). A process-oriented approach, in essence, refers to "research focusing on the process of collaboration rather than the effect of collaboration" (Janssen, Kirschner, Erkens, Kirschner, & Paas, 2010a, p. 141). The need for such an approach was highlighted by Janssen et al. (2010a), who noted that the majority of published research in the area was effect-oriented in nature, that is, examining the effects of cooperation and collaboration on dependent variables such as student achievement, time on task and use of metacognitive strategies (Nichols, 1996; Klein & Pridemore 1992; Mevarech & Kramarski, 2003). Process-oriented studies, by contrast, examine key social and interaction processes *during* collaborative learning such as giving elaborated explanations (Webb & Farivar 1999), negotiating meaning (Beers et al., 2007), co-constructing solutions and lines of reasoning (Van Boxtel et al., 2000), and developing and formulating arguments during collaboration (Janssen et al., 2010b; Kuhn & Udell 2003). To provide an example of one such process-oriented focus, what follows is an overview of research on the process of giving and receiving explanations, a process which Webb and colleagues (Webb 1989; Webb & Farivar 1999; Webb & Mastergeorge, 2003; Webb et al., 2002; Webb, Topper, & Fall, 1995) have studied extensively.

Webb and colleagues have demonstrated that giving elaborate explanations (e.g., an explanation that contains a reason as to why a specific problem should be addressed in a certain way) correlates positively with student achievement when working on mathematics

problems (Webb, 2009; Webb et al., 2008; Webb & Mastergeorge, 2003; Webb et al., 1995), and science problems (Webb, Nemer, Chizhik, & Sugrue, 1998). Conversely, giving explanations without an elaboration (e.g., telling someone the answer without giving a clarification) does not correlate with student achievement (Webb, 1991). This research by Webb showing the benefits of explanations on student achievement in the context of mathematics and science was further supported by research highlighting positive relationships between the provision of explanations and student understanding in elementary science (Howe et al., 2007). Furthermore, this line of research by Webb and colleagues has shown that the relationship between receiving explanations and learning is not straightforward. Although receiving an explanation which does not contain an elaboration, or receiving no explanation at all, is negatively correlated with learning (Webb 1989; Webb & Farivar 1999), additional conditions have to be met in order for elaborate explanations to be effective for the receiver. For example, in studies focused on mathematics problem-solving, Webb and Farivar (1999), Webb et al. (1995), and Webb and Mastergeorge (2003) found that elaborate explanations were only effective when the receiver was able to apply the explanation in a related task (i.e., transfer their understanding to other problems).

The research by Webb and colleagues also focuses on the conditions under which the provision of quality explanations is more likely to occur. For example, it has been found that group-ability composition can affect the quality of explanations provided during the collaborative process. Webb et al. (1998), for instance, demonstrated that it is important that a certain level of expertise is available within the group because the quality of explanations (in terms of level of detail provided) is higher in groups that include some above-average students than in groups without these students. Webb's work shows how systematically studying aspects of the collaborative process can lead to more insight into the conditions under which optimal group processes unfold and how these processes affect student learning.

Whereas the research on giving and receiving explanations uses the individual as the unit of analysis, other process-oriented studies focus on the group as the unit of analysis (Barron, 2003; Dillenbourg et al., 1996). Barron (2003), for example, in a sample of 36 elementary school students, studied the differences between successful and less successful triads in terms of group performance on a problem-solving task. Barron found marked differences between these groups with respect to how group members responded to proposals by other group members and how well they were able to maintain joint attention. The more successful groups were found to react more appropriately or with a higher level of engagement to correct proposals offered by a group member. Appropriate or engaged

responses included accepting the proposal or starting a constructive discussion in response to a proposal. Inappropriate responses included ignoring other students and/or their proposals, or outright rejections of the proposed solution without discussion. Furthermore, members of successful groups were better than members of unsuccessful groups at maintaining joint attention because their contributions were more often in line with previous discussions. Barron also demonstrated that the members of successful groups typically outperformed members of less successful groups on individual mastery of mathematics problems and transfer tests of problems at a similar level of difficulty. Again, this process-oriented research study supports an understanding of how collaborative processes such as responding appropriately and maintaining joint attention contribute to individual and group performance.

1.4.2. CSCL and the challenges of orchestration

Coupled with a strong, emergent research focus on process-oriented dimensions of collaborative learning is a focus on the process of collaborative learning in CSCL environments. Importantly, the term “computer-supported” in CSCL refers not only to online, or remote, communication but also to face-to-face communication and interactions. Computer support may take the form of a distant interaction, either synchronously or asynchronously, but it can also take the form of a group of students working together in situ using a computer to, for example, construct a model or simulation, or browse through information on the internet and discuss the content (Stahl, Koschmann, & Suthers, 2006). As with collaborative learning research more broadly, the field of CSCL has shifted from a narrow focus on the individual learner to a focus on both individual and group learning (Stahl et al., 2006).

The addition of computers into a collaborative learning environment changes the nature of interactions in a group setting, and implies a range of new challenges associated with the coordination of teacher behaviour, student behaviour, learning materials, and computer processes. According to Dillenbourg et al. (2009) the most critical question which CSCL research seeks to address is, under which conditions is a CSCL environment effective? This question prompts two more specific questions: (a) under which conditions do particular interactions occur? and, (b) which interactions are predictive of learning outcomes? In considering these questions, Dillenbourg et al. (2009) refer to *challenges of orchestration*. Orchestration involves a process of coordination of various supportive interventions, across different learning activities and social levels. Four challenges of orchestration are of particular relevance here: (1) Orchestrating scaffolds at different social planes; (2)

Orchestrating self-regulation, and external regulation; (3) Orchestrating individual motivation and social processes; and, (4) The teacher as orchestrator.

Orchestrating scaffolds at different social planes refers to the fact that scaffolding in CSCL comes from many sources that operate across different social planes, with scaffolds potentially provided by the teacher, the software, the learning materials, and peers. For example, while scaffolding in the form of prompts may be delivered by the teacher at the whole class level, subsequent scaffolding for the same task may be delivered by peers at the group level, and related scaffolding at the individual level may be provided by written or graphical learning materials.

According to Tabak (2004), an approach which incorporates “synergistic scaffolds” (p. 307) is needed to design and implement integrated sets of interacting interventions in the classroom that operate across different social planes of scaffolded activity. Where the various scaffolds support each other, and operate in a complementary manner, the potential synergy can be realised. However, if scaffolds on various levels are not orchestrated properly, the potential learning benefits for the group may be limited, or worse, the different scaffolds may interact and impact negatively on learning. In the case of dialogue-based interaction in CSCL using the IM methodology for instance, orchestrating scaffolding at different social planes requires: a teacher facilitating an environment of open dialogue by modelling and coordinating exchanges and prompting students to clarify their ideas and logic; a software tool that supports the process of structuring ideas; and, learning materials which provide support to students in guiding their collaborative thinking and interactions (e.g., instructional supports for peer-to-peer prompting, in the case where a teacher hands over facilitation support directly to students). Crucially, as noted by Tabak (2004), effective design thinking is needed in advance of instruction to simulate and optimise synergistic scaffolding and a functional interdependence between different forms of scaffolding. In the absence of effective teacher-led prompts to support dialogue and argumentation in a student group, for example, the efficacy of the learning material scaffolding may be diminished (e.g., notes or graphics with prompts designed to support peer interaction). In the current thesis, simulation and pilot work in advance of Study 3 (see Chapter 5) highlighted the need for facilitators in an IM session to model specific prompting behaviours during systems model-building activity, before handing over to students control of the use of prompts designed to support peer-to-peer interactions. Similarly, if peer prompts provided by learning materials (e.g., a poster with sample prompts placed in front of students) are inconsistent with the scaffolding provided by the teacher (e.g., different verbal prompts are used by the teacher), the efficacy

of the learning materials may be diminished. In essence, the scaffolding provided across different planes of activity must be complimentary and synergistic in the service of successful group workings. This presents a significant design challenge for researchers and practitioners in the field of CSCL.

A related challenge of orchestration highlighted by Dillenbourg et al. (2009) is the challenge of *orchestrating self-regulation and external regulation*. The basic premise here is that learning processes and outcomes in collaborative learning are, to some extent, dependant on the availability of regulatory resources within students as learners, and within the learning environment (Kirschner, Sweller, & Clark, 2006). These resources act as scaffolding that allows students, for example, to monitor and regulate their own activity and learning, and the activity and learning of their group. Again, *orchestrating and coordinating self-regulation and external regulation* requires careful design of the learning environment. This usually involves the provision of some external instructional support that enables regulation. For instance, instructional support could take the form of graphic organisers which provide relevant prompts for the learning activity at hand (Gan, 2010). These prompts can be used by students to self-regulate their own approach to a task, or they can be used in peer learning, allowing students to monitor and prompt other members of their group during a shared learning task. Again, in the current thesis, a graphic organiser was used in the third experimental study (Chapter 5) to allow students to engage in peer-to-peer prompting during a CSCL task.

Orchestrating individual motivation and social processes highlights the need to focus on social-emotional processes and the design of environments where group members are, for instance, supported to “feel safe, take risks and share ideas” (Dillenbourg et al., 2009, p. 14). Noting that motivation is a key factor in CSCL success, Crook (2000) stresses the importance of attending to social factors, such as the perceived quality of experience, in the design of CSCL environments. Eales, Hall, and Bannon (2002), for example, highlight the importance of supporting students’ sense of control, such as feelings of ownership over learning. In a study by Van Den Bossche et al. (2006), it was found that interpersonal and sociocognitive processes play a role in the development of mutually shared cognition, which in turn influence levels of perceived team effectiveness. More specifically, questionnaire data was collected from 75 teams (average of 3.45 students per team) of university business students following a 7-week team project. The questionnaire included measures of team learning behaviours, psychological safety, independence, social cohesion, task cohesion, group potency, mutual shared cognition, and perceived team effectiveness. Multiple regression and

path analysis revealed that interdependence, task cohesion, psychological safety, and group potency significant predicted mutually shared cognition, which in turn contributed to higher perceived team effectiveness. Such results highlight the importance of social processes in collaborative learning. As such, each of the experimental studies in this thesis (Chapters 3-5) addressed social processes in the IM learning process, including: consensus, perceived efficacy, trust, team orientation, and attitudes towards group learning. An exploration of the role of each of these factors in collaborative learning is provided in Chapter 2 Section 2.6.

Finally, Dillenbourg et al. (2009) highlight the role of the *teacher as orchestrator*. In particular, they note the evolving role of the teacher or facilitator in CSCL environments, transitioning “from the sage on the stage to the guide on the side” (Dillenbourg et al., 2009, p. 14). This type of orchestration refers to the teacher becoming less of a knowledge provider, and taking on the role of a conductor, orchestrating a broad range of activities, including, for example, supporting student interaction, and providing instructional support. This evolving role of the teacher is a key issue for the design of CSCL environments, as careful attention and consideration must be given to providing teachers with the tools and means to monitor and guide classroom activities, and to flexibly adapt the environment, while also refraining from taking centre-stage. This design challenge is explored in more detail in Study 3 (Chapter 5), as the facilitator in the peer-to-peer prompting condition gradually relinquishes control of the IM session in one experimental condition, thereby passing control and responsibility for guiding and prompting to the students themselves. The challenges of orchestration identified by Dillenbourg and colleagues can be difficult to conceptualise and respond to in practice. Indeed, the overall challenge of designing and orchestrating effective scaffolds in CSCL environments is exacerbated by the fact that there is currently no single guiding framework for CSCL research and practice. According to Stahl (2010), there exist a number of influential theoretical frameworks in the CSCL research community, each of which model specific influences on collaborative learning (e.g., including dialogicality [Linell, 2009; Mercer, 2000; Wegerif, 2007], Situated Learning [Lave & Wenger, 1991], and Conversation Analysis [Sacks 1965, 1995; Schegloff 2007]). In an attempt to integrate and visualise the major categories of these influences, Stahl provides a graphical representation of the CSCL design landscape (see Figure 3).

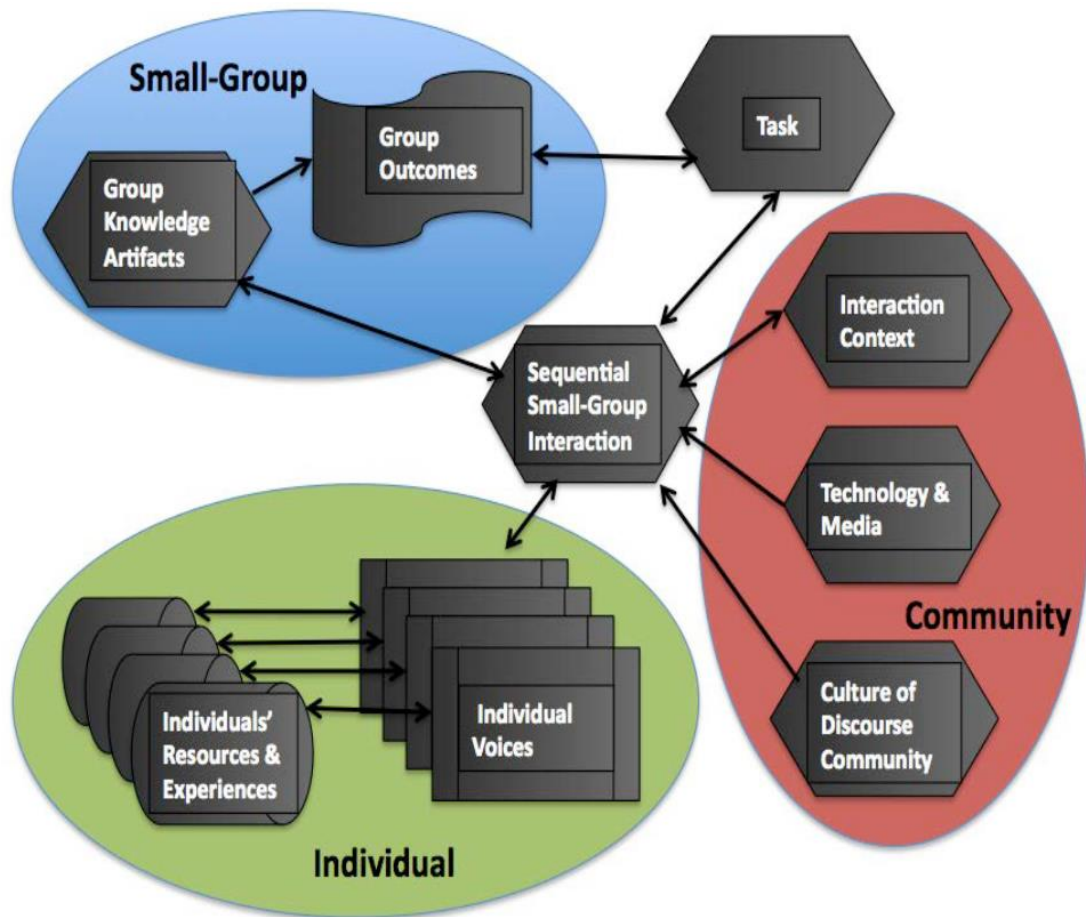


Figure 3. A diagram of influences on sequential small group interaction (sourced from Stahl, 2013)

This figure places at its centre *Sequential Small-Group Interaction*, which Stahl describes as “the dialogical interaction through which individual participants form into a collective knowledge-building agency” (2010, p. 255). From Stahl’s perspective, it is this sequential interaction which transforms the *Individual Voices* of group members into meaning-making at the level of the group. This shared meaning, co-constructed by the group through their dialogical interactions is, according to Stahl, embodied in the *Group Knowledge Artifacts*, such as linguistic phrases or physical objects. Further, as per Figure 3, these interactions may also be influenced at the community level, by the specific *interaction context*, the socio-technical environment including *technology and media* supporting the interactions, and the existing culture, or previous history of the *discourse community*. In the case of Warfield’s IM methodology, the shared meaning-making emerges through the facilitated discussion, and is realised in both the discussion at the group level and also in the *problematique* generated by the group, which provides a visual representation of the group’s logic in the form of a *Group Knowledge Artifact*. Finally, from Stahl’s perspective, this

process of collaborative knowledge building produces the *Group Outcomes*, which are contingent upon the *Task* at hand.

In combining major influences across theoretical frameworks in CSCL, Stahl is developing a representation of what he terms *Group Cognition* (Stahl, 2010). According to Stahl, group cognition is about much more than simply bringing different people together, a situation in which members may benefit to differing degrees from the presence of, or interaction with, other members. Rather, group cognition is about the group as a whole working to make meaning and develop collective cognitive responsibility (Zhang, Scardamalia, Reeve, & Messina, 2009) and new knowledge together (Cress & Kimmerle, 2008; van Aalst, 2009).

To provide an example, Zhang et al. (2009) report on a design experiment which sought to build collective cognitive responsibility in the context of a co-constructed knowledge building activity. In this study, the Knowledge Forum tool was used over 3-years in a Grade 4 classroom which used three different collaborative structures: fixed small-groups (Year 1), interacting small-groups with cross-group knowledge-sharing (Year 2), and opportunistic collaboration, with groups forming and disbanding based on the class members own wishes or decisions (Year 3). The results of this study found that the Year 3 model, which according to Zhang and colleagues maps “most directly onto organic and distributed social structures in real-world knowledge-creating organisations” (p. 7), resulted in both the highest levels of knowledge building, as measured by analysis of students’ essays, and the highest levels of collective cognitive responsibility, as measured by awareness of contributions (e.g., knowing the other members, and emergent issues), complementary contributions (e.g., building upon or referencing others’ contributions), and distributed engagement (e.g., degree of equality or variance in roles and contributions). Consistent with Stahl’s theoretical perspective, such results highlight that group cognition is about more than a group of students individually benefiting from group interactions, but rather the collective benefits which may emerge at the group level. Importantly, in a society where team-based work is increasingly valued and prevalent (Koc et al., 2015), such team-level learning outcomes represent a crucial outcome of group work. To the extent that individuals can embrace these outcomes as important and rewarding outcomes of group work, this may help to reinforce the development of increasingly well-developed teamwork skills in society.

More recently, in envisioning the future of CSCL on the ten-year anniversary of the launch of the *International Journal of Computer-Supported Collaborative Learning*, and in his final letter as editor-in-chief, Stahl (2015) noted that, despite its considerable contribution

to educational research, the field of CSCL has yet to make a major impact on schooling around the world. Stahl suggested that a significant barrier which currently impedes this goal, is that “teachers and policy makers do not yet have a clear understanding and appreciation of the social basis of learning and how small-group collaboration can be effectively orchestrated with classroom instruction, book learning, Internet browsing and individual reflection to form a mutually supportive and flexible learning environment” (p. 338). Stahl goes on to state that “there is now a need for teacher professional development in guiding and supporting collaboration as well as the development of curriculum aligned with established standards across grades” (p. 338). Crucially, Stahl believes that such a curriculum and pedagogy should incorporate a learning-sciences emphasis on student-centred, collaborative, explorative, immersive, problem-solving, computer-supported approaches. Each of these factors noted by Stahl played a significant role in this thesis, both in terms of experimental work, and informing the design of the pilot applied systems science curriculum.

1.4.3. The challenge of measuring collaborative learning

As well as the challenges of orchestration outlined above, collaborative learning, with or without computer-support, also presents challenges of measurement. According to Ghodrati (2015), the challenge of conceptualising collaborative learning, as evidenced by the variety of theoretical perspectives in the field, contributes to a challenge in measuring collaborative learning. Stemming from these multiple perspectives, a core consideration in the analysis of collaborative learning is whether or not the added value stemming from interaction between students can adequately be measured or inferred at the level of interaction (i.e. at the group level) or if this may only be derived from cognitive changes at the individual level (Strijbos & Fischer, 2007). As highlighted by Collazos et al. (2007), and more recently by Xing, Waldholm, Petakovic, and Goggins (2015), approaches to measuring and evaluating collaborative learning have tended to focus on (a) individual level outcomes (e.g. student knowledge gain) or (b) emergent collaborative products, as opposed to processes in collaboration. However, as noted in Section 1.4.1., a sole focus on collaborative learning outcomes, at the individual or group level, in the absence of investigation of collaborative learning processes, has contributed to inconsistent findings in the literature. The need to move towards a process-oriented approach to measuring and analysing collaborative learning is now well-established (Janssen et al. 2010a), and thus informed the approach to measuring collaborative learning in the current thesis. At the individual level, studies in the current thesis include measures of perceived consensus, objective consensus, and team orientation,

whereas group level measures include an analysis of the variety and complexity of collaborative argumentation using the Conversational Argument Coding Scheme (Seibold & Meyers, 2007) and calculations of the complexity of collaboratively-generated systems models. The use of the Conversational Argument Coding Scheme in Studies 2 and 3, which was designed for the analysis of argumentation during group dialogue, and thus allows for coding of interaction between participants (see Section 2.4.1. for a detailed description), alongside the aforementioned individual level indicators of collaborative learning, such as consensus and team orientation, were thus included in the current research in an attempt to address the challenge of measuring collaborative learning at these two levels.

1.5. Designing CSCL environments: Applied systems science education

One of the primary goals of CSCL is to make good use of computers in teaching and learning environments and to design artefacts, activities, and environments that enhance the practices of collaborative knowledge-building and group meaning-making. However, it is commonly noted that technology operating in isolation is insufficient to support learning. According to Stahl, Koschmann, & Suthers (2006), using a CSCL approach to support teaching and learning requires a much more holistic approach, including multifaceted design considerations and implementation strategies. Among those factors which need to be addressed are: the design of curricula around CSCL tools; the development of teaching and learning resources; the design of participation structures; and the purposeful design of CSCL tools for specific tasks and goals. This need for a multifaceted design approach in CSCL is appropriately framed by LeBaron (2002) who, in a commentary entitled *Technology does not exist independent of its use*, stated “technology is what people use it to do” (p. 437). Stahl et al. (2006) build on this commentary by LeBaron, by stating that “In order to design technology to support collaborative learning and knowledge building, we must understand in more detail how small groups of learners construct shared meaning using various artifacts and media” (p. 417). With this in mind, this thesis explores the use of IM as a CSCL tool which can be used to support student learning in a university context.

While IM has been used to support group project work in many organisational and professional contexts, it had not yet been extensively used in educational contexts to support student learning. Given the structured nature of the methodology and the way in which it can be used to support systems thinking in relation to complex societal problems, IM has great potential as an educational tool around which a systems science curriculum can be built. However, as noted above by LeBaron (2002), having access to a CSCL tool, even one which has been successfully applied in a variety of work contexts, is no guarantee of learning success in a classroom context. Adapting a tool for use in an educational context requires the design of participation structures (such as facilitation or prompting protocols), the design of teaching and learning resources (such as graphic organisers for instructional support), and the design of a curriculum that structures activities around specific learning outcomes (Stahl et al., 2006). As such, a primary aim of this thesis is to move towards the development of IM as an educational tool, by addressing these design requirements. Figure 4 below provides a visualisation of the core design components addressed in this thesis.

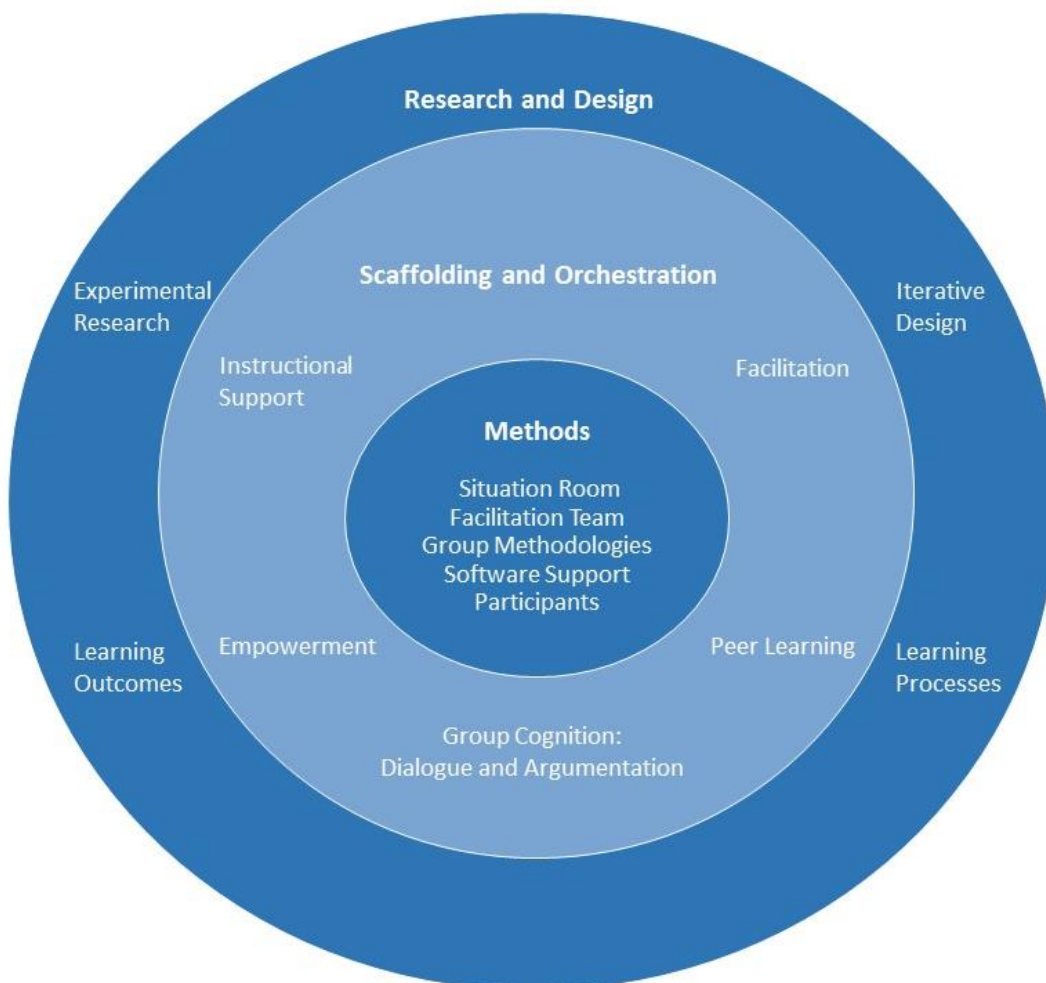


Figure 4. Applied systems science education design components

This figure includes three layers of design. At its core, is the *Methods* layer of applied systems science curriculum design. This is comprised of Warfield's IM methodology and the five factors which he highlights as critical to its implementation: (1) A productive working space, which Warfield referred to as a Situation Room; (2) a Facilitation Team; (3) Group Methodologies; (4) Software Support; and, (5) Participants.

Surrounding the *Methods* layer is the *Scaffolding and Orchestration* layer. This layer recognises the need to provide support and instructional guidance to students in their use of the core IM methodology. This involves addressing Dillenbourg et al.'s (2009) challenges of orchestration described above (see Section 1.4.), as well as specific challenges associated with the *facilitation of dialogue and argumentation* and the cultivation of *group cognition* in efforts to support an understanding of complex problems. A core and related challenge in this context involves the *empowerment* of students in the collaborative process, such that they begin to regulate and direct their own learning and support learning amongst their peers.

The final layer, *Research and Design*, involves experimental investigation and iterative design of the components within the *Scaffolding and Orchestration* layer in the context of a broader curriculum design process, such that experimental study findings and an understanding of the link between CSCL processes and outcomes can be used to inform the iterative design and delivery of an applied systems science curriculum.

In conclusion, throughout his career Warfield highlighted the need for a systems science approach to complex problems, including the development of methods to support shared understanding, and the integration of such methods into university education. Advancing upon Warfield's vision requires situating his perspective on systems science education alongside current research and applications of collaborative learning. Notably, at the core of Warfield's method is a focus on the facilitation of dialogue in the service of system design. The research reviewed in this chapter, including work by Mercer, Wegerif and others, demonstrates the power of dialogue in educational settings. As such, dialogue plays a prominent role throughout this thesis, specifically in the form of collaborative argumentation, which is described in detail in Chapter 2. Furthermore, Learning Sciences research, as described in this chapter, highlights the need to consider both instructional and social processes in the context of collaborative learning, highlighted by Dillenbourg's *challenges of orchestration*, and Stahl's representation of the components of *Group Cognition*. Building upon the above perspectives, Chapter 2 provides a more in-depth examination of research relating to collaborative argumentation, instructional support for collaboration, as well as key social-emotional processes that are central to collaborative learning.

Chapter 2: Collaborative learning processes and outcomes

2.1. Chapter overview

This chapter provides a description of additional research relevant to the experimental studies presented in Chapters 3-5. The chapter opens with a broad overview of collaborative learning research, before focusing more specifically on collaborative argumentation. Collaborative argumentation, as a form of dialogue-based interaction, is central to the experimental research presented in this thesis, specifically in Studies 2 and 3 (Chapters 4 and 5). Central to the research reviewed in this chapter are studies that have focused on supporting and cultivating collaborative argumentation, for example, using prompts or discourse instructions. Next, the concept of peer learning is introduced, along with research that highlights the potential benefits of peer learning. This focus on peer learning is central to the experimental research carried out in Study 3 (Chapter 5). Following this, social-emotional factors which are influential in the context of collaborative learning are reviewed. Chapter 2 then closes by providing a rationale for each of the experimental studies in the current thesis.

2.2. An overview of collaborative learning outcomes

Collaborative learning has been described as “an educational psychology success story” (Johnson & Johnson, 2009, p. 365). This success story is built upon a body of research which has been growing steadily since the 1970s (Slavin, 1996). Several meta-analyses have been carried out showing that collaborative and cooperative learning approaches can be effective for promoting critical thinking (Alavi, 1994), problem-solving (e.g., Qin, Johnson, & Johnson, 1995; Lou, Abrami, & d'Apollonia, 2001; Roseth, Johnson, & Johnson, 2008), as well as learning gains (Johnson & Johnson, 1989), student achievement (Slavin, 1989), and student engagement (Schaffert et al., 2006). For example, Johnson and Johnson (1989) conducted a meta-analysis with the aim of comparing the effects of employing cooperative learning approaches versus competitive learning approaches, or individual learning approaches on core learning outcomes. The results of the meta-analysis showed that students in cooperative learning classrooms learned significantly more than students in classrooms which adopted a competitive approach (mean Effect Size [ES] = +0.67), and more than students in individual-learning focused classrooms (mean ES = +0.64). Furthermore, it was found that cooperative classroom approaches were associated with other learning-related benefits, with the meta-analysis reporting medium to large positive effects on outcomes such as: positive student attitudes toward the subject matter and learning, liking of other students, and feelings of social support.

Slavin (1989) also conducted a meta-analysis of cooperative learning studies, finding a small positive effect of cooperative learning on student achievement (median ES = +0.21). Slavin's meta-analysis concluded that, in the context of cooperative learning, strategies for promoting *positive interdependence* and *individual accountability* contributed to learning gains, reporting that students learned significantly more in groups where both positive interdependence and individual accountability were operative, rather than one alone. Positive interdependence refers to the link which exists between group members, "such that ... each team member cannot succeed unless the others succeed and/or that each member's work benefits the others (and vice versa)" (Kreijns et al., 2003, p. 339). Individual accountability refers to the idea that "all group members are held accountable for doing their share of the work, and for mastery of all of the material to be learned" (p. 339). Together, positive interdependence and individual accountability are important features of successful collaborative and cooperative learning exchanges.

In a further analysis of the effects of collaboration and cooperation, Qin, Johnson and Johnson (1995) conducted a meta-analysis assessing the impacts of cooperative versus competitive approaches to problem-solving. The meta-analysis examined 46 studies, containing a total of 63 relevant empirical findings. In order to delineate between different kinds of outcomes across these studies, the problem-solving activities were divided into four categories: *linguistic*, which included problems solved through written and oral language; *non-linguistic*, which included problems solved through symbols, mathematics, or actions; *well-defined*, which included problems which involved clearly defined operations and solutions, and; *ill-defined*, which included problems which lacked clear definitions, operations and solutions. The results of this meta-analysis reported that those in cooperative groups displayed better performance on average than those in competitive groups across all four categories of problem-solving, with the effect sizes for non-linguistic and ill-defined problems generally higher than effect sizes for linguistic and well-defined problems: linguistic (mean ES = +0.26), non-linguistic (mean ES = +0.67), well-defined (mean ES = +0.34), and ill-defined (mean ES = +0.77).

More recently, Roseth, Johnson, and Johnson (2008) conducted a meta-analysis to assess the effects of cooperative, competitive, and individualistic goal structures on educational achievement and peer relationships in early adolescents. This meta-analysis included 148 studies conducted with over 17,000 participants. For the purpose of this meta-analysis, achievement was defined by reference to task-performance, based on measures including: comprehension, quality and accuracy of answers on tests, quality and accuracy of problem-solving, time taken to reach solutions, or time spent on the task, higher level reasoning and critical thinking, creativity, recall and retention, and transfer of knowledge. The results of the meta-analysis found that cooperative goal structures were associated with increased achievement when compared with competitive

goal structures (mean ES = +0.46) and individualistic goal structures (mean ES = +0.55). In focusing on positive peer relationships (defined as liking and/or support for others, and broadly including concepts such as group cohesiveness, social support, and friendly and caring interactions) Roseth et al. (2008) documented effects across a range of measures. These measures included: rating of classmates according to degree of liking, listing adjectives to describe classmates, number of dimensions used to describe classmates, and observations of interactions during free time. Averaged across these measures, the results of the meta-analysis found that cooperative goal structures were associated with enhanced positive peer relationships when compared with competitive goal structures (mean ES = +0.48) and individualistic goal structures (mean ES = +0.56).

It is also worth noting that meta-analyses have also been conducted in contexts in which computer technology is used as part of the collaborative task or environment. For example, Lou et al. (2001) extracted 486 independent findings from 122 studies involving collaborative small groups using computer technology, with a total sample population of 11,317 students. Lou et al. reported that, on average, small group learning had significantly more positive effects than individual learning on student individual achievement (mean ES = +0.16), group task performance (mean ES = +0.31), as well as several process-related measures such as: positive peer interaction (mean ES = +0.33), use of strategies (mean ES = +0.50), and perseverance (mean ES = +0.48); and also for affective outcomes such as: attitudes towards group work (mean ES = +0.52), and attitudes towards classmates (mean ES = +0.52).

As can be seen from the above meta-analyses, a wide variety of dependent variables have been investigated in the context of collaboration, with research showing positive effects of collaboration on both educational outcomes such as student achievement (e.g., Sung & Hwang, 2013) and collaborative processes such as positive peer interaction (e.g., Lou et al., 2001).

2.3. Process-oriented research in collaborative learning

As highlighted in Chapter 1, collaborative learning research can broadly be divided into two approaches: effect-oriented research, and process-oriented research. The reason for this divide was borne of a recognition by researchers that, when used alone, the traditional effect-oriented approach to collaborative learning research represented something of a *black box* approach. In particular, an exclusive focus on outcomes curtails our understanding of the workings of the collaborative process, and thus researchers and practitioners found it difficult to understand what exactly was happening during collaboration. This in turn made it difficult to explain differential effects of collaborative learning across studies that adopted different collaborative processes (Janssen et al., 2010a).

In contrast, process-oriented research seeks to study the processes which occur *during* the collaboration, thereby focusing on the nature of collaborative interactions, as opposed to solely focusing on the outcome of collaboration, in an attempt to establish which features of interaction are likely to produce or contribute to learning gains (Janssen et al., 2010a). As such, while effect-oriented research has examined a wide range of effects of collaborative learning, such as student achievement (e.g., Sung & Hwang, 2013), and group task performance (e.g., Inkpen, Booth, Klawe, & Upitis, 1995), process-oriented research has sought to understand the interaction processes at play during collaborative learning. For example, as noted in Chapter 1 Section 1.4. a series of studies by Webb and colleagues examined the process of students giving and receiving explanations during collaborative learning, finding that providing elaborate explanations is positively associated with student achievement. Findings in relation to such learning processes are particularly relevant to understanding how dialogue and argumentation might be optimised in the context of collaborative learning using IM.

Another example of process-oriented research is provided by Janssen et al. (2010b), who investigated the role of representational guidance in students' development of arguments during a CSCL task. In this study, 39 groups of 2-4 students were set a task which involved analysing a series of historical texts, constructing an argument, and writing an essay, using the *Debate* tool. Students were assigned to one of two conditions, each of which involved the use of a different version of the tool, and more specifically, a different level of representational guidance. In one condition groups used the *Graphical Debate* version, and in another condition groups used the *Textual Debate* version. The *Graphical Debate* version enabled students to add boxes representing arguments, supports, and refutations to an argument field, thereby building a graphical representation of the various components of their argument. In the *Textual Debate* version, students built their argument in a listwise manner. Once students had generated their representations of the argument, they were required to collaboratively write an essay detailing their argument. Both the constructed representations and the essays were then assessed by the researchers. Assessment criteria for the quality of representations included: the extent to which propositions adequately supported the central claim of the argument; correctness and quality of elaborations to justify inclusion of propositions; use of additional information to mitigate or counter arguments; and, use of references to persons, eras, or events to explain the historical context. Quality assessments for the essays included: how well the essay covered all topics found in the texts provided; quality of grounds used; and, conceptual quality of the argumentation. The results of this study

showed that students in the *Graphical Debate* condition constructed higher quality argument representations, and also produced higher quality essays than students in the *Textual Debate* condition. The authors concluded that the process of providing representational guidance in a CSCL environment has a significant impact on the quality of collaborative argumentation, as differences in the forms of representational guidance afforded to students by the tool impacted on their success in forming a well-grounded and conceptually strong argument. The study also highlights the value of adopting a process-oriented approach to collaborative learning research, and is relevant in the context of this thesis as it highlights conditions under which argumentation and collaborative project work can be supported using CSCL tools. In light of the centrality of argumentation in the design of systems models using Warfield's IM methodology, the following section provides an overview of research on argumentation, as well as the use of argumentation in the context of collaborative learning.

2.4. Argumentation and collaborative learning

Developing an ability to engage in argumentation is an important life skill. The utility of this skill is evident in many scenarios - an academic engaging in debate, a researcher positing a theory, a politician lobbying for a policy, or an entrepreneur pitching a product idea, to name but a few. In scenarios such as these, an individual must cite relevant facts, coordinate reasons and objections in relation to core claims, respond to rebuttals and counterclaims in a reasonable manner, and make full use of their powers of persuasion to convince others of their position and justify their conclusions (Scheuer, Loll, Pinkwart & McLaren, 2010). However, argumentation is more than just a method for persuading others, it is also an essential tool which individuals may employ collaboratively in order to arrive at rational decisions and conclusions that promote the adaptive success of the group. In this way, argumentation skills are central to both critical and collaborative thinking.

The development of critical thinking skills has been highlighted as an important goal for education. Critical thinking involves a number of component skills including reflective judgement, analysis, evaluation, and inference, all of which are skills which increase the likelihood of arriving at rational decisions and conclusions (Dwyer, Hogan, & Stewart, 2015). Furthermore, it has been noted that the practice of argumentation may also promote critical thinking skill development (Veerman, Andriessen, & Kansellar, 2002).

More generally, research suggests that critical thinking training interventions (e.g., Abrami et al., 2008; Alvarez-Ortiz, 2007; Hitchcock, 2004; Reed & Kromrey, 2001; van Gelder, 2001; van Gelder, Bissett & Cumming, 2004) can be used to enhance critical thinking

skills. A number of different approaches to cultivating critical thinking skills have been investigated in the literature (Abrami et al., 2008; Dwyer, 2011). In a meta-analysis of different types of critical thinking interventions, Abrami et al. (2008) reviewed 117 studies in an effort to understand how best to support the development of critical thinking skills. Four types of critical thinking interventions were identified, in accordance with Ennis' (1989) typology: *general*, *infusion*, *immersion*, and, *mixed*. In this context, *general* refers to intervention approaches where critical thinking skills and dispositions are key learning objectives, but the intervention does not involve specific subject matter content. *Infusion* approaches involve critical thinking skills being practised on the subject matter within an existing course, and the objective of teaching critical thinking skills is also made explicit to students in this process. In the *immersion* approach, critical thinking skills are again practised on specific course content, however, the objective of teaching critical thinking is not made explicit to students. Finally, the *mixed* approach involves the teaching of critical thinking skills alongside or independently of the specific course content. Comparing these different critical thinking intervention approaches, the results of the meta-analysis by Abrami and colleagues (2008) revealed the *mixed* approach had the largest effect on critical thinking performance ($g+ = .94$), followed by *infusion* ($g+ = .54$), *general* ($g+ = .38$) and *immersion* ($g+ = .09$). The results of this meta-analysis suggest that, while a variety of broad curriculum-based approaches can be adopted in efforts to cultivate critical thinking skills, approaches that couple an explicit focus on critical thinking, alongside the existing course content, are most beneficial.

A related strand of research has focused on instructional support tools that can be used in critical thinking interventions. One such approach relevant to the current thesis is argument mapping. An argument map, according to Dwyer (2011, p. 111) provides a “diagrammatic version of any prose-based argument”. As is the case with IM systems models, argument mapping serves to structure the logical interdependencies between ideas or propositions and reduce the cognitive load associated with assimilating large quantities of information (Pollock, Chandler & Sweller, 2002). Notably, evidence for the benefits of argument mapping as a critical thinking intervention is growing (e.g., Alvarez-Ortiz, 2007; Butchart et al., 2009; Dwyer, Hogan, & Stewart, 2012; van Gelder, 2001; van Gelder, Bissett & Cumming, 2004). For example, Dwyer et al. (2012) delivered an argument mapping-infused critical thinking training intervention to 74 university students, over the course of 8 weeks, to test the impact of argument mapping training on critical thinking ability. More specifically, the study involved two conditions. Students in the experimental condition participated in an

e-learning critical thinking course, which involved the use of Argument Maps (AMs) and weekly online critical thinking training videos and exercises. Students in the control group did not receive any critical thinking training. Both groups of students completed the Halpern Critical Thinking Assessment (HCTA; Halpern, 2010), before and after the intervention. The results of this study found that participation in the argument mapping-infused critical thinking training significantly enhanced overall critical thinking ability in comparison with the control groups.

The findings of Dwyer et al. (2012) are consistent with findings from studies showing the benefits of argument mapping for critical thinking skills (e.g., Alvarez-Ortiz, 2007; Butchart et al., 2009) and highlight, more generally, the potential benefits of using instructional supports in the development of thinking skills. These findings in relation to the cultivation of critical thinking skills in the classroom raise two important considerations for the design of applied systems science education, and more specifically, for the development of argumentation skills, which operate at the core of collaborative systems design work using the IM methodology.

First, Abrami et al.'s (2008) meta-analytical findings suggest that the cultivation of higher-order skills such as critical thinking is best achieved when situated alongside the primary course content. In the context of applied systems science education, this implies that any effort to teach systems thinking and build systems models should align with broader learning goals in the student's primary subject area. In the current thesis, this implied a focus on system design in areas relevant to the student's core subject area (i.e., psychology). As such, across the experimental studies and the pilot curriculum presented in this thesis, students developed systems models focused on medication adherence (Health Psychology), government transparency (Political Psychology), e-book design for children (Educational Psychology), and critical and collaborative thinking (Educational Psychology). Second, numerous studies, including that of Dwyer and colleagues (2012), have shown the positive impact of structured instructional supports in the development of argumentation skills. This consideration features prominently in the design of Study3 (Chapter 5) in particular, which involved the use of graphic organisers to support peer-to-peer prompting for the purpose of prompting collaborative argumentation and the building of elaborated systems models.

Importantly, Kuhn and Udell (2003) suggest that the ability to propose, critique and defend a position is required across all domains of knowledge, and is central not only to the acquisition of knowledge but also the application of knowledge in everyday problem-solving situations. At the same time, research suggests that people often demonstrate limited

argumentation skills (e.g., Tannen, 1998). This has been documented in various studies which report deficiencies in argumentation skills in informal settings (Kuhn, 1991), as well as in professional and scientific domains (Stark, Puhl & Krausse, 2009). To address these limitations, there is a growing trend in the use of instructional support to enhance argumentation skills, particularly in collaborative learning settings (Scheuer et al., 2010). Empirical studies (e.g., Schwartz, 1995; Shirouzu, Miyake, & Masukawa, 2002) have shown that, when embedded in learning practices, argumentation in collaborative problem-solving activities fosters higher-order understanding in the form of abstraction, while also supporting a process of learning that goes beyond merely recalling concepts (Kirschner, Paas, & Kirschner, 2009). Furthermore, in recent years, there has been an increased emphasis on aligning classroom practices with scientific practices, including a focus on scientific argumentation and collaborative problem-solving tasks. This convergence of interest and alignment of curriculum goals across critical and collaborative thinking, and scientific practice, is consistent with the vision of John Warfield when he highlighted the need to move beyond critical thinking, to a focus on applied systems design thinking and practice in education.

According to Berland (2011), scientific argumentation involves overlapping goals of collaboratively making sense of the phenomenon under study, and convincing one's collaboration partners that a specific set of arguments are relevant and sound in the context of the problem being addressed. In other words, it involves both the acts of proposing and defending claims, which involves a process through which students can engage in questioning and challenging both their own, and others', ideas. Likewise, such processes provide students with opportunities to identify the strengths and weaknesses of their understanding of a topic, and that of their peers (Bell & Linn, 2000; de Vries et al., 2002). This form of collaborative scientific argumentation has been found to support performance when solving both well-structured and ill-structured problems (Jonassen & Kim, 2010).

2.4.1. Measuring and analysing argumentation

In the context of Stahl's (2013) conceptualisation of *Group Cognition*, the exercising of key thinking skills, including core components of critical thinking - reflective judgement, analysis, evaluation, and inference - are assumed to take place during *sequential small-team interaction*, the process which Stahl places at the core of his model (Figure 3, p. 36). Importantly, measures have been developed which allow for specific components of dialogue and argumentation to be coded and quantified, allowing researchers to manipulate aspects of

the collaborative learning environment and measure the effects of these manipulations on the style and complexity of argumentation that groups engage in. These measures and methods allow researchers, for example, to analyse what is happening in the central node of Stahl's *Group Cognition* model, that is, what is happening during small-group interactions, and how, for instance, various forms of instructional support impact on the dialogue and argumentation interactions which occur. In the context of collaborative learning, while students' collaborative arguments (e.g., as presented in the form of an essay, an argument map, or a systems model) may be considered a product or an *outcome* of learning, this outcome is arrived at via the *process* of argumentation. As such, while an effect-oriented approach may seek to analyse the argument product, a process-oriented approach would seek to analyse the dialogue and key components of the argumentation interactions which occurred between students during the development of their final product.

Analysis of dialogue and argumentation, however, is a complex process. As such, numerous theoretical perspectives have been drawn upon in designing frameworks and coding schemes for analysis and measurement of dialogue and argumentation, including: structuration theory (Giddens, 1979), logic and argument theory (Toulmin, 1958), rhetoric and argument theory (Perelman & Olbrechts-Tyteca, 1969), pragmatic conversational argument theory (Jackson & Jacobs, 1980), minimally rational argument theory (Canary, Brossmann, Brossmann, & Weger, 1995) and structuration argument theory (Seibold & Meyers, 2007). A number of coding schemes for assessing the quality of argumentation have been devised, which vary in terms of the ways in which they label and categorise features of dialogue and argumentation. Walton (2000), for example, conceptualises an argument as a set of moves. More specifically, Walton characterised six types of dialogue moves in an argument – persuasion, inquiry, negotiation, information seeking, deliberation, and eristic. Approaches such as Walton's, according to Andriessen and Baker (2014) seek to provide a means of analysing argumentation by reference to whether or not appropriate moves have been made, and whether or not the dialogue progresses towards a constructive outcome.

One of the more commonly used argumentation coding schemes, Toulmin's Argument Pattern (Toulmin, Rieke, & Janik, 1984), is comprised of the following categories:

- Data: consists of evidence, information, facts, or procedures that lead to the claim.
- Claims: the conclusion at which one arrives after considering the data.
- Warrants: how the data or evidence leads to the claim.

- Backings: explain why the warrant has authority and provides further validity for the argument.
- Qualifier: indicates the degree of certainty the arguer attributes to the claim.
- Rebuttals: are counter claims or refutations of one or more components of the argument.

While Toulmin's model has been influential in the field of argumentation theory, it is considered to be more useful in analysing completed declarative arguments than in analysing the dynamic process of argumentation (Noroozi, Weinberger, Biemans, Mulder, & Chizari, 2013). When considering argumentation as a process of collaborative discourse, Toulmin's model is considered to be less appropriate, due to its lack of attention to the interaction and interdependency between arguers (Andrews, 1995). van Eemeren and Grootendorst (1999), for example, argue that Toulmin's model does not consider both sides of an argumentation interaction, rather it only considers the proponent's side. As such, while Toulmin's rubric has been widely used to assess argumentation in learning contexts (Nussbaum, 2008; Erduran, Simon, & Osborne, 2004), the debate as to its appropriateness in the context of collaborative discourse (Andriessen & Baker, 2014) suggested it was not optimal for use in analysis of argumentation in the experimental studies in this thesis.

An alternative approach to analysing argumentation is the Conversational Argument Coding Scheme (CACS), developed by Seibold and Meyers (2007), which is a commonly used method for investigating arguments involving diverse communicative interactions, and was explicitly designed for the analysis of argumentation in the context of group dialogue. This coding scheme, the development of which was influenced by Toulmin's scheme among others, has been used in various contexts involving argument-relevant behaviour including: group deliberations (Seibold & Meyers, 2007), jury decision-making (Burnett & Badzinski, 2000), televised political discussions (e.g., Brossmann, Canary, Sillars, & LoVette, 1990) and studying intergroup conflict (Ellis & Maoz, 2007). To provide an example of one application of the CACS in the context of small group decision-making, Lofstrand (2015) found that, compared to groups who were unsuccessful (based on measures of group decision satisfaction and group efficiency), successful groups engaged in more reasoning activities, especially responses and justifications. As such, successful groups were characterised by argumentation moves beyond simple generative mechanisms (levels of which did not differ between groups) and engaging in more complex forms of discussion and argumentation. Importantly however, no research to the author's knowledge, has used the CACS to examine changes in dialogue or

argumentation in the context of collaborative learning in classroom settings, or how different types of facilitation or instructional support impact on changes in the complexity of collaborative argumentation in such contexts. Thus, a key issue for exploration in this thesis is how best to support collaborative argumentation in the classroom, as measured by the CACS. Specifically, the CACS is used as a means to assess the variety and complexity of argumentation evidenced by students in different experimental learning conditions (Studies 2 and 3, Chapters 4 and 5).

The CACS identifies 16 conversational codes grouped under 5 argumentation categories, with the codes representing different levels and types of argumentation (Beck, Gronewold & Western, 2012; see Table 1 below). The five argument categories include the following: (1) *generative mechanisms* (assertions and propositions) are considered to reflect simple assertions or arguments; (2) *reasoning activities* (elaborations, responses, amplifications, and justifications) are higher-level argument messages and are most often extensions of generative mechanisms; (3) *convergence-seeking activities* (agreement and acknowledgements) refer to statements that provide some recognition and/or agreement with other statements; (4) *disagreement-relevant intrusions* (objections and challenges) consist of statements denying agreement with arguables, or posing further questions; and (5) *delimiters* (frames, forestall/secure, and forestall/remove) consist of messages designed to frame or contextualise the conversation. The remaining codes are termed *nonarguables* (process, unrelated and incompletes) which consist of statements regarding how the group approach the task, side issues and incomplete or unclear ideas and statements.

Table 1. *Conversational Argument Coding Scheme (Seibold & Meyers, 2007)*

I. Arguables
A. Generative mechanisms
1. Assertions: Statements of fact or opinion
2. Propositions: Statements that call for support, action, or conference on an argument-related statement
B. Reasoning activities
3. Elaborations: Statements that support other statements by providing evidence, reasons, or other supports
4. Responses: Statements that defend arguables met with disagreement
5. Amplifications: Statements that explain or expound upon other statements to establish the relevance of the argument through inference
6. Justifications: Statements that offer validity of previous or upcoming statements by citing a rule of logic (provide a standard whereby arguments are weighed)
II. Convergence-seeking activities
7. Agreement: Statements that express agreement with another statement
8. Acknowledgement: Statements that indicate recognition and/or comprehension of another statement but not necessarily agreement with another's point
III. Disagreement-relevant intrusions
9. Objections: Statements that deny the truth or accuracy of an arguable
10. Challenges: Statements that offer problems or questions that must be solved if agreement is to be secured on an arguable
IV. Delimiters
11. Frames: Statements that provide a context for and/or qualify arguables
12. Fore stall/secure: Statements that attempt to forestall refutation by securing common ground
13. Fore stall/remove: Statements that attempt to forestall refutation by removing possible objections
V. Nonarguables
14. Process: Non-argument-related statements that orient the group to its task or specify the process the group should follow
15. Unrelated: Statements unrelated to the group's argument or process (tangents, side issues, self-talk, etc.)
16. Incompletes: Statements that do not contain a complete, clear idea because of interruption or a person's discontinuing of a statement

2.4.2. Supporting argumentation in the classroom

Since approximately the mid-90's, collaborative argumentation has been a growing focus of enquiry in collaborative learning research (Nussbaum, 2008). Collaborative argumentation has been identified by educational researchers as a potentially powerful way to overcome deficiencies associated with traditional individualistic education, approaches which deemphasise the voice of students in the classroom (Osbourne, 2010). Given the potential benefits of collaborative argumentation as a catalyst for learning, it follows that emphasis should be placed on providing opportunities for such interactions in educational contexts. However, it has been noted that effective collaborative argumentation, as with other forms of collaborative learning, does not occur spontaneously in a classroom setting (Dillenbourg, 2002). In order to achieve this, it is necessary to provide collaborative groups with facilitation and instructional support, such as prompts designed to cultivate and sustain quality interactions during the collaborative learning process (Gabelica, Bossche, Segers, & Gikselaers, 2012). More generally, cultivating and supporting collaborative argumentation requires educational design thinking, including the design and use of scaffolding to guide effective interactions (Cáceres, Nussbaum, Marroquín, Gleisner, & Marquínez, 2017).

In their review of argumentation research, Asterhan and Schwarz (2016) provide an overview of what they term “enablers and inhibitors of argumentive dialogue” (p. 172) in educational contexts. More specifically, Asterhan and Schwarz point to five categories of enablers or inhibitors which have been subjected to empirical study. These are: (1) task design; (2) communication media; (3) process support; (4) individual characteristics; and, (5) social and cultural factors.

The *task design* category refers to design decisions which educators must make in developing a learning task. These design decisions include: the choice of topic for discussion; the resources made available to students; and the sequencing of activities. These task design decisions impact on the likelihood of students engaging in productive argumentation (e.g., Andriessen & Schwarz, 2009; Jiménez-Aleixandre, 2007). For example, it is important that the chosen topic is amenable to discussion and, as such, can be problematised to evoke engagement (Eagle & Conant, 2002). Similarly, Sadler, Barab, & Scott (2007) suggest that framing topics within moral or social dilemmas is likely to enhance student engagement (e.g., framing a discussion of scientific literacy around the growing anti-vaccination or climate change denial movements).

The category of *communication media* refers to the idea that communication media can influence the content and nature of human communication, as suggested by communications research. For example, Kraut, Fussell, Brennan, and Gergle (2002) reported that computer-mediated communication (CMC) often contains less social or off-topic communication, and is often more structured and less ambiguous than communication conducted in person. Furthermore, the affordance offered by CMC, enabling students to re-read and revise their contributions before sending them, has been found to encourage reflection (Guiller, Durndell, & Ross, 2008). However, despite such promising results, it is noted by Asterhan and Schwarz (2016) that there is little empirical research which directly addresses the effects of CMC on argumentation in educational settings.

As regards the category of *individual characteristics*, a number of individual differences such as prior domain-specific knowledge, epistemological beliefs, and motivation have been highlighted as factors for consideration in the context of supporting argumentation. For example, Asterhan and Schwarz (2016) note that while general agreement exists regarding the importance of student engagement for argumentation, little is known about the role of motivation.

The category of *social and cultural factors* addresses issues such as social relations, peer status, and friendship. Research suggests that students' quality of friendships, feelings of relatedness, and peer acceptance, for example, are very important to students of all ages (Aikins, Bierman, & Parker, 2005; Kingery, Erdley, & Marshall, 2011; Wentzel, Barry, & Caldwell, 2004). Desire to maintain such feelings then, may negatively impact on students' willingness to engage critically with their peers, as demonstrated by Asterhan (2013). Furthermore, research by Webb (2009) reported that students of lower peer status participate less frequently in peer-driven group work. Such results highlight the importance of considering social-emotional factors in the context of collaborative argumentation. As such, Section 2.6. in this chapter presents a discussion of a set of social-emotional factors, including consensus, team orientation, attitudes towards group work, perceived efficacy, and trust, each of which are discussed in the context of their role in collaborative learning.

Of the five categories of enablers or inhibitors identified by Asterhan and Schwarz (2016), *process support* warrants the most consideration in the current thesis. As noted by Asterhan and Schwarz (2016), while task design and choice of communication media may affect the likelihood of argumentation, process support has a direct impact on the argumentation discourse itself. They distinguish between three types of process support: (1)

software design for supporting argumentation, (2) discourse instruction, and (3) teacher scaffolding.

A range of approaches to *software design for supporting argumentation* have been developed. These include: visual representations of argumentation structures (e.g., Schwarz & de Groot, 2007), computerised collaboration scripts (e.g., Fischer, Kollar, Stegmann, & Wecker, 2013), automated group arrangement to create maximal divergence of ideas (e.g., Clark & Sampson, 2008) and, predefined sentence openers and dialogue move classifiers (e.g., Jeong & Joung, 2007). According to Asterhan and Schwarz, these software tools may be used in both face-to-face and online contexts, with support for real-time graphical display of arguments (and thus reduced cognitive load for students) recognised as one of the key advantages of such process support. In this way, such tools provide a similar affordance to that provided by the IM software, which itself reduces cognitive load during systems model-building sessions by (a) presenting relational statements due for consideration on screen, and (b) generating a graphical representation based on participants input.

The second types of process support discussed by Asterhan and Schwarz is *discourse instruction*, which refers to instructions given as regards the type of discourse which is expected from students in their collaborative argumentation. Of note, it has been found that different types of discourse instructions can serve to shape student argumentation in different ways (e.g., Asterhan, Butler, & Schwarz, 2010; Felton, Crowell, & Liu, 2015; Garcia-Mila et al., 2013; Golanics & Nussbaum, 2008; Nussbaum & Karash, 2005). For example, Asterhan et al. (2010) investigated the effects of disputative or deliberative discourse goal instructions on undergraduate student's argumentation. Disputative argumentation is position driven, wherein the speaker seeks to defend their viewpoint, and win the argument at the other's expense. Conversely, deliberative argumentation is issue driven, and characterised by a willingness to listen, critically examine different ideas, and make concessions when met with persuasive arguments. While both types of argumentation may involve critical reasoning, only deliberative argumentation allows for collaborative knowledge-building, and a move towards a shared position. The different goal instructions provided to students in Asterhan et al.'s (2010) study reflect these distinctions. More specifically, students in the disputative condition were given the following discourse instructions:

“The goal of a ‘critical discussion’ is to convince one another of the correctness of one's own solutions, in this case: to the questions about evolution. So a good discussion is one in which each participant criticises the other's ideas by providing

adequate arguments and justifications that support one's own ideas and weaken the validity of the other person's ideas. We should emphasise that ultimately there can be only one winning side. At all times during the discussion, try and come up with arguments that could back up your solution and undermine your partner's claims. How could you convince him (her)? What reasons and evidence could help you reach these goals? What are the weaknesses in the other person's solutions?" (p. 175).

Students in the deliberative condition were given the following instructions:

"The goal of a 'critical discussion' is to reach a better and deeper understanding of the topic under discussion, in this case: evolution. So, a good discussion is one in which both participants explore each idea and solution in depth, by providing adequate arguments and justifications. We should emphasise that a critical discussion will help both of you gain a better understanding of the topic. At all times during the discussion, try to discover the weaknesses and strengths in each solution and idea, whether it was proposed by yourself or your partner. At all times during the discussion, try to critically think about each idea or solution, whether it is logical or successful. To what extent do the justifications, evidence and explanation support the proposed solutions? Are there alternative solutions?" (p. 175).

Analysis of the dialogue of student groups in each condition revealed that deliberative goal instructions resulted in a higher frequency of collaborative interpersonal behaviours such as attempts at joint problem-solving and attempts to maintain a pleasant atmosphere. Furthermore, the deliberative groups also displayed a lower frequency of competitive behaviours, including behaviours indicative of interpersonal conflict, and moves which sought to devalue other's contributions.

Similarly, Garcia-Mila et al. (2013) conducted a study with high school students comparing the effects of disputative versus deliberative goal instructions on argumentative discourse. In their study, sixty-five dyads engaged in discussion about sources of energy and climate change. Thirty-one dyads in the disputative condition were asked to discuss with the aim of persuading their peer, and were provided with the following instructions: "The goal of the task is to convince your partner of the choice you have made about the dilemma by means of a good justification" (p.16). The remaining thirty-four dyads, in the deliberative condition, were asked to reach consensus, and were provided with the following instructions: "The goal of the task is to reach a justified agreement with your partner and propose a consensus solution to the problem" (p.16). Subsequently, their argumentation was analysed using a

rubric based on Toulmin's schema, with utterances coded as either a: claim, data, warrant, backing, or rebuttal, and combined to form argument structures to examine the nature of the interactions (e.g., claim-data; claim-backing, claim-rebuttal, claim-data-warrant; claim-data-backing, claim-data-warrant-backing-rebuttal, and so on). The results of this study found that student dyads who engaged in argumentation with the aim of reaching consensus, as opposed to persuading others, produced a greater variety of argument structures, and showed increased levels of two-sided, balanced reasoning. For example, a significantly higher number of rebuttals were used by students in the deliberative condition. Differences were also found in more complex argument sequences, with claim-data-backing-rebuttal and claim-data-warrant-backing-rebuttal sequences being more frequently observed in the deliberative condition. Garcia-Mila et al. (2013) interpreted these findings as suggesting that students who are instructed to achieve consensus are more likely to pay attention to both sides of an issue, given that rebuttals, in Toulmin's scheme, represent an acknowledgement of the limitations of claims. Similarly, analysis of the discourse of those in the deliberative condition revealed that the argumentation discourse was not as polarised as in the disputative condition, as illustrated by the use of a broader range of arguments and evidence. Overall, these findings suggest that explicit discourse instructions can play a significant role in shaping the emergent nature and quality of collaborative classroom argumentation.

A related type of process support for argumentation reviewed by Asterhan and Schwarz (2016) is *teacher scaffolding*. One of the key findings which emerges from research on teacher scaffolding is that the most effective instructional support involves low-content teacher interventions, which instead of providing explicit content-specific explanations and instructions, is characterised by instructions or prompts which seek to elicit student thinking (e.g., Chiu, 2004; Gillies, 2004; Webb et al., 2008; Webb, 2009). In these situations, the discourse or argumentation among peers is not being led by the teacher *per se*, but rather the teacher provides students with prompts which encourage key discourse or argumentation behaviours such as making use of evidence, seeking clarification, or challenging other's views (Anderson et al., 1998; Chinn, Anderson, & Waggoner, 2001; Mercer & Littleton, 2007; Webb, 2009).

As noted by Asterhan and Schwarz (2016), research focused on *Collaborative Reasoning* (e.g., Anderson, Chinn, Waggoner, & Nguyen, 1998), *Accountable Talk* (Resnick, Asterhan, & Clarke, 2015; Resnick, Michaels, & O'Connor, 2010), or *Exploratory Talk* (Mercer & Littleton, 2007), has highlighted the importance of teacher behaviours in prompting student reasoning in situations involving collaborative discourse and

argumentation. Importantly, such prompts can target student's own reasoning, for example, by prompting students for further elaboration ("Would you like to elaborate on this idea?"), challenge ideas ("Is this always true?"), and by asking students to explicate their reasoning ("Why do you think that?"). Prompts can also be used to direct student's attention to the reasoning of others, for example, by asking students to apply their own reasoning to someone else's ("Given your reasoning, do you agree or disagree with the arguments presented by John, and why?"). Notably, as well as having a positive impact on the quality of the teacher-facilitated dialogue, research has found that the use of prompts also serves as a model for students to imitate in peer-to-peer interactions (van Steendam, Rijlaarsdam, Sercu, & van den Bergh, 2010).

2.4.3. Prompts as instructional support for argumentation

Prompts designed to support collaborative argumentation can be delivered and applied in a number of different ways. For example, prompts can be used in face-to-face interactions (King, 1990), or in online CSCL interactions (e.g., Yiong-Hwee & Churchill, 2007). Prompts can also be applied using instructor-driven facilitation methods (Davis, 2003) and in peer-to-peer learning exchanges (Gan & Hattie, 2014; King, Staffieri, & Adelgais, 1998). Also, prompts can come in a variety of different forms, for example, using sentence openers or open-ended questions. Yiong-Hwee & Churchill (2007), for example, examined the effect of sentence opener prompts on students' argumentation in an online learning environment. In their study, 42 undergraduate students took part in an online group discussion as part of their teacher training coursework, in which they had to critique videos depicting social issues and provide arguments for their critique. A number of prompts were used based on Paul's (1993) classification of questions to support Socratic thinking, and other prompts were developed by Yiong-Hwee & Churchill (2007). Key sentence-opener prompts included:

1. Probe and evaluate information for relevance and justification (*Probe Reasons*); e.g., "The indicators/facts supporting my opinion are...."
2. Construct plausible inferences (*Probe Implications and Consequences*); e.g., "If this is the case, then...."
3. Identify assumptions (*Probe Assumptions*); e.g., "The justification of this assumption is...."
4. Distinguish relevant points of view (*Probe Viewpoints*); e.g., "A different viewpoint is...." and,

5. Ask questions for clarification (*Probe Clarification*) e.g., “Please elaborate....”
6. Take a stand e.g., “I agree that....”

After the group discussion, data were analysed in two ways. First, argumentation in the forum was analysed using Henri’s (1992) classification of argument depth to assess the impact of sentence openers. This process first involved dividing the text into single idea units, of which there were 1175 following the removal of off-task idea units, and idea units which were not arguments. Next, arguments were coded as *surface* or *in-depth*, in accordance with Henri’s (1992) classification. Surface arguments refer to statements which “repeat what has been said without adding any new elements” or propose “solutions without offering explanations” (p. 214). In-depth arguments are those which “reflect organisation and critical evaluation of information” (p. 214). Overall, 91% of arguments which used sentence-openers were identified as in-depth, as opposed to 62% of arguments which did not use sentence openers. This suggests that sentence openers are a useful means of prompting and guiding argumentation. More specifically, of the six categories of sentence openers, *Probe Reasons* and *Take a stand* were most frequently associated with in-depth arguments (37% and 32%, respectively).

In an attempt to gain a richer understanding of student’s use of sentence openers, a subset of students was interviewed. The aim of these interviews was to explore students’ perceptions of the extent to which the sentence openers aided their argumentation. These interviews revealed a number of perceived benefits, as reported by students. As an example, one participant described the sentence openers as “building blocks for producing thought-provoking comments” (p. 216). Another participant suggested that sentence openers help students “to think and critique from multiple perspectives” (p. 216). Another stated that “the sentence openers allow me to think about all aspects of the video instead of just what I am comfortable with” (p. 216). Notably, Yiong-Hwee & Churchill state that such results are consistent with previous research showing that sentence openers can assist student’s argumentation by offering possibilities for lines of inquiry, and promoting reflection (e.g., Guzdial & Turns, 2000; Scardamalia & Bereiter, 1991).

Another commonly used prompting strategy is question asking. Question asking, which is often described as a fundamental strategy of engaging with learners in collaborative learning settings (Graesser, Person, & Huber, 1993), has been found to have positive effects on collaborative discourse and argumentation in both university and high-school contexts. Question asking can serve a number of functions, such as: prompting students to check each

other's thinking or writing, prompting provision of further explanations, and encouraging justification of assertions (Webb, 1995).

King (1990), for example, in a sample of undergraduate and graduate university students, found that higher-order questions - including open-answer questions, deep-reasoning questions aimed at causes and consequences, and goal-oriented questions - are effective in eliciting explanations, in which justifications may be enclosed. More specifically, King (1990) conducted two studies with a total of 65 students to examine the effects of question asking on the quality of interactions and explanations offered by students in a group discussion. In the first study, students were assigned to one of two conditions: a peer questioning condition, and a discussion condition. In small groups of two or three, students in the peer questioning condition were provided with a set of question stems to use in their group discussion, which focused on the contents of a course lecture. Sample question stems included:

- How would you use to?
- Explain why....
- How are and similar?
- What conclusions can you draw about.....?

Before the group discussions began, students in the peer questioning condition were given training over the course of thirty minutes in the use of the question stems. Students in the discussion condition were not given any support for their discussion, and were simply told to engage in a discussion.

Following the lecture and the small group discussions, which were recorded by the researchers, all students were tested for comprehension of the lecture material. Group discussions were also coded and analysed using a variation of Webb's (1989) categories of quality of explanations. The results of this study found that students in the peer questioning condition outperformed students in the discussion condition on comprehension of the lecture material. Furthermore, significantly more explanations were provided by students in the peer questioning condition, as well as significantly more critical thinking questions, and significantly less low-level elaborations. The authors therefore concluded that peer questioning, supported by question stems, facilitated higher-levels of explanations and elaborations, and, overall, had a positive effect on classroom discourse and argumentation. Importantly however, the author cautioned that this effect may simply be due to the act of

asking questions, as opposed to the support of the question stems. To explore further this effect, a second study was carried out.

In King's (1990) second study, students in both conditions received training in the use of question stems, including modelling of question use, and guided practice. However, only those in one condition, the guided peer questioning condition, were provided with the question stems during the task. Those in the unguided peer questioning condition did not have direct access to the question stems during the task itself. The results of this study found that, while the overall number of questions asked in each condition was not significantly different, students in the guided peer questioning condition gave, and received, significantly more explanations than those in the unguided peer questioning condition. They also gave fewer low-level elaborations, however this difference was not significant. Also, students in the guided peer questioning condition asked more critical thinking questions, and fewer recall questions than students in the unguided peer questioning condition. The authors therefore concluded that, in the absence of the question stems to serve as instructional support, students may have been more limited in the kinds of questions available to them based on their memory of the questions stems introduced during the training phase of the study. The lack of instructional supports and structure may have contributed to the lower levels of explanations and elaborations offered. Overall, the results of these two studies suggest that prompting, in the form of question asking, is a useful support for collaborative discourse and argumentation. However, it also suggests that additional support, in the form of external prompts or question stems that are easily accessible during a discussion task may be needed to maximise the benefits of prompting instructions on argumentation outcomes.

Consistent with King (1990) is research by Veerman et al. (2002). Veerman et al., in the context of teaching about effective pedagogical interactions in a university student sample, found that asking open questions, as well as questions aimed at inferring knowledge, were positively associated with argumentation performance, measured by reference to the frequency of information exchange (e.g., checking, challenging, and countering) and related constructive activities (e.g., explaining, evaluating, and summarising).

Other approaches designed to enhance classroom argumentation have included a more explicit focus on the teacher. For example, in the context of an observational study, Webb et al. (2008) investigated the extent to which teachers engage in practices which support student collaboration and discourse. The study involved the observation of three teachers in two elementary schools interacting with a total of 36 students. Teacher's interactions with their class were video recorded and analysed. Notably, while all teachers had undergone specific

training and instruction in eliciting the details of student thinking, teachers differed in how they probed for these details. The training which the teachers received (as part of their regular professional development) focused on *Thinking Mathematically*. During this training, teachers were instructed in how to encourage students to “solve problems in their own ways and how to engage their students in conversations in order to help them explain their thinking and debate their reasoning” (p. 364). Webb et al. reported that the differences in the extent to which teachers encouraged and prompted students to elaborate on their explanations corresponded strongly with the nature and extent of students explaining to each other during their collaborative conversations. That is, in the classroom with the greatest amount of correct and complete student explaining, the teacher did the most to elicit student explanations. During both whole-class and paired discussions, teachers who elicited more elaborated explanations were those who pushed students to clearly describe their thinking by asking questions intended to clarify and make explicit the steps in their mental processes, even when their answers and strategies used to solve puzzles and problems were correct. These same teachers also worked with students to correct misconceptions, so they could verbalise a correct explanation when their initial answers or strategies were incorrect. Conversely, in the classroom with the smallest amount of correct and complete explaining, the teacher was least likely to encourage students to explain their thinking. In both the whole-class and paired discussions, this teacher rarely asked students to clarify their thinking when their strategies were correct, and infrequently requested elaboration of students’ thinking when their explanations were ambiguous or incorrect. While the results of this study may seem expected or intuitive, they nonetheless stress the important point that for collaborative argumentation to be effective it is necessary for teachers or facilitators to provide students with an adequate amount of instructional support to guide them through the process of collaboration. In the absence of such support, or when this support is minimal, the levels of effective collaboration observed in student groups may be limited.

Overall, the research reviewed in this section suggests that instructional supports, such as prompts, play an important role in supporting collaborative discourse and argumentation, by supporting students’ attempts to engage more critically and deeply with the material at hand, through the promotion of, for example, higher-level explanations and elaborations (King, 1990), and in-depth arguments (Yiong-Hwee & Churchill, 2007). Furthermore, this research has identified various ways of delivering prompts, including questions (e.g., “Do you agree or disagree and why?”), question stems (e.g., “How are

and similar?”), and sentence openers (e.g., “The indicators/facts supporting my opinion are....”). However, a number of research questions arise which warrant further exploration.

First, while a review of the literature highlights prompting as a prominent focus in the research on collaborative argumentation, the effects of different types of prompts on cognitive and social-emotional outcomes of collaborative discourse remains relatively unexplored. Hattie and Timperley (2007), for example, distinguish between prompts at the task-level, and at the process-level. Task-level prompting provides information and guidance in relation to how well a task is being performed. Task-level prompts may focus on, for example, distinguishing correct from incorrect answers, acquiring more or different information, and building more surface knowledge (Gabelica et al. 2012; Hattie & Timperley 2007). Process-level prompts, on the other hand, seek to address potential shortcomings of task-level prompting. At the process-level, prompts may be used to address processes and strategies necessary to complete a task (Ketelaar, et al. 2012), support for error detection and information searching, or steps for the revision of work done (Gan & Hattie, 2014). While the studies described in this section may have, in some cases, used one or both of these types of prompts, they did not distinguish between them, nor did they investigate their relative effects on argumentation. Therefore, as described in more detail in Study 2 (Chapter 4), a comparison of the efficacy of task-level prompting versus process-level prompting as approaches to supporting collaborative argumentation is an important focus of investigation in the current thesis. In the context of IM, these two approaches to prompting highlight two different facilitator-driven approaches to building a systems model, one of which prompts qualitatively deeper reasoning and a focus on the process of reasoning that shapes the emergence of consensus-based systems models in a collaborative group dialogue. Thus, a more thorough review of the research on different types of prompting is provided in the introduction to Study 2.

Second, while the argumentation research described above includes examples of prompting which was delivered by both teachers and students (e.g., King’s research which incorporated peer questioning), no research to the author’s knowledge has sought to explicitly compare the effects of prompts delivered by teachers with prompts delivered by peers in the context of collaborative argumentation. This is somewhat surprising, given the increased prevalence of peer learning methodologies more broadly, and the growing movement away from didacticism and teacher-driven discussion to more collaborative forms of classroom discourse, with greater emphasis on student-centered learning (Hogan, 2006; Havnes, 2008). With this in mind, Study 3 (Chapter 5) investigates the effects of facilitator-driven versus

peer-to-peer prompts in the context of collaborative argumentation. In the context of an IM session, these two approaches to building a systems model represent different ways in which a collaborative group can be empowered, either through a trained facilitator supporting process-level collaborative reasoning, or by being empowered to support their own process-level collaborative reasoning. The following section therefore, provides an introduction to the concept of peer learning. This is followed by further discussion of the potential benefits of peer learning approaches for collaborative argumentation in Study 3 (Chapter 5).

2.5. Peer learning

A primary objective of classroom dialogue and argumentation is meaning-making in both teacher-student and student-student (or peer-to-peer) interactions (Gan, 2011). Lemke (1990, p. 1) uses the term “*talking science*” to describe a collaborative process of active and engaged reasoning in relation to problems - a process of “...observing, hypothesizing, describing, comparing, classifying, and analyzing”. As noted, cultivating these collaborative, metacognitive processes and skills is now seen as a top priority in university education (Hogan, Hall, & Harney, 2017). However, as noted in Chapter 1, teacher-dominated discourse is common in classrooms and lecture halls (Hardman & Abd-Kadir, 2010; Beauchamp & Kennewell, 2010), and this can limit opportunities for student dialogue and engagement (Strayer, 2012; Alexander, 2004; Cazden, 2001; Nystrand, Wu, Gamorgan, Zeiser, & Long, 2003) and negatively impact on students’ collaborative dialogue skills (Alexander, 2004; Duschl & Osborne, 2002; Mercer & Littleton, 2007). One approach which has great potential to increase opportunities for collaborative discourse and argumentation in the classroom setting is peer learning.

Peer learning is a unique form of collaborative learning, defined as “the acquisition of knowledge and skill through active helping and supporting among status equals or matched companions” (Topping, 2005, p. 631). Critical to educational practice in higher education is the development of lifelong learning skills (Prins, Sluijsmans, Kirchner, & Strijbos, 2005), including the ability to provide feedback, suggestions, and advice to peers for performance improvement. While collaborative learning can be useful in developing teamwork skills (Beckman, 1990), it does not necessarily involve an explicit focus on providing prompting, feedback, and assessment amongst peers. In contrast, peer learning, as an approach to collaborative learning, promotes a participatory culture of learning (Kollar & Fischer, 2010) and explicitly requires peers to interact in a constructive manner, which often implies a more

direct focus on peer prompting, feedback, and assessment. In other words, peer learning involves a greater focus on learning *from* one another, as opposed to *alongside* one another.

2.5.1. Peer learning as a pedagogical tool

In university education contexts, many studies have found that formative assessment, which involves providing feedback to students on their work, is critical for learning (Boud, 1990; Dierick & Dochy, 2001; Topping, 2003). However, resource constraints in many universities have led to a reduction in the quantity and quality of feedback received by students (Gibbs & Simpson, 2004). Increased modularisation, for example, has generally reduced course delivery time, thereby reducing the number of assignments and available feedback cycles (Higgins, Hartley, & Skelton, 2002). Furthermore, as class sizes increase, many courses have removed all formative assessment entirely, relying solely on exams as a measure of learning, whereas other courses that use continuous assessment rather than end-of-course exams provide feedback late in the term, often after exams have been completed (Gibbs & Simpson, 2004). One solution to the limited scope for instructor feedback is better use of in-class formative peer learning designed to facilitate and accelerate learning for individuals and groups. Specifically, formative peer assessment may involve the provision of qualitative comments in addition to (or instead of) the provision of marks or grades. The comments provided in this context are referred to as peer feedback (Gielen, Peeters, Dochy, Onghena, & Struyven, 2010). Importantly, peer feedback provides mutual benefits. The learner is provided with a performance check, set against the criteria of the task, as well as feedback on strengths and weakness (Falchikov, 1995), and the peer providing feedback may learn by reviewing the work of their peer, observing different strategies or approaches to the task at hand, and internalising key learning criteria and standards used for assessment (Topping, 1998).

An examination of the empirical literature reveals that peer learning has been operationalised in a number of different ways, with both positive and negative effects on learning observed across different studies. In a review of the literature, Boud, Cohen, and Sampson (1999) highlight five potential positive effects of peer assessment strategies including: working with others; critical enquiry and reflection; communication and articulation of knowledge, understanding and skills; managing learning and how to learn; and self and peer assessment. However, Boud and colleagues also note peer learning is typically used in an informal and ad hoc manner, and until peer learning methodologies are formalised into curriculae, as with other pedagogical approaches, results are likely to be mixed. This

need for formalisation is echoed by Sluijsmans and van Merriënboer (2000), who, after analysing peer assessment skill in teacher education, conclude that peer learning must be integrated into the regular course content and assessment if consistent learning benefits are to be observed.

Recent studies have compared the effects of peer learning versus teacher-driven learning, reporting that peer learning can be equally as effective (e.g., Cho & Schunn, 2007; Gielen, Tops, Dochy, Onghena, & Smeets, 2010) or can even provide additional benefits (e.g., Cho & MacArthur, 2010; Cho & MacArthur, 2011; Hartberg, Gunersel, Simpson, & Balester, 2008; Prins et al., 2006; Yang, Badger, & Yu, 2006). Cho and MacArthur (2010), for example, conducted a study investigating the effects of receiving feedback from a single expert (e.g., a teacher), a single peer, or multiple peers in the context of a written task. The results of their study revealed that students who received feedback from multiple peers improved the quality of their writing to a significantly greater degree than those who received feedback from an expert (Cohen's $d = 1.23$). The results of this study indicated no significant differences in quality improvement between the single expert and single peer condition. The authors offer a number of possible explanations for this result. While peers may not have the same extensive, elaborated content-related knowledge as teachers for example, they may provide comments which are more accessible and understandable to other peers. As peers often experience the same difficulties, they may be more effective in detecting these difficulties from the perspective of the learner when reviewing the work of their peers. Furthermore, peers may be more effective in communicating both perceived difficulties and potential solutions, as they tend to use the same language as their peers, with less jargon. This claim is supported by research conducted by Cho, Chung, King, and Schunn (2008) who asked technology users to evaluate written responses to technical questions raised by other users. These responses had either been written by experts or other novice users. The reviewers, who believed all responses had been written by experts, rated as most useful the responses which were, in fact, written by novice users. This suggests that, in some cases, peers may be better able to produce effective, accessible feedback.

While these research findings highlight the benefits of peer learning, significant gaps in the peer learning literature remain. For example, less research has examined the effects of peer learning in the context of collaborative argumentation or problem-solving, with the majority of studies investigating the effects on written tasks (e.g., Cho & MacArthur, 2011; Hartberg et al., 2008; Patchan, Schunn, & Correnti, 2016; Novacovich, 2016) as opposed to dialogue-based tasks. Furthermore, less is known about the kinds of instructional support

necessary to cultivate effective peer feedback or prompting, especially in the context of discourse-based tasks. Research by Gan and Hattie (2014) however, who conducted a study of peer feedback in the context of a collaborative written chemistry task, provides a useful insight into the potential of peer prompting in collaborative argumentation. In their study, Gan and Hattie (2014) used question prompts, informed by the work of Hattie and Timperley (2007) to support students in the generation of peer feedback comments and questions. Participants in the study were 121 year-12 secondary school students, who were in the process of writing chemistry investigation reports. This study included two conditions: a prompted peer feedback condition, and an unprompted peer feedback condition. In each condition, students were divided into pairs to work on their chemistry task, which involved first individually conducting a chemistry experiment and writing a report, before exchanging written feedback with their peer on each other's report. In the prompted condition, peers were given a review form which contained three question prompts:

- What did he/she do well? Give explanations to support your feedback.
- What didn't he/she do well? Give explanations to support your feedback.
- How can he/she improve on the current piece of work? Give explanations to support your feedback.

Students in the unprompted condition were not presented with question prompts to use in formulating their feedback. Results demonstrated that the question prompting resulted in a significant increase in the number of peer comments related to knowledge of errors, suggestions for improvement, and process-level feedback. Gan and Hattie conclude therefore, that with adequate instructional support (in this case question prompts) peers are capable of delivering feedback "beyond just giving the right answers" (p. 874), and can in fact provide solutions, strategies and corrective approaches to their peers.

Overall, while both feedback and prompts are routinely delivered by teachers, and although the power and potential of peer learning and assessment is being increasingly recognised, empirical understanding of how feedback and prompts can be used to facilitate peer learning in dialogue-based collaborative learning tasks is still poorly understood. The findings of Cho and MacArthur (2010) and Gan and Hattie (2014) have promising implications for peer learning, and students' ability to provide adequate peer feedback using prompts. However, it remains to be seen whether or not this effect can be replicated in the context of dialogue-based tasks. Importantly, without confirming transfer effects, it is not appropriate to simply transfer and apply results and insights about the effects of peer

feedback or prompts on written tasks, to discourse-based tasks. Just as findings from studies of feedback or prompting at the individual level cannot simply be translated to the group level (Gabelica et al., 2012), written versus dialogue-based tasks may require different levels of peer interaction, and also may require different supports for successful outcomes to be achieved. More specifically, in the context of an IM structuring session, providing effective peer-to-peer prompts to support collaborative argumentation may place too many demands on the peer-prompt-deliverer. Alternatively, with additional instructional support from a facilitator who initially models and coordinates the process of selecting and delivering peer-to-peer prompts, and with the use of external supports designed to structure prompting, students may be able to effectively take on the role of peer-prompter in a collaborative systems model-building task. This process of modelling and coordinating prompting behavior is discussed in greater detail in Chapter 5. In particular, Study 3 (presented in Chapter 5), seeks to examine if the positive effects of peer-to-peer prompting observed in the context of collaborative written tasks, can be extended to collaborative argumentation in a systems design task, specifically, by investigating the effects of facilitator-driven prompting versus peer-to-peer prompting on outcomes in an IM session.

Importantly, it is hypothesised across experimental Studies 1 – 3 in the current thesis that the benefits of supporting dialogue, process-level reasoning, and empowerment of students in prompting and supporting one another’s dialogue may influence not only the quality of collaborative argumentation, but also key social-emotional outcomes, including higher levels of consensus, and team-orientation in collaborative groups. The next section examines these social-emotional processes, among others, in more detail.

2.6. From instructional processes to social processes - social psychological factors in collaborative learning

To this point, this chapter has focused primarily on various instructional or pedagogical processes which impact on collaborative learning and collaborative argumentation in particular. However, as noted by Nussbaum (2008), a focus on the instructional and cognitive components of teaching and learning has in the past contributed to a neglect of the social processes of learning. Collaborative learning, by design, involves a form of social interaction between students who are engaging in a shared learning task. That we should not neglect the social processes inherent in this collaboration is further highlighted by Stahl (2010), who suggests that the power of collaborative learning stems from its potential to unite multiple people in achieving the coherent cognitive effort of a group. This unity and coherence, or

group synergy, can be operationally defined in many different ways, and an important goal of CSCL research is to explore how this synergy occurs, measure its occurrence using a variety of indicators, and seek to design and implement methodologies which can support and enhance specific indicators and outcomes. The need for consideration of these issues is summed up well by Wegerif (1998) who noted that “forming a sense of community, where people feel they will be treated sympathetically by their fellows, seems to be a necessary first step for collaborative learning. Without a feeling of community people are on their own, likely to be anxious, defensive and unwilling to take the risks involved in learning” (p. 48). With this in mind, a number of social psychological variables were selected for consideration in the experimental studies presented in this thesis. As outlined below, these social psychological variables may be instrumental in supporting and sustaining the types of high level outcomes that Warfield prioritised as part of a broader societal effort to enhance applied systems science applications across a range of problem-solving contexts.

2.6.1. Consensus

As noted in Chapter 1, Warfield’s approach to applied systems science has at its core a focus on the construction of shared understanding in relation to complex issues and, more specifically, the construction of consensus-based systems models that can be used to inform the design of a collaborative response to complex societal problems. In collaborative learning settings more generally, teams and other forms of groups are comprised of individuals who bring various experiences, perspectives, skills, knowledge, and biases to bear on the issue the group is addressing. Through interaction and discussion, members are confronted with the conflicting views of their colleagues and will often seek to reconcile dissimilar assumptions, beliefs, and arguments that relate to the underlying issue being addressed (Mohammed & Ringseis, 2001). As noted by Eden, Jones, Sims and Smithin (1981), “when considering the working of teams in organisations, it seems important and indeed commonsensical that such working involves the interaction and negotiation of shared and idiosyncratic understandings. A team is continually involved in some process of negotiating reality amongst its members” (p. 39). Similarly, Bettenhausen (1991, p. 350) described the development of shared understanding as an “essential group process.”

As such, it is recognised that individuals often enter a group problem-solving setting with different viewpoints, and an integral part of the group effort is dedicated to resolving differences in how members conceptualise problems, and arrive at consensus. In the context of applied systems science, for example, a core goal of the collaborative learning process

involved in building a systems model is to achieve consensus regarding the logical interdependencies between sub-problems in a problem situation. Indeed, only those interdependencies that are viewed by the majority as significant relations within the system are selected for inclusion, and considerable dialogue and deliberation is often required before individuals are ready to cast their votes in an IM structuring session. As such, the first social psychological variable of interest in the current research is consensus.

Consensus, which may be defined as general agreement among all or a majority of group members, has long been considered a desired outcome of group decision-making processes. As noted by Whyte, for example, "the task, after all, of a decision-making group is to produce consensus from the initial preferences of its members" (1989, p. 41). Reaching consensus on a solution to a problem is advantageous for many reasons, especially with regard to implementing an action plan designed to resolve a shared problem. If there is a high level of consensus amongst group members as to key decisions and conclusions, progress toward a solution to a shared problem may be easier to achieve. For example, Mohammed and Ringseis (2001) found that groups who reported higher levels of consensus in relation to a problem had greater expectations about the implementation of decisions reached by the group, and also experienced higher levels of overall satisfaction with the process. They also found that the highest levels of consensus were evident in groups in which the members questioned each other's suggestions, accepted legitimate suggestions and incorporated other's viewpoints into their own perspective.

In group decision-making contexts where consensus is prioritised as a goal, there is an important distinction to be made between the consensus process and the consensus outcome. Fisher (1980) addresses this distinction in his four-phase decision emergence model. According to Fisher, the emergence of a consensus *outcome* entails a process of working through four stages of group activity: orientation, conflict, emergence, and reinforcement. First, the orientation stage is characterised by a focus on clarification and agreement. During the conflict stage, the group engages in discussion of decision alternatives, and the prevalence of attempts to persuade others in relation to key issues increases, which often includes criticism of other's ideas and conflict at the group level. Following the conflict stage, the emergence stage is generally characterised by willingness to compromise to achieve consensus, and the emergence of decisions from productive interaction. Last, in the reinforcement stage, the group reaches consensus on the emergent decision, expresses favourable views about the decision reached, and are committed to their decision.

Importantly, Fisher (1980) suggests that the consensus-building process must pass through a cognitive conflict phase. This cognitive conflict phase often involves deliberation and debate, but also the potential for the emergence of a stronger consensus from conflicting views. Indeed, researchers have suggested a link between the expression of cognitive conflict during the decision process and the consensus decision outcome (Anderson & Martin, 1999; Fisher, 1970, 1980; Priem, 1990; Sambamurthy and Poole, 1992). When expressed and resolved during group decision-making, research suggests that cognitive conflict will produce a strong consensus on the decision outcome, while premature consensus due to concurrence-seeking "smooths over" considerable latent disagreement.

Sambamurthy and Poole (1992), for example, found that the degree of confrontiveness in cognitive conflicts (i.e., the extent to which groups addressed their differing perspectives during a decision-making process) was positively associated with their level of consensus at the end of the process. More specifically, in this experimental study examining different group decision support system (GDSS) features, 36 small groups of undergraduate students were assigned to one of three conditions in a strategic planning task. Group members were presented with six competing strategy proposals which they had to evaluate in order to select the one which was most consistent with the needs of stakeholders. In the first condition, groups worked with a GDSS which afforded communication features such as: simultaneous input of ideas, public display of ideas, anonymous input of ideas, and a summary display of the group's evaluations based on ratings, rankings, and voting. These features were also present in the second condition, with the addition of features which displayed the group's evaluations against task criteria, and publicly presented the summary of the group's evaluations on a grid. Finally, the manual condition involved groups working on the task without GDSS support. Following the task, the researchers analysed group discussions using the Group Working Relations Coding System (Poole & Roth 1989). This coding system allowed researchers to assess the degree of confrontiveness in cognitive conflict across conditions, coded as the degree to which groups engaged in interaction patterns such as focused work, critical work, opposition, capitulation, tabling, open discussion, and relational integration. In that context, the lowest level of confrontiveness is indicated by periods of *focused work*, in which participants are task-focused, and do not engage in any disagreement, or *relational integration* in which discussions are tangential to the main topic or involve joking or other positive social behaviours. *Critical work* on the other hand, involves a higher level of confrontiveness, as participants disagree with one another, or *opposition* in which such disagreements or conflicts are acknowledged. The most

confrontive patterns of interaction in this coding scheme involve *open discussion*, in which conflict is negotiated and all participants' concerns are addressed. Following this coding, regression analysis revealed a significant positive relationship between confrontiveness and the level of consensus achieved in the condition in which the group's evaluations were publicly displayed against task criteria. The authors concluded therefore, that facilitating cognitive conflict, by making differing perspectives or disagreements more salient and open for discussion, is an important factor in supporting consensus-building. In other words, the environment which promoted more cognitive conflict also promoted higher levels of consensus.

Similarly, Anderson and Martin (1999) reported a positive relationship between argumentativeness and consensus in the context of university students' group projects. Argumentativeness was defined by as a positive constructive trait involving a person's willingness to argue issues with another person (Infante & Rancer, 1996), and had previously been found to have a positive impact on decision-making, as groups with higher levels of argumentativeness were more likely to engage critically with all sides of an issue (Nemeth, 1986). Thus, Anderson and Martin (1999) hypothesised that argumentativeness would also have a positive impact on levels of consensus. In their study, 208 undergraduate students worked in groups of five to seven members to complete group projects over a one-year period. The results of this study found that argumentativeness was positively associated with higher levels of perceived consensus across groups working on their group projects. As such, Anderson and Martin (1999) concluded that, in the context of group problem-solving or discussion, group members who are argumentative (i.e., engaging in debate and counter-argument in a contrastive manner) may contribute to a positive climate in their group, and thus support the emergence of a stronger sense of perceived consensus.

The research conducted by Anderson and Martin (1999) highlights the need to consider the important distinction between perceived consensus and objective consensus. Perceived consensus refers to the extent to which members of a group report feeling that consensus exists within the group. Objective consensus, however, refers to actual levels of agreement in relation to specific proposals, arguments, relations, and so on (e.g., based on stated preferences, voting patterns, etc.), as opposed to perceived levels of agreement amongst group members as a whole. Importantly, both perceived and objective consensus are potentially critical variables which need to be considered in efforts to enhance the successful workings of groups using CSCL tools, particularly if the goal is to use CSCL tools to enhance group problem-solving and decision-making.

Importantly, while Warfield designed IM as a consensus-based problem-solving tool, no research to the author's knowledge has investigated factors that influence levels of perceived and objective consensus that emerge during an IM session. On a basic level, for example, it is unclear what effect, if any, the presence or absence of dialogue has on the level of consensus achieved in the production of a systems model. However, one might expect, based on the findings of Anderson and Martin (1999) and Sambamurthy and Poole (1992), that the absence of dialogue, and thus the absence of opportunities for cognitive conflict and argumentation, may have a limiting effect on consensus building. Therefore, Study 1 (Chapter 3) investigates the effects of the presence versus absence of dialogue on levels of consensus in the context of a systems model-building task. Furthermore, Anderson and Martin's (1999) and Sambamurthy and Poole's (1992) findings also suggest that promoting cognitive conflict and argumentativeness may positively influence consensus. However, it is unclear if argumentation in an IM session can be differentially promoted by different styles of facilitation and prompting, and subsequently, what impact this may have on levels of consensus. With this in mind, Study 2 (Chapter 4) investigates the effects of prompting style on levels of consensus in the context of a systems model-building task. Finally, as noted above in Section 2.5., peer learning has been found to be associated with benefits such as: ability to work with others, communication and articulation of knowledge, and critical enquiry and reflection, all of which may be conducive to consensus-building (Boud et al., 2001). Therefore, Study 3 (Chapter 5) investigates the effects of peer-to-peer prompting versus facilitator-driven prompting on levels of consensus in the context of a systems model-building task.

2.6.2. Team Orientation

As noted in Chapter 1, a recent survey of large multi-national companies (including Chevron, IBM, and Seagate Technology) reported that teamwork, specifically *the ability to work in a team structure* is highly sought after by employers (Koc et al., 2015). In a synthesis of the empirical literature, Salas, Sims and Burke (2005) developed the Big-Five model of effective teams, in which team orientation is described as a key component of effective teamwork. Team orientation refers to the "Propensity to take other's behaviour into account during group interaction and the belief in the importance of team goals over individual members' goals" (Salas et al., 2005, p. 561). Furthermore, it refers to an individual's propensity for functioning as part of a team, and the degree to which the individual prefers to work in group or team settings for task accomplishment (Driskell & Salas, 1992).

A preference for group work has long been identified as a key component of teamwork (Hackman, 1987), and organisations frequently use an individual's willingness and enthusiasm to work in groups as a selection criterion (Eby & Dobbins, 1997; Stevens & Campion, 1994). Notably, research has found team orientation to be positively related to cooperative team behaviours, and team performance. For example, Eby & Dobbins (1997) studied 148 graduate students taking part in a management course. The students were divided into teams of three to six and were asked to complete a business strategy task over the course of eight weeks. This task involved: developing a marketing plan for a fictional organisation, and making strategic decisions about investments, material purchases, sales, and manufacturing processes. Before beginning the task, each individual completed a survey assessing collectivistic orientation, previous experience of working in teams, perceptions of team cooperation, as well as measures of self-efficacy for teamwork, locus of control, and approval motivation. Furthermore, a team collectivistic orientation score was calculated for each team, based on the average collectivistic orientation of team members. The results of this study found that team collectivistic orientation was positively related to team cooperation. Furthermore, following multiple regression analyses, it was revealed that team cooperation mediated the relationship between team collectivistic orientation and team performance, as measured by performance on the business strategy and decision-making task. The results of this study suggest that the more team members are oriented or inclined to work with others, the more likely they are to cooperate and perform together at a higher level. One further noteworthy result from this study was the positive association between past positive experiences of working in teams and collectivistic team orientation. This result suggests that team orientation is malleable and may be influenced in different ways by more positive or negative experiences of working in teams.

The results reported by Eby and Dobbins (1997) are consistent with findings of Kirkman and Shapiro (2001), who demonstrated that teams who are higher in collectivism, were more productive, cooperative, and empowered than teams lower in collectivism. In this study, 81 teams of employees from two large multinational companies completed a series of surveys including measures of collectivism (using scale items adapted for work/team contexts, e.g., "every person has a responsibility for all others in his or her workgroup or unit"), team productivity (as rated by both team members and external team leaders, and based on team goals, ability to reach deadlines, ability to solve problems, and quality of work), team cooperation (using a scale developed by Campion et al., [1993] which addresses willingness to share information, communication, and cooperation on work tasks), and team

empowerment (using Kirkman and Rosen's [1999] scale), which addresses the extent to which team members agreed or disagreed that the team has confidence in itself, can select different ways to do the team's work, believes that the team's work is valuable, and makes a difference to the organisation). Multiple regression analyses revealed that the level of team collectivism was significantly positively associated with higher team productivity as rated by team members, higher team productivity as rated by team leaders, higher team cooperation, and higher team empowerment.

It is worth noting that each of the studies described above measured collectivism, as opposed to team orientation. While team orientation and collective orientation are frequently used interchangeably in the team and group work and learning literature, they are not strictly synonymous. As noted by Salas et al. (2005), unlike team orientation, collective orientation is not context specific, that is, it relates more broadly to group goals across contexts, as opposed to working team goals. However, in the case of both the Eby and Dobbins (1997) and Kirkman and Shapiro (2001) studies above, the measures of collectivism were adapted to the team or working group context. Also, more recent research has reported benefits of team orientation on outcomes in collaborative efforts. In a meta-analysis, Bell (2007) analysed the relationship between various commonly researched team composition variables and team performance. Two of these team composition variables, collectivism and preference for teamwork, closely relate to the concept of team orientation. As regards collectivism, the analysis of effects was based on 14 correlations across a total of 1299 teams. A medium to large positive effect ($\rho = .40$) for collectivism on team performance was reported. As regards preference for teamwork, the results of the meta-analysis of 10 correlations (including a total of 490 teams) revealed a small to medium positive effect ($\rho = .22$) of preference for teamwork on performance outcomes.

Last, Wang, Li, Wu, and Liu (2014) examined the effects of cooperative goals on the relationship between team orientation and team member exchange, in 93 teams in a university setting. Team member exchange (TMX) is defined as "the extent to which a member provides information, feedback, and help for other members and, in turn, receives ideas and assistance from other group members" (p. 686). Given previous research showing that when the average team orientation of team members is higher, the team are more willing to work together and help each other (Mohammed & Angell, 2004), Wang et al. hypothesised that the average team orientation will be positively related to TMX. Furthermore, it was hypothesised that the relationship between team orientation and TMX would be mediated by cooperative goals. Here, Wang et al. (2014) refer to cooperation and competition theory, according to

which group members perceive three kinds of goals for their group: cooperative goals, competitive goals, and independent goals (Deutsch, 1973). When the group has cooperative goals, the goals of the group members are positively related. In contrast, when the group has competitive goals, members believe that the behaviours of other members toward the achievement of the group goals detract from their own goals for the group. Where there are independent goals, group members tend to think that their own goals are not related to others' behaviours. Wang et al. hypothesised that cooperative goals would mediate the relationship between average team orientation and TMX. Notably, results showed that, in the sample as a whole, team orientation at Time 1 significantly predicted TMX at Time 2, and this effect was mediated by cooperative goals at Time 2. These findings suggest that team orientation may represent an important factor in collaborative learning, as collaborative learning involves cooperative goals, and the components of TMX such as the provision of information, feedback, and help for other team members, all represent positive collaborative learning behaviours that may be instrumental in supporting cognitive and social-emotional outcomes of group work.

Overall, the research discussed above suggests that higher levels of team orientation are associated with a number of positive team behaviours and outcomes, including: cooperation, TMX, empowerment, team performance, and team productivity. These behaviours and outcomes may be particularly important in the context of collaborative learning and peer learning in an educational context, and in the context of working through an applied systems science curriculum, where cooperation and team member exchange are necessary for group project work focused on collaborative systems design. Importantly, as reported by Eby and Dobbins (1997), levels of team orientation may be influenced by past experiences of working in teams, and thus potentially harnessed through the design of positive educational experiences of working in a team context. Given the influential nature of team orientation as suggested by the research described above, the cultivation of team orientation represents an important goal in the design of collaborative applied systems science education. It may be the case for example, that the facilitation or instructional support provided by teachers may influence the emergence of team orientation in a student group. Indeed, this is a question addressed in Studies 2 and 3 (Chapters 4 and 5), which include a measure of team orientation as an outcome and investigate the effects of task-level versus process-level prompting (Study 2) and facilitator-driven prompting versus peer-to-peer prompting (Study 3) on changes in team orientation over time.

2.6.3. Attitudes towards group learning

While high levels of team orientation are desirable in group work contexts, it is not uncommon for students to be averse to group work, with many students reporting the experience to be discomforting (Cantwell & Andrews, 2002). In their study of 290 secondary level students, Cantwell and Andrews (2002) conducted a factor analysis of survey responses which revealed three attitudes towards participation in group work: a preference for group work environments, a preference for individual work environments, and a sense of discomfort in group environments. They found that both students who reported a preference for individual learning and students reporting discomfort in group learning were distinguished by higher levels of social anxiety and lower levels of sociability.

Crucially, research has found that negative attitudes towards group work can have negative consequences for learning, evidenced by the fact that while positive perceptions of group work are associated with feelings of achievement in students, negative perceptions of group work are not (Volet & Mansfield, 2006). Such results suggest that, while there is strong scientific support for the benefits of students working in groups (e.g., Johnson, Johnson, & Smith, 2014; Gillies & Boyle, 2010; Slavin, 1996), additional attention must be paid to the attitudes and levels of comfort that students display in response to group work initiatives, such that group work can be designed in a way to maximise benefits for a larger cohort of students in school and university settings.

Of note, research carried out by Wolfe (2008) revealed high levels of negative perceptions of group work among students. In this study, Wolfe surveyed 222 students in an American liberal arts college on their perceptions of team projects. A majority (131 out of 222) described at least one bad experience with team projects. The majority of these (69.5%) related to incidents in which one or more team member did not do their fair share of the work, while 16% reported team members failing to engage at all (i.e., not showing up for meetings). The survey also revealed discrepancies between students' reported confidence in themselves, and their confidence working in a broader group setting. For example, while students rated themselves highly in their own ability to work in a team (3.41 out of 4 on a likert scale item), and their own listening skills (3.46 out of 4), they rated less highly their ability to handle team conflict (3.0 out of 4) or their ability to trust in the commitment of other team members (2.62 out of 4). That fact that a majority of students reported negative experiences of group work, and rate their confidence in handling group conflict and their trust in other group members as poor, is a cause for concern, and suggests that more needs to be

done to provide supportive, structured collaborative learning environments that enhance positive perceptions of group work generally.

In line with this, Chiriac (2014) examined students' experiences and perceptions of group work in higher education. A primary aim of the research was to give university students a voice regarding collaborative learning as a means of teaching and learning. In doing so, Chiriac sought to address questions such as "Do the students' appreciate group projects or do they find it boring and even a waste of time?" (p. 3), and "Would some students prefer to work individually?" (p. 3). To address these and other questions, Chiriac conducted a qualitative study with 210 university students, divided into groups of between 4 and 8. The data were collected through a study-specific, semi-structured questionnaire and analysed using content analysis. The results of this analysis revealed that the majority of the students (97%) believed that group work facilitated the learning of academic knowledge, the cultivation of collaborative abilities, or both. Many students reported that they learned more, or different things, when working in groups than they would have if working alone. By discussing and questioning each other's points of view and listening to their fellow students' contributions, the students reported an enhancement of their academic learning, compared to working alone. Notably, however, students sometimes perceived group work as being ineffective due to loss of focus and the presence of conflicts. One respondent stated, "you sometimes are out of focus in the discussion and get side-tracked instead of considering the task" (p. 6). Another respondent claimed that group work "feels unnecessary sometimes" and that "individual work is, in certain situations, preferable" (p. 6). In addition, responses suggested that group work might be perceived by some students as inefficient and time consuming, as highlighted by another respondent, "the time aspect, everything is time consuming" (p. 6). Many students also reported that both the group climate and group processes might be the source of negative perceptions of group learning. Examples of negative experiences or *process losses* included insufficient communication, unclear roles, problems with group members, and fear of conflict. Chiriac (2014) proposed that these problems with may relate to the structure of group work or *way of working*. In this context a positive *way of working* involves a well-organised group structure. According to students, groups with an effective *way of working* are those "with clear and distinct rules and structure" (p. 6), while groups that work less well together lack a developed process of cooperation. Consistent with research reported in Section 2.6.1. on the link between constructive conflict and consensus-building, students argued that fear of conflict in a group environment may

have negative consequences on communication and sharing of information, with one student stating that, “Fear of conflicts leads to much not [being] made known” (p. 6).

It should be noted that not all studies focused on student groups report high levels of negative attitudes towards group work, with some studies reporting predominately positive attitudes (e.g., Haberyan, 2007) and others reporting mixed findings. For instance, some studies have found that students recognise the benefits of group work, but still prefer individual work (e.g., McCorkle et al., 1999; Pineda, Barger, & Lerner, 2009). However, regardless of the exact prevalence of negative to positive attitudes, it remains important for educators working to develop effective collaborative learning exercises and programmes to seek to optimise the design of learning environments to maximise benefit for all students. As such, issues with group communication, inadequate structure, and group climate, which may contribute to negative perceptions of group work, warrant consideration in the design and implementation of collaborative learning methodologies.

Overall, the research described above suggests that attitudes towards group work warrant consideration as part of the overall design of collaborative learning environments. While it is clear that not all students have negative attitudes towards group work (e.g., Cantwell & Andrews, 2002; Haberyan, 2007; Hansen 2006), given that collaborative learning methodologies are being increasingly widely applied, it is in the interest of researchers, teachers, and students that consideration be given to ways in which such methodologies can be designed and delivered to maximise the benefits of collaborative learning, by providing a supportive environment for all students. With this in mind, Study 3 (Chapter 5) highlights the importance of empowering students through peer learning and includes a measure of discomfort in group learning, specifically, to assess the impact of facilitator-driven versus peer-to-peer prompting on students’ attitudes towards group learning.

2.6.4. Perceived efficacy

When designing and implementing any new educational intervention or learning methodology, it is vital to consider both the actual efficacy of the intervention or method (e.g., in terms of learning gains) and also the learner’s judgement of efficacy. As noted, collaborative learning methods have been found to have beneficial effects on learning (Stahl, et al., 2006), critical thinking (Alavi, 1994), academic achievement (Hiltz, Coppola, Rotter & Turoff, 2000), and student engagement (Schaffert, et al., 2006), but the sustainability of these benefits may be constrained if the students themselves do not perceive the collaborative learning methods to be useful or effective. For this reason, levels of perceived efficacy of the

specific CSCL method in use during any given intervention is an important consideration. More specifically, if CSCL tools such as IM are to be adopted by groups for use in educational settings, it is imperative that they are perceived as efficacious by the user group.

As noted in Chapter 2, Section 2.2. the results of early meta-analyses highlighted a number of factors as influential in the success of collaborative learning, including positive interdependence of group members, and individual accountability (Slavin, 1989). However, the factors which influence students' perceptions of the efficacy of CSCL methodologies are less well researched. It is useful then, to consider related research on factors which influence students' perceptions of educational technologies and levels of satisfaction in relation to the use of educational technology more broadly. As can be seen in Table 2, a broad range of factors have been found to impact on students' perceptions of educational technologies.

Table 2. *Factors found to impact on students' perceptions of educational technologies*

Author(s)	Factors
Arbaugh (2000)	Perceived usefulness and perceived ease of use, flexibility of e-Learning, interaction with class participants, student usage, and gender
Volery and Lord (2000)	Ease of access and navigation, interface, quality of interaction, instructor attitudes and behaviour, instructor technical competence
Arbaugh (2002)	Perceived flexibility of the medium, perceived usefulness and perceived ease of use, media variety, prior instructor experience, virtual immediacy behaviors, and interaction
Arbaugh and Duray (2002)	Perceived usefulness and perceived ease of use, and perceived flexibility
Hong (2002)	Gender, age, scholastic aptitude, learning style, and initial computer skills, interaction with instructor, interaction with fellow students, course activities, discussion sessions, and time spent on the course
Kanuka and Nocente (2003)	Motivating aims, cognitive modes, and interpersonal behaviors
Liaw, Chuang, and Chen (2007)	Learner autonomy, multimedia factors, instructor assistance
Liaw (2008)	Perceived usefulness, learner characteristics, system quality, synchronous and/or asynchronous interaction

Two of the more commonly investigated factors (e.g., Arbaugh, 2000; Arbaugh, 2002; Arbaugh & Duray, 2002; Liaw, 2008) are perceived usefulness and perceived ease of use. These factors are two of the core components of the Technology Acceptance Model (Davis, 1989). According to this model, perceptions of the degree to which a technology is useful, and easy to use, influence users' attitudes toward the technology. The model also suggests that these attitudes in turn influence users' intentions and decisions to adopt the technology. While perceived usefulness and perceived ease of use are thus influential in perceptions of learning technologies, the review of studies which follows will focus primarily on issues relating to perceived usefulness, as opposed to perceived ease of use. In the absence of a substantial body of literature on the impact of perceived efficacy on perceptions of learning technology, perceived usefulness is a related construct which may inform understanding of the impact of perceived efficacy in this context. Also, of note, the IM tool used in the current research, is not operated by students directly, but rather by a facilitator. As such, perceived ease of use is not a relevant consideration in this context.

In a study of student satisfaction with an e-learning MBA programme, Arbaugh (2000) reported a positive association between perceived usefulness of the e-learning methodology and levels of student satisfaction with the programme. In this study, 111 university students completed survey measures of perceived usefulness, perceived ease of use, perceived flexibility of e-learning, interaction difficulty, perceived instructor emphasis on interaction, and perceived satisfaction with the course. Regression analyses revealed that perceived usefulness of the e-learning methodology was positively associated with levels of programme satisfaction. Interestingly, perceived instructor emphasis on interaction was also positively associated with perceived satisfaction. Taken together, these results suggest that if students perceive the computer-supported learning process to be broadly useful, and if they perceive the instructor to be making efforts to facilitate group interaction, it is more likely that they will be more satisfied with their programme of learning.

The above findings presented by Arbaugh (2000) are consistent with those of Selim (2003), who reported on a study which sought to investigate student usage of course websites. In this study, survey responses from 403 undergraduate students, addressing the Technology Acceptance Model constructs of perceived usefulness and perceived ease of use, were analysed. The results of structural equation modelling found that perceived usefulness of the technology predicted self-reported usage of course websites. Notably, these results are consistent with more recent research by Liaw (2008) who also found that perceived usefulness predicted intention to use e-learning systems. In particular, responses from 424

university students assessing their perceptions of the use of the e-learning tool Blackboard, revealed that perceived usefulness significantly predicted behavioural intention to use Blackboard. Notably, from a range of predictive factors included in the analysis, perceived usefulness accounted for the largest amount of variance in intention to use Blackboard (i.e., 58% of the variance).

Overall, the results of these studies suggest that the degree to which an educational method or tool is perceived to be useful or effective, has a significant bearing on both the likelihood that it will be used by students as well as their overall satisfaction with their programme of learning. As such, in collaborative learning contexts, it may be critical to consider factors which may positively influence students' perceptions of the efficacy of methods or tools they are using to support learning.

Another important factor which has consistently been shown to influence students' perceptions of the efficacy of educational technology is the behaviour of the instructor. In studies which have examined the perceived effectiveness and success of e-learning courses, the quality of instruction is often seen as crucial (Collis, 1991; Liaw, Huang, & Chen, 2007). For example, Collis (1991), when reviewing the impact of early audio-visual and computer-based educational tools concluded that "it is not the technology but the *instructional implementation* of the technology that determines its effects on learning" (p.146). This viewpoint is supported by more recent research by Liaw and colleagues (2007). In this study, 168 students completed surveys assessing various components of e-learning, such as learner autonomy, teachers as e-learning tutors, and multimedia supports. Following regression analyses of the survey responses, it was revealed that teacher monitoring and helping was a significant predictor of students' positive attitudes towards e-learning. This suggests that even in the context of e-learning, which may offer various instructional affordances to the user, the instructional role and support of the teacher remains influential in students' attitudes towards e-learning methods.

Consistent with Liaw et al. (2007) are the findings of Volery and Lord (2000). Here, they sought to investigate critical success factors in online education through a questionnaire which was administered to 47 university business students. The questionnaire included measures of: technology characteristics, instructor characteristics, and student characteristics. Of note, and consistent with Collis' (1991) and Liaw et al.'s (2007) research, the results of a factor analysis revealed that the instructor was found to play a critical role in students' perceptions of the online course. More specifically, and as per the factor loadings, key instructor behaviours included: encouraging student interaction, explaining the use of the

technology, having a positive attitude towards the technology, and handling the technology effectively. As such, Volery and Lord concluded that the behaviour of the instructor plays a crucial role in student's perceptions of educational technologies, with these findings suggesting that instructors should adopt interactive teaching or facilitation styles that encourage peer-to-peer interaction.

Volery and Lord argued that the instructor will continue to play a central role in computer-mediated education, albeit their role will become one of a *learning catalyst*, more so than the traditional *provider of knowledge* role. Notably, their conclusion regarding the role of the instructor is consistent with one of key challenges for CSCL, as identified by Dillenbourg et al. (2009). As described in Chapter 1 Section 1.4.2., Dillenbourg et al. (2009) refer to the evolution of the *teacher as orchestrator*, which involves the teacher transitioning from "the sage on the stage to the guide on the side" (p. 14). This redefining of the instructor's position allows them to play a role which involves asking questions, engaging the students in critical, reflective thinking and supporting student interaction and collaboration, thereby providing students with a more engaging and interactive learning experience, which may be anticipated to have a positive impact of the student's perception of their learning experience.

Overall, the findings reported by Liaw (2008), Selim (2003), and Arbaugh (2000), suggest that students' perceptions of the usefulness or efficacy of educational methods or tools may impact significantly on their satisfaction with, and subsequent usage of, such tools. Importantly however, the findings of Liaw et al. (2007) and Volery and Lord (2000) suggest that the manner in which the instructor provides instructional guidance, or prompts effective interaction, may have an impact on the degree to which the students perceive the educational method or tool to be efficacious, favourable, or otherwise useful. With this in mind, Studies 1-3 (Chapters 3-5), addressed this design consideration, by including a measure of perceived efficacy of the IM methodology, to investigate the impact of instructional support manipulations, including the presence versus absence of dialogue (Study 1), task-level versus process-level prompting (Study 2), and facilitator-driven prompting versus peer-to-peer prompting (Study 3), on students' perceptions of the efficacy of the process.

2.6.5. *Trust*

Last, another influential social-emotional variable to consider in the context of CSCL is the level of trust that exists amongst group members. A number of different definitions of trust exist, such as "the expectancy that the word, promise, verbal or written statement of another

individual or group can be relied upon" (Rotter, 1967, p. 651) or "one party's (the trustor) confident expectation that another party (the trustee), on whom the trustor must rely, will help the trustor reach his or her goals in an environment of risk and uncertainty" (Huff, Cooper, & Jones, 2002, p. 25). Based on either of these definitions, trust implies an expectation that others will act or behave reliably, and in a manner that is consistent with their word.

Johnson and Johnson (1975) highlighted trust as a prerequisite for effective collaboration and collaborative learning among students. As noted by Ennen, Stark, and Lassiter (2015), collaborative learning requires students to work together and, in many cases, they are relying on each other to reach their shared goal. This need to rely on others implies a need for trust. In their research, which sought to investigate the importance of trust for satisfaction, motivation, and academic performance in collaborative learning, Ennen et al. (2015) gathered data from 252 university students who were taking part in semester-long group work. In the first week of the group work, after meeting their group members, students completed a measure of trust and a measure of perceived similarity with their group members. The measure of perceived similarity required participants to indicate how similar they believe they are to their group members on 24 different characteristics, such as values, goals, and personality. The measure of trust addressed students' propensity to trust (e.g., "In this project/discussion group, most people speak out for what they believe in"), perceived trustworthiness (e.g., "We have complete confidence in each other's ability to perform tasks"), and cooperative behaviors (e.g., "While making a decision, we take each other's opinion into consideration"). Monitoring behaviors, which are negatively related to trust (e.g., "In this team people watch each other very closely") were also captured as part of the trust measure. At the end of the semester, when students had completed their group work project, they again completed the trust measure, as well as measures of satisfaction with the group (e.g., "All in all, how satisfied are you with the members of your project/discussion group?") and motivation to work with groups in future (e.g., "Because of this group experience, I am motivated to work in project/discussion groups in the future"). A significant positive relationship was found between trust and perceived satisfaction, such that higher levels of trust were associated with higher levels of satisfaction with the group. Furthermore, higher levels of trust were also associated with better academic performance. Specifically, a significant positive relationship was found between levels of trust and project grades at the group level. Finally, a significant positive relationship was reported between trust and motivation to work in groups in the future, such that students who indicated higher levels of

trust in their group at the end of the semester were more motivated to engage in group work in the future.

Notably, the findings of Ennen et al. (2015) are consistent with findings from Chiu, Hsu, and Wang, (2006), Chang (2009), De Hoyos Guevara (2004), Huff et al. (2002) and Simons and Peterson (2000), each of whom have reported positive outcomes associated with higher trust in collaborative settings. For example, research conducted by Simons and Peterson (2000) suggests that trust plays an important role in moderating the relationship between task conflict (also known as cognitive conflict) and relationship conflict. As noted in Section 2.6.1., cognitive conflict is an important process through which groups discuss and debate differences of opinion, which may help them to move towards consensus (Fisher, 1980), and which may also contribute to quality decision-making (Fiol, 1994; Janssen, van de Vliert, & Veenstra, 1999). Conversely, relationship conflict, according to Simons and Peterson (2000), is characterised by perceptions of incompatibility, and has a negative influence on satisfaction and commitment. Simons and Peterson (2000) surveyed 380 workers from large US companies and included measures of task conflict (e.g., “To what extent are there differences of professional opinion in your executive group?”), relationship conflict (e.g., “How much tension is there among members in your executive group?”), and trust in group members (e.g., “We are all certain that we can fully trust each other”). The results of regression analyses revealed that task conflict had a significant positive association with relationship conflict, while trust had a significant negative association. Additional analyses showed that high levels of task conflict coupled with low levels of trust were strongly associated with high levels of relationship conflict. Conversely, when trust levels were high, task conflict was only weakly related to relationship conflict. As such, the authors concluded that trust plays a significant role in collaboration by preventing task conflict from escalating to relationship conflict. Such results are consistent with a more recent study by Peterson and Behfar (2003), who also reported results demonstrating that high levels of trust in groups serves as a buffer against future relationship conflict.

In the context of collaboration, trust has also been found to impact on information or knowledge sharing (Roberts & O’Reilly, 1974; Mooradian, Renzl, & Matlzer, 2006; Chiu, Hsu, & Wang, 2006). For example, in a study of decision support systems, Chiu et al. (2006) found that levels of trust are positively associated with quality of knowledge shared. In this study, data were collected from 310 members of an online working community in Taiwan, who were invited to complete a survey which included items measuring knowledge sharing, trust, as well as other measures such as social interaction ties, shared vision, and norms of

reciprocity. Once the surveys were completed, the researchers examined the messages posted in the online working community to assess quality of knowledge sharing. Quality of knowledge shared was assessed with items which addressed six attributes of knowledge: relevance, ease of understanding, accuracy, completeness, reliability, and timeliness. The results of structural equation modelling revealed a significant positive relationship between trust and quality of knowledge shared. In the context of collaborative learning, this may represent an important finding. While adequate sharing of knowledge would likely have a positive influence on the success of the group's collaborative efforts, a lack of quality knowledge sharing may hamper such success, as the full complement of knowledge available to a group to inform learning or decisions may not be shared.

Last, in a qualitative study focused on trust in collaborative learning contexts, Huff et al. (2002) asked 135 undergraduates students to visualise themselves in a scenario in which they had to work with three other students on a semester-long project. Then, each student was asked to describe the characteristics of a group member they would (a) trust, and (b) not trust. Participants were also asked questions relating to conditions needed for trust in a group, and the effects of a lack of trust in a group. These responses were then analysed qualitatively by the researchers. Analysis of students' responses revealed that effort, commitment, reliability, and openness were considered to be the most important factors in perceptions of trustworthiness, and that open communication was one key way to harness group trust. Furthermore, students highlighted a number of negative consequences of distrust in a group, with a lack of cohesiveness, lack of open and honest communication, and lack of sharing of ideas most commonly identified by participants.

Overall, the research described above highlights the potential benefits of trust in the context of collaborative learning, with trust supporting knowledge sharing (Chiu, Hsu, & Wang, 2006), motivation to work, group satisfaction, and the academic performance of groups (Ennen et al., 2015). Trust also moderates the relationship between task conflict and relationship conflict (Simmons & Peterson, 2000) with task conflict typically only escalating to relationship conflict in situations of low group trust. Also, students recognise that distrust can be associated with lack of cohesiveness, and lack of open, honest communication (Huff et al., 2002). These results suggest that trust, in a variety of ways, is influential in the success of collaborative learning groups, and may interact with other aspects of the learning situation in shaping learning processes and outcomes. Based on findings that trust is associated with satisfaction in group learning and motivation to work in groups in future, for example, it may follow that higher levels of trust will also be associated with higher levels of perceived

efficacy of collaborative learning methodologies, higher levels of team orientation, and lower levels of discomfort in group learning. Furthermore, the finding that trust mediates the relationship between task conflict and relationship conflict, may have implications for the way in which consensus emerges in collaborative learning settings. As such, the effect of trust on perceived efficacy (Studies 1-3), perceived consensus (Studies 1-3), objective consensus (Studies 1-3), team orientation (Studies 2 & 3), and discomfort in group learning (Study 3), is investigated in the current thesis in the context of a broader effort to examine the conditions that influence the performance of student groups during the construction of collaborative systems models.

2.7. Rationale for the current research

A number of different approaches to collaborative learning research have been implemented in the Learning Sciences literature. These range from qualitative, descriptive and interpretative approaches such as discourse analysis, to quantitative, comparative approaches such as experimental research, as well as more iterative design approaches such as design-based research (DBR). Each of these approaches have distinct advantages and disadvantages, and provide different affordances to the researcher in terms of research design and analysis. For example, more qualitative approaches place a strong emphasis on the situated nature of collaborative learning, and may focus on certain situational factors (Strijbos & Fischer, 2007). Interventionist and experimental approaches on the other hand, offer more scope for *a priori* hypothesis generating and statistical testing, to analyse the effects of systematic variations or manipulations of the collaborative learning environment. DBR approaches to collaborative learning research again differ significantly from experimental approaches. In DBR, effort is not made to control or constrict aspects of the learning environment, while isolating key variables for manipulation. According to Barab and Squire (2004), a key distinction between these approaches is that while experimental research seeks to focus on identifying, controlling, and analysing a few key variables, DBR characterises the learning situation in all its complexity, and rather than focusing on hypothesis testing, attends to multiple aspects of the design to develop a profile of the design in practice through multiple iterations. As such, while various approaches offer different advantages and affordances, determining the appropriate approach to research is contingent upon the goals of the research under design. In the case of the current research, in building upon the previous literature, and with the aim of addressing the research goals of this thesis, an experimental approach was adopted in Studies 1, 2, and 3, followed by a pilot curriculum. While other

methods of investigation and analysis are often adopted in the Learning Sciences, such as discourse analysis or DBR, an experimental approach was deemed the most suitable with regard to the goals of the thesis as a means to statistically analyse and understand key manipulations of the collaborative learning process, which can inform future research and practice. The experimental manipulations in each of the three studies centred around the facilitation of the IM process, which served as the context in which the learning took place, providing both the task – systems-model building, and the tool – Interpretive Structural Modelling. While the IM process has been extensively employed, with numerous reports of beneficial and successful applications in a variety of collaborative contexts (as highlighted in section 1.2.1.), there remains a dearth of experimental investigation of the effects of different types of facilitation or prompting on outcomes and processes. With this in mind, the current thesis primarily adopted an experimental approach to the investigation of facilitation or prompting styles in the context of the IM process.

It is important to note at this stage, that the IM process itself was not modified during its application in the current research. The process itself was chosen as a coherent, widely-applied method of engaging participants in a collaborative problem-solving process, and a means by which groups can work together to generate systems models. The systems model-building capability, using the ISM software, represents a unique affordance in a CSCL technology, which served as the primary task around which dialogue and argumentation took place in Studies 1-3. In essence, the systems-model building task, as a function of the IM process, provided the context for the experimental investigation of the effects of facilitation or prompting styles on collaborative learning.

2.7.1. Study 1

Building upon John Warfield's vision for systems science education, the current thesis highlights the importance of dialogue and collaborative argumentation in CSCL activities focused on systems model-building, specifically, using IM. Experimental manipulations focused on dialogue and the facilitation of collaborative argumentation are thus central to each of the three experimental studies outlined in this thesis (Chapters 3-5). Similarly, in-depth instruction and guidance focused on dialogue, argumentation, and the development of facilitation skill is central to the pilot applied systems science education curriculum described in Chapter 6. As described in Chapters 1 and 2, while there is accumulating evidence suggesting that dialogue and collaboration can facilitate better learning outcomes (Barron, 2003; Cho & MacArthur, 2010; Coleman, 1998; Mercer et al., 2004; Webb, 2009; Webb &

Palincsar 1996; van Boxtel et al., 2000), there have been no experimental studies focused specifically on dialogue and the facilitation of collaborative argumentation in the application of IM. More generally, systems science education programmes tend to focus more attention on the mathematics of systems modelling, with less attention on collaborative model-building and the role of dialogue and argumentation in the design of systems models. Also, little research has addressed the effects of dialogue on social-emotional processes that are an important part of collaborative learning.

Building upon the above, the main goal of Study 1 is to investigate the impact of dialogue on key social-emotional processes in the context of an IM systems model-building session, including: perceived consensus, objective consensus, and perceived efficacy of the IM methodology. As described in Section 2.6.1., consensus, which is positively associated with levels of satisfaction with collaborative processes (Mohammed & Ringseis, 2001), has been found to be positively influenced by cognitive conflict (Anderson & Martin, 1999; Sambamurthy & Poole, 1992). As such, it is hypothesised that the presence, as opposed to the absence, of dialogue will result in significantly higher levels of perceived and objective consensus. Furthermore, as levels of trust in group contexts has been found to influence the quality of knowledge sharing (Chiu, Hsu, & Wang, 2006), and moderate the relationship between task conflict and relationship conflict (Simmons & Peterson, 2000), it is also hypothesised that higher levels of trust will result in higher levels of perceived and objective consensus in an IM session.

Regarding perceived efficacy of the IM methodology, given the research reviewed in Section 2.6.4, reporting that higher levels of perceived usefulness of educational technology is positively associated with perceived satisfaction (Arbaugh, 2000), and predicts behavioural intention to use educational technology (Liaw, 2008), it is similarly likely that perceived efficacy of the IM methodology will impact on students' desire to engage with the process in future. As such, and based on findings that instructor characteristics, including the encouragement of interaction, has been found to be a key factor in student's perceptions of the success of educational technology (Volery & Lord, 2000), it is hypothesised that the presence, as opposed to the absence, of dialogue will result in significantly higher levels of perceived efficacy of the IM methodology. Furthermore, building upon research which has found that trust is positively associated with levels of satisfaction with collaborative processes (Ennen et al., 2015), it is hypothesised that higher levels of trust will result in higher levels of perceived efficacy of the IM methodology.

2.7.2. *Study 2*

In line with the emphasis Warfield placed on critical thinking as a key component of systems science education (Warfield, 2010), and Stahl's view of immersive, explorative, problem-solving as a core component of CSCL education design (Stahl, 2015), a focus on collaborative argumentation in the context of systems modelling work is central to both Studies 2 (Chapter 4) and 3 (Chapter 5). Both studies involve a specific focus on the facilitation of argumentation during a collaborative systems model-building task. Notably, in response to research suggesting that argumentation is central to a range of learning outcomes, including informal reasoning skills (Andriessen & Baker, 2014) and problem-solving (Jonassen & Kim, 2010), the Learning Sciences and broader educational literature has devoted considerable effort to researching ways in which argumentation skills can be cultivated and supported. One of the most commonly used pedagogical approaches to supporting argumentation involves the use of instructional supports such as feedback or prompts, with approaches such as question asking found to be useful in eliciting more complex forms of argumentation (Graesser, Person, & Huber, 1993; Veerman et al., 2000). However, neither the use of prompting, nor an investigation of the effects of different types of prompts in the context of systems model-building tasks have been reported in the literature to date. As such, the primary goal of Study 2 is to ascertain whether different kinds of prompting, specifically task-level versus process-level prompting, have an impact on the variety and complexity of argumentation students engage in during a collaborative systems model-building task, as measured by the CACS (Seibold & Meyers, 2007). It is hypothesised, based on prompting research described in detail in Chapter 4 Section 4.2.2., that process-level prompts, which facilitate deeper questioning and probe for expression of additional viewpoints, will result in more varied and complex forms of argumentation than task-level prompts.

Furthermore, Study 2, building upon Study 1, also seeks to address key social-emotional processes in collaborative learning. As such, Study 2 attempts to ascertain whether the different types of prompts provided to groups during collaborative discussions influence students' levels of (a) perceived and objective consensus, (b) perceived efficacy of the IM methodology, and (c) team orientation. In relation to consensus, previous research by Mohammed and Ringseis (2001) found that the highest levels of consensus were evident in groups in which the members questioned each other's suggestions, accepted legitimate suggestions and incorporated other's viewpoints into their own perspective. As such, process-

level prompts, which seek to promote deeper questioning and consideration of additional viewpoints, may have a positive effect on consensus. Similarly, by prompting for deeper reasoning and engagement with the topic at hand, process-level prompts may facilitate more cognitive conflict and argumentativeness, thus creating conditions for consensus to emerge (Anderson & Martin, 1999; Sambamurthy & Poole, 1992). It is therefore hypothesised that process-level prompts, as opposed to task-level prompts, will result in significantly higher levels of perceived and objective consensus. As in Study 1, it is also expected that the differences in facilitation (in this case in terms of prompts provided by the facilitator) will have an impact on students' perceptions of the efficacy of the IM methodology. As such, it is hypothesised that higher levels of process-level prompts, rather than task-level prompts, will result in significantly higher levels of perceived efficacy of the IM methodology, in response to deeper and more engaging collaborative argumentation and interaction in the process-level prompting condition. Similarly, given research by Eby and Dobbins (1997) which demonstrated that levels of team orientation may be influenced by previous positive experiences of working in teams, it is hypothesised that students in the process-level prompt condition will report significantly higher levels of team orientation than students in the task-level condition, following the systems model-building task.

2.7.3. Study 3

While numerous studies have investigated the effects of peer learning versus conventional teacher-driven learning, reporting that peer learning may provide additional learning benefits when compared with teacher-driven learning (e.g., Cho & MacArthur, 2010; Prins et al., 2006; Yang et al., 2006), significant gaps in the literature remain. Notably, while benefits of peer feedback, such as improvements in quality of writing (e.g., Cho & MacArthur, 2010; Patchan & Schunn, 20016), have been documented in the literature, less research has examined the effects of peer learning in collaborative argumentation tasks, or more broadly in CSCL contexts. Furthermore, while research has demonstrated the effectiveness of graphically organised prompts on performance of written tasks (Gan & Hattie, 2014), less is known about which kinds of instructional support are necessary to cultivate effective peer-to-peer feedback or prompting, especially in the context of dialogue-based tasks. Thus, the primary goal of Study 3 is to ascertain whether peer-to-peer prompting, as compared with facilitator-driven prompting, has an impact on the style and complexity of argumentation in a systems model-building task. Based on the available literature, described in further detail in Chapter 5, it is hypothesised that peer-to-peer prompting, as opposed to facilitator-driven

prompting, will result in more varied and complex forms of argumentation in the context of a systems model-building task.

Study 3 also seeks to examine whether peer-to-peer prompting, as compared with facilitator-driven prompting, has an impact on key social-emotional processes in CSCL, specifically on perceived and objective consensus, perceived efficacy of the IM methodology, team orientation, and discomfort in group learning. It is expected that differences in the manner in which the sessions are facilitated, by facilitator-driven prompting, or peer-to-peer prompting, will impact on levels of consensus as peer-to-peer prompting may facilitate more cognitive conflict, thus harnessing consensus (Anderson & Martin, 1999; Sambamurthy & Poole, 1992) and may also facilitate consensus-building by offering additional scope for students to question each other's suggestions, and incorporate the viewpoints of others (Mohammed & Ringseis, 2001). Thus, it is hypothesised that peer-to-peer prompts, as opposed to facilitator-driven prompts, will result in significantly higher levels of perceived and objective consensus. Furthermore, consistent with research highlighting the promotion of student interaction as a significant factor in students' positive perceptions of educational technology (Volery & Lord, 2000), it is hypothesised that peer-to-peer prompts, by providing opportunities for more direct student interaction, will result in significantly higher levels of perceived efficacy of the IM methodology, than facilitator-driven prompts.

As regards team orientation and discomfort in group learning, a review by Boud et al. (2001), found that peer learning promotes team-skills, such as the ability to work with others, and effective communication. However, the potential of peer-to-peer prompting as a pedagogical approach to enhancing team orientation has not been investigated to date. This line of enquiry represents a worthwhile extension of existing research, as effects on team orientation may have considerable positive effects on the broader collaborative experience of students in a learning environment (Bell, 2007; Eby & Dobbins, 1997). While high levels of team orientation are desirable in group learning contexts however, it is not uncommon for students to be averse to group work or find group work to be discomforting (Cantwell & Andrews, 2002). Such negative attitudes towards group work can have negative consequences for learning (Volet & Mansfield, 2006). As such, it is important to consider the impact that various types of facilitation or prompting have on levels of discomfort in the collaborative learning environment. Based on the literature described in Section 2.6.2., it is hypothesised that peer-to-peer prompting, as opposed to facilitator-driven prompting, will result in higher levels of team orientation, and lower levels of discomfort in group learning in a collaborative systems model-building task.

2.7.4. Pilot applied systems science education curriculum

Finally, Chapter 6 builds upon each of the previous experimental studies by describing a pilot applied systems science education curriculum. This pilot curriculum provides an opportunity to apply the findings of Studies 1-3, as well as key components of the body of literature reviewed in Chapters 1 and 2 and integrate them into a curriculum. This chapter provides a detailed account of the design, implementation, and evaluation of the pilot curriculum. More specifically, this evaluation includes a detailed collection of students' reflections on the weekly learning activities as well as broader reflections on the experience of learning through the applied systems science methodology. As such, this pilot module provides practical insights and a useful starting point for further applied systems science course development work.

Chapter 3 - Study 1: Investigating the effects of dialogue and trust on consensus and perceived efficacy of the IM methodology

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3.1. Chapter overview

This chapter presents Study 1, which seeks to explore the influence of dialogue on both objective and perceived consensus, and perceived efficacy of the IM methodology during a systems model-building task. In particular, this study addresses the potential negative effects of inhibiting dialogue in the process of building a consensus-based systems model in an educational context. The effects of initial levels of trust on group outcomes are also examined.

3.2. Introduction

As highlighted in Chapter 1, dialogue is central to collaboration and the development of shared meaning and understanding (Buber, 1958; Gadamer, 1960). Dialogue is seen as a process which offers the possibility of altering damaging communication patterns which groups may engage in, and instead supporting positive, open, and constructive patterns of communication that provides a means of effective collaboration (Bohm, 1996). As noted by Asterhan & Schwarz (2010, p.261), “the extent to which students learn from collaborative activities depends on the depth and the quality of the dialogue peers engage in”. This claim is supported by numerous research studies which have highlighted various examples of dialogue moves which add depth and quality to group discussions. These dialogue moves include: explaining ideas to others (Coleman, 1998), elaborating on each other’s ideas and problem-solving (King & Rosenshine, 1993; van Boxtel et al., 2000), engaging in reasoned argumentation (Asterhan & Schwarz 2007, 2009; Chin & Osborne 2010; de Vries et al., 2002; Schwarz et al., 2000), and producing and receiving elaborated help (Webb, 2009; Webb & Palincsar, 1996).

A core objective of John Warfield in developing the IM methodology was to facilitate groups in reaching a shared understanding and consensus when addressing complex problems (Warfield & Cardenas, 1994). However, Warfield did not investigate the optimal conditions

under which the IM methodology supports the development of consensus, and this question remains under-explored in the research literature. In the context of IM structuring, there is often considerable variation across the group in ratings of the relative significance of discrete paths of influence in the problematique. The IM process utilises a majority voting strategy to make decisions regarding the inclusion of paths of influence in the model, with a public vote made visible to the group after a period of reflection in relation to each binary relation presented during structuring. This voting strategy may influence emergent levels of consensus, even in the absence of dialogue in advance of voting. However, a movement toward greater perceived and objective consensus may be more likely in the context of open discussion, because members of a working group who initially have disparate views in relation to the nature of a problem may find greater grounds for consensus after being provided with the opportunity to openly discuss their thinking, and thus engaging in cognitive conflict.

While there is accumulating evidence suggesting that dialogue can facilitate better learning outcomes, little research has addressed the effects of dialogue on other critical social processes which, in turn, may impact on the collaborative learning process. Building upon the literature reviewed in Chapter 2, it is likely that dialogue plays a critical role in social processes and outcomes such as consensus and perceived efficacy. For example, as described in Chapter 2 Section 2.6.1., a study by Mohammed and Ringseis (2001) reported that groups in which the members questioned each other's suggestions, accepted each other's suggestions, and incorporated the viewpoints of others into their own thinking, were more successful at reaching consensus. What is not clear from such findings is if this relationship exists for both perceived and objective consensus. Higher levels of perceived consensus may serve to complement high levels of objective consensus when it comes to the sustained successful workings of a group who seek to resolve a problematic situation.

Furthermore, Peterson (1997) highlighted that the extent to which a group leader encourages open dialogue, can influence group processes and outcomes. In particular, Peterson found that differences in approach by process-directive leaders, versus outcome-directive leaders, had a significant impact on group processes. Process-directive leaders aim to foster the decision-making process by encouraging discussion and by remaining open regarding their own position. Outcome-directive leaders, however, do not encourage discussion in the group but rather focus solely on reaching a decision. It was found that process-directive leaders facilitated more positive group dynamics (including group confidence, and higher ratings of perceived leader effectiveness) and outcomes (including

higher decision quality). Similarly, Flowers (1977) found that open group dynamics where dialogue and discussion are encouraged facilitates not only more solutions in group problem-solving work, but also more sharing of information in comparison with groups where dialogue and discussion are not encouraged. Furthermore, as described in Chapter 2 Section 2.6.1., the findings of Anderson and Martin (1999) and Sambamurthy and Poole (1992) suggest that engagement in cognitive conflict and argumentation is positively associated with the building of consensus. As such, in the context of CSCL, it may be imperative that the facilitator of any group session provide ample opportunities for open dialogue and discussion in the group, as in the absence of dialogue and open sharing of information, it is likely that high levels of consensus will not be reached, and that students will not perceive the process to be sufficiently efficacious. Therefore, in the current study it is hypothesised that, compared to a condition where no dialogue occurred in advance of group voting in an IM structuring session, the presence of dialogue will result in higher levels of both perceived and objective consensus, and higher levels of perceived efficacy of the IM methodology.

Another factor relevant to consensus and perceived efficacy is trust. Individuals who score higher on measures of trust are more open to sharing and receiving of information in collaborative contexts. According to Johnson and Johnson (1989) “To disclose one’s reasoning and information, one must trust the other individuals involved in the situation to listen with respect” (p. 72). This is consistent with research which has found that people who are high in trust engage in more open communication, social negotiation, critical thinking and social interaction (Kreijns, Kirschner, & Jochems, 2002). More specifically, Kreijns et al. (2002) found that trust is a key component in creating social environments in which group members can interact and engage openly and critically. In the context of collaborative learning, Kreijns (2004) note that trust reinforces open communication between group members, and thereby enhances critical thinking. These findings are also consistent with research which suggests that higher levels of trust in a group lead to increased levels of quality knowledge sharing (Chiu et al., 2006), and that higher levels of trust may increase the likelihood that knowledge received is adequately understood (Mayer, Davis & Schoorman, 1995). As such, it is hypothesised in this study that higher trust will result in higher levels of both perceived and objective consensus.

Importantly, the notion of trust can extend from trust in a group, or group process, to trust in technologies or methodologies used to support collaborative learning. For example, Marsh and Dibben (2005) argue that it is vital that we facilitate both trust at the group level and also trust in CSCL technology, in order to enhance the quality of group work with such

technology. They claim that the degree to which users trust the technology to help them to achieve their aims may influence the prospective users' decision to adopt it. Notably, research by Ennen et al. (2015) found that higher levels of trust are significantly related to higher levels of satisfaction in the context of group learning. It is possible that these effects of trust extend to perceptions of specific group learning methodologies, including the perceived efficacy of group methodologies. As such, in the current study, it is hypothesised that higher levels of trust would result in higher levels of perceived efficacy of the IM methodology.

Last, in addition to a main effect of dialogue condition and trust on outcomes, an interaction effect is predicted. Specifically, it is predicted that, when compared with participants in the no dialogue group, participants in the dialogue group would report higher perceived and objective consensus and higher perceived efficacy of the IM methodology, and that these effects would be largest for individuals who score highly on the measure of trust.

3.2.1. The current study

In summary, the research reviewed above suggests the importance of both dialogue and trust in the context of collaborative learning. In the current study, it is hypothesised that:

1. The presence of dialogue will produce higher levels of perceived and objective consensus.
2. The presence of dialogue will produce higher levels of perceived efficacy of the IM methodology.
3. High levels of trust will produce higher levels of perceived and objective consensus.
4. High levels of trust will produce higher levels of perceived efficacy of the IM methodology.
5. The presence of dialogue, and high levels of trust will interact to produce the highest levels of perceived and objective consensus.
6. The presence of dialogue, and high levels of trust will interact to produce the highest levels of perceived efficacy of the IM methodology.

3.3. Method

3.3.1. Design

Two 2 (condition: dialogue versus no dialogue) x 2 (trust: high versus low) between-subjects ANOVAs were carried out to assess the effects of the presence or absence of

dialogue, and higher versus lower trust, on perceived consensus and perceived efficacy of the IM methodology respectively. A coefficient of concordance test was used to assess the statistical significance of differences in objective consensus across conditions before and after the experimental manipulation (i.e., differences in Kendall's W).

A priori sample size calculations were conducted using G*Power (Faul, Erdfelder, Lang, & Buchner, 2009). Based on an extensive meta-analysis of different educational factors which reported a large effect for collaborative learning (Hattie, 2009), a Cohen's d of 0.42 was used to calculate an appropriate sample size for the current study. This calculation suggested a minimum sample size of 34 was required to achieve adequate power at a desired power level of 0.8 and a probability level of 0.05.

3.3.2. *Participants*

Participants were first and second year psychology students ($N= 30$) comprising 8 males and 22 females, aged between 17 and 32 years ($M= 19.4$, $SD= 2.90$), from the National University of Ireland, Galway. Participants were recruited, via a university research participation platform, to participate in a group work session focused on the consequences of social media usage. They were offered research participation credits in exchange for their participation. Two groups of 15 participants, matched in terms of both mean and variance on the trust scale, were assigned at random to either the open dialogue or no dialogue condition.

3.3.3. *Measures and materials*

Trust. Trust was measured using a combination of the propensity to trust and perceived trustworthiness scales used by Jarvenpa, Knoll and Leidner (1998). The 11 items were rated on a 5-point likert scale (1 = strongly agree, 5 = strongly disagree; e.g., "Most people tell the truth about the limits of their knowledge"). The scale had good internal consistency ($\alpha = .72$).

Perceived efficacy of the IM methodology. Perceived efficacy of the IM methodology itself was measured using a scale developed specifically for this study as there was no such scale available. The scale included 7 items rated on a 5-point likert scale (1 = strongly agree, 5 = strongly disagree; e.g., "I believe that Interactive Management can be used to solve problems effectively"). The scale had good internal consistency ($\alpha = .88$).

Perceived consensus. The method of measurement used in this study was similar to that used by Kenworthy and Miller (2001): participants first gave their opinion (via the voting of problems relations) and were then asked to rate how representative they perceived their opinions to be in relation to the opinion of other members of their group. While Kenworthy and Miller asked participants for a percentage estimate, perceived consensus in the current study was measured using a 4-item scale with five-point likert ratings (1 = strongly agree, 5 = strongly disagree; e.g., “Generally speaking, my peers and I approach online social media in a similar manner”). The scale had good internal consistency ($\alpha = .77$).

Objective consensus. Objective consensus was measured using Kendall’s coefficient of concordance (Kendall’s W) in relation to likert scale judgement across a random set of ten relational statements in relation to the topic at hand. A sample item from this set is: “Not wanting personal details to be seen by everyone *significantly impacts* on the desire to share information and experiences with your network of contacts, family and friends”. Items were scored by each individual using a 7-point likert scale (1 = strongly agree, 7 = strongly disagree). Objective consensus, as measured by Kendall’s W, was computed for each group before and after the experimental manipulation (i.e., dialogue versus no dialogue conditions). High values occur when there is greater agreement between raters in the group.

Interpretive Structural Modelling. Interpretive Structural Modelling (ISM) is a computer-mediated idea-structuring methodology, that is designed to facilitate group problem-solving (Warfield & Cardenas, 1994). The ISM programme was run on a PC by co-facilitators in both the dialogue and no dialogue conditions. The relational statements that groups were to vote on were displayed on a large screen via an overhead projector (see procedure section below for a more detailed description of the IM methodology).

3.3.4. Procedure

At the time of recruitment, prospective participants were presented with information in relation to the nature of the study, including details as to its focus on collaborative inquiry and the consequences of online social media. Informed consent was obtained via the research participation platform two weeks prior to the laboratory component of the study, at which point participants were asked to complete the trust scale, and presented with a set of sixteen statements, eight of which related to possible negative consequences associated with online social media and eight of which related to possible benefits of online social

media. Participants were asked to first rank order the five most important negative consequences and second, rank order the five most important benefits or uses of online social media. The statement rank-orderings and trust scale data were collected and coded. The sum of ranks across the sample as a whole ($N = 30$) were computed and the top five negative consequences and top five benefits of online social media were identified for use in the IM session, the purpose of which was to map interdependencies between the costs and benefits of online social media.

Participants were then invited to part-take in an IM session. They were coded as being either high and low trust by means of a median split based on their trust scores. Participants high and low on trust were then randomly allocated to either the dialogue ($n = 15$, $M = 19.60$ years, $SD = 3.54$ years) or no dialogue ($n = 15$, $M = 19.27$ years, $SD = 2.19$ years) group. As a result, there were four categories of participants: dialogue, high-trust ($n = 8$), dialogue, low-trust ($n = 7$), no dialogue, high-trust ($n = 7$) and no dialogue, low-trust ($n = 8$). Before the IM session began, each participant completed the objective consensus scale.

Participants assigned to the no dialogue group were directed to a room in which the seating was arranged in rows facing the group facilitator, thereby limiting non-verbal communication between participants. The steps in the IM process were explained to participants and then the IM session began. A set of relational statements appeared one at a time on an over-head screen and participants were informed that they were not permitted to openly discuss the relations with the other group members; they were asked instead to raise their hand to declare their vote when it was called for. Specifically, for each relation presented on the screen (does A influence B), participants were asked to think about the relation and after a period of deliberation (30-40 seconds), participants were asked to raise their hands if they believed that, yes, A does indeed influence B. If a minimum of 10 out the 15 participants voted 'yes', then a yes vote was entered, and the relation appeared in the final problematique.

Participants in the dialogue condition were directed to a room in which chairs were arranged in a circle, such that all of the group members could see each other. Again, the IM process was explained to participants and then the IM session began. Relational statements were presented one at a time on an over-head screen and participants, under the direction of a neutral facilitator, were asked to openly discuss each relation with the other members of their group before voting. Deliberation and discussion was fostered by the facilitator, by prompting for opinions and elaborations, and it continued until all views in the group had

been expressed, after which the facilitator asked participants to raise their hands if they believed that, yes, A does indeed influence B. Again, if a minimum of 10 out of the 15 participants voted 'yes', then a yes vote was entered, and the relation appeared in the final problematique. When all of the relations had been completed in each group, the IM session closed. All participants then completed the objective consensus measure for a second time, as well a measure of perceived consensus, and a measure of perceived efficacy of the IM methodology.

3.4. Results

A series of two 2 (condition: dialogue versus no dialogue) x 2 (trust: high versus low) between-subjects ANOVAs were used to examine effects on perceived consensus and perceived efficacy of the IM methodology, respectively. Objective consensus was analysed using Kendall's coefficient of concordance (Kendall's W).

3.4.1. Perceived efficacy.

The ANOVA revealed a significant main effect of condition, $F(1, 26) = 6.18, p = .02$, partial $\eta^2 = .19$, with higher perceived efficacy in the dialogue condition ($M = 23.53, SD = 3.23$) than in the no dialogue ($M = 19.80, SD = 4.74$). There was no condition x trust interaction effect. The means and standard deviations for perceived efficacy are presented in Table 3. There was also a significant main effect of trust level on perceived efficacy of ISM, $F(1, 26) = 4.34, p = .047$, partial $\eta^2 = .14$, with higher perceived efficacy in the high trust group ($M = 23.27, SD = 4.40$) than in the low trust group ($M = 20.07, SD = 3.94$).

3.4.2. Perceived consensus.

The ANOVA revealed a significant main effect of condition, $F(1, 26) = 7.50, p = .01$, partial $\eta^2 = .22$, with perceived consensus higher in the dialogue condition ($M = 14.53, SD = 2.53$) than in the no dialogue condition ($M = 12.07, SD = 2.58$). There was no trust x condition interaction effect. The means and standard deviations are presented in Table 3. There was also a main effect of trust on perceived consensus, $F(1, 26) = 8.43, p = .007$, partial $\eta^2 = .25$, with perceived consensus higher in the high trust group ($M = 14.6, SD = 2.75$) than in the low trust group ($M = 12.0, SD = 2.27$).

Table 3. Means and standard deviations of perceived consensus and perceived efficacy across conditions and trust levels

Dialogue Condition	Trust Level		Perceived Consensus	Perceived Efficacy
Dialogue	Low	<i>M</i>	13.14	21.71
		<i>SD</i>	1.95	3.30
No Dialogue		<i>M</i>	11.00	18.63
		<i>SD</i>	2.14	4.07
Dialogue	High	<i>M</i>	15.75	25.13
		<i>SD</i>	2.43	2.30
No Dialogue		<i>M</i>	13.29	21.14
		<i>SD</i>	2.63	5.40

3.4.3. Objective consensus.

Kendall's coefficient of concordance (Kendall's W) was used to measure concordance (i.e., agreement of ratings in relation to specific ISM paths of influence) within groups before and after the experimental manipulation. No statistically significant differences between conditions were found ($p > .05$ for all four comparisons; see Table 4).

Table 4. Objective consensus scores across conditions and trust levels

Dialogue Condition	Trust Level	Pre	Post
Dialogue	Low	.17	.26
	High	.44	.18
No dialogue	Low	.21	.38
	High	.47	.50

3.5. Discussion

Study 1 examined the effects of the presence or absence of dialogue, and high versus low trust, on perceived consensus, objective consensus, and perceived efficacy of the IM methodology, in the context of a systems model-building task. The results of the study revealed that, in comparison with those in the no dialogue group, participants in the open dialogue group reported higher levels of perceived efficacy in relation to the IM

methodology, and higher levels of perceived consensus. Results also revealed that, in comparison with those low on trust, participants with higher trust also reported higher levels of perceived efficacy in relation to the IM methodology, and higher levels of perceived consensus. However, no significant differences were found in relation to objective consensus.

The finding that those in the open dialogue condition reported higher perceived efficacy of the IM methodology, suggests these students found the IM methodology to be broadly useful and valid and effective as a method of mapping the interdependencies between the consequences and benefits of online social media. This result is consistent with research conducted by Flowers (1977) who found that more open groups, who used dialogue and discussion when working together, establish positive norms of information sharing. This, according to Flowers, in turn influences their responsiveness to group design methodologies. Conversely, in the no dialogue condition, deprived of the opportunity for dialogue before their collective voting, participants may not have considered the process to be an effective method in helping them to structure their collective knowledge and reach a consensus view in relation to the consequences and benefits of social media usage, and as such, resulted in more negative judgements of the efficacy of the IM methodology. These results are also consistent with Volery and Lord (2000) who found that the role of the instructor or facilitator is critical in students' perceptions of educational technologies. In particular, Volery and Lord highlighted the importance of asking questions, and supporting interaction and collaboration. In doing so, the instructor provides students with a more engaging and interactive learning experience, one which may be anticipated to have a positive impact on the student's perception of their learning experience. Volery and Lord's research suggests that, in a condition in which a facilitator does not provide opportunities for engagement and dialogue, students may not respond well to the learning technology around which the task is taking place.

The results of this study also revealed that, in comparison with students with low trust, students with high trust reported significantly higher levels of perceived efficacy of the IM methodology. This result is consistent with previous research, described in Chapter 2 Section 2.6.5., which has found that trust can influence key social and learning processes, which may in turn influence the perceived efficacy of collaborative learning activities. For example, Ennen et al. (2015) found that trust is positively associated with levels of perceived satisfaction in group learning, and also positively associated with motivation to engage in group work in the future. Similarly, Huff et al., (2002) reported that trust is

associated with increased levels of satisfaction, effort, and motivation in the context of collaborative learning. As such, these factors may have mediated the relationship between trust and perceived efficacy of the IM methodology in this study, such that those with higher trust perceived greater benefits from the systems model-building task.

Notably, the results of the current study also revealed a significant main effect of both dialogue and trust on levels of perceived consensus. That those in the open dialogue condition reported higher levels of perceived consensus is consistent with previous research on the positive impact of open dialogue. For example, Mohammed and Ringseis (2001) found that the highest levels of consensus were evident in groups in which the members questioned each other's suggestions, accepted legitimate suggestions and incorporated other's viewpoints into their own perspective. In the current study, participants in the open dialogue condition had the opportunity to question suggestions, and consider and engage with others' viewpoints, and thus may have arrived at higher levels of perceived consensus. Conversely, those in the no dialogue condition, being unable to engage in any of these dialogue moves, may not have perceived a sense of consensus with the rest of the group. Similarly, the absence of dialogue means there was no opportunity for cognitive conflict or argumentativeness, which have both been found to contribute to the development of consensus (Sambamurthy & Poole, 1992; Anderson & Martin, 1999).

Participants with higher trust also reported higher levels of perceived consensus in response to the collaborative systems model-building efforts of the group. These results are consistent with research which has shown that higher levels of trust in a group leads to increased levels of knowledge sharing (Roberts & O'Reilly, 1974; Mooradian, Renzl, & Matlzer, 2006), and increased quality of knowledge sharing (Chiu et al., 2006), with individual group members perceiving knowledge sharing as less costly (Currall & Judge, 1995). Furthermore, as reported by Mayer et al. (1995) higher levels of shared trust in a group may increase the likelihood that knowledge received is adequately understood and absorbed so that the individual can put it to use. Although trust did not interact with the open dialogue versus no dialogue experimental manipulation, an analysis of the means across groups indicated that the highest perceived consensus scores were observed in open-dialogue, high-trust participants, and the lowest perceived consensus scores were observed in no-dialogue, low-trust participants. The effect of both trust and open dialogue in this regard represents an important finding in relation to CSCL tool use, and IM in particular, as higher perceived consensus is likely to lead to higher endorsement by the group of any action in

response to a shared problem. Achieving higher levels of consensus and promoting more coherent collective action was a critical objective of Warfield's when he first developed the IM process (Warfield & Cardenas, 1994). Furthermore, the results of the current study resonate with the results of a study conducted by Mohammed and Ringseis (2001), who found that more open groups had higher expectations in relation to the successful implementation of any decision reached by the group. Taken together, the impact of both open dialogue and high trust on perceived consensus and perceived efficacy of the IM methodology suggest that both social-emotional variables and contextual variables associated with conditions of tool use may have an important influence on CSCL processes.

While higher levels of perceived consensus were reported in both the open dialogue condition, and in students with high trust, no corresponding increase was found in relation to objective consensus. Contrary to the hypothesised effect, a trend toward a decrease in objective consensus in the open dialogue, high-trust group was observed. This may suggest that students in the open dialogue, high-trust group although judging themselves to be higher in levels of perceived consensus, were actually developing a more differentiated and complex view in relation to the influences at play in the problem situation, and thus did not arrive at objective consensus. By engaging in discussion, participants may have started to delve more deeply into the complexity of the relational statements posed during structuring, and thus moved away from their initial, more shallow reactions to the questions at pre-test. That this trend towards a significant change in objective consensus (albeit a decrease) was present in the open dialogue, high-trust group, but not the open-dialogue, low-trust group may reflect the higher openness to sharing and receiving of information in collaborative contexts associated with higher trust (Johnson & Johnson, 1989; Kreijns et al., 2002). Thus, it may be the case that those in the open dialogue, high-trust group were more open to the multiple perspectives being shared by other participants, but in the relatively short time available were still in a stage of exploration and consideration of multiple perspectives when the session closed, as opposed to having consolidated and reconciled the various perspectives into an emerging consensus. Future research should seek to clarify whether or not open dialogue or trust influence the emergence of a complex, differentiated view in the context of group-based system design work, and what impact (if any) this has on the ability of a group to act in a cohesive manner to resolve problematic situations. However, it is also important that future studies seek to examine these effects using a larger sample size than was used in the current study. The non-parametric comparison of Kendall's coefficient of concordance using small

samples was not ideal, and future studies should seek to replicate the current research using larger samples.

These results, combined with results from studies showing increased learning gains in more open and interactive groups (e.g., Ada, 2009) suggest that open dialogue is a critical factor in the success of CSCL tool use. Importantly, these results have implications for the future design of CSCL tools and how they are used. For example, these results are consistent with research by Peterson (1997), who found that the extent to which a leader was process-directive, and encouraged open discussion in advance of decisions had a significant positive impact on group confidence, ratings of perceived leader effectiveness, and quality of decision-making. As such, in the context of CSCL use, it may be important that the facilitator of any group session provide both ample opportunities, and instructional support, for open dialogue in the group.

Furthermore, given Marsh and Dibben's (2005) argument that it is vital for CSCL researchers to understand and facilitate both trust at the group level, and perceptions of CSCL technology, in order to enhance the quality and efficacy of interactions with learning technologies, the results of this study as regards perceived efficacy of the IM methodology are particularly valuable. According to Marsh and Dibben, the degree to which users trust in technology to help them to achieve their aims will likely influence their decision to engage with it in future. It is therefore important for researchers to determine which factors influence students' perceived efficacy of tools such as IM. In line with this goal, this study has identified both dialogue and trust as relevant factors, which certainly warrant further investigation.

3.5.1. Limitations and future research

Although the purpose of the experimental manipulation was to examine variation in outcomes associated with the presence or absence of dialogue, there was also systematic variation in the length of time for which the two groups deliberated before voting. Based on a small-scale trial run of this study, it was not deemed satisfactory to leave people in the no-dialogue group for too long before voting, as this created an uncomfortable atmosphere in the group. Therefore, the facilitator usually called for a vote after approximately 30 – 40 seconds. In the open dialogue group, deliberations had to continue until all the views in the room were expressed and with 15 people in the group, this could take up to 10 minutes for any given relation. However, the strategy used by the facilitator in the open dialogue group was to allow for longer periods of deliberation for the first 15 relations and then begin to

request votes after less time thereafter. Decisions also became faster (sometimes within 1 minute) over time in the open dialogue group as they became more familiar with the propositions and relations in the set and thus began to formulate more refined views in relation to influences at play. Nevertheless, this confound of dialogue condition with deliberation time was a somewhat unavoidable consequence of the experimental manipulation used in the current study. Ultimately, the open dialogue IM session lasted 110 minutes whereas the no dialogue session lasted 45 minutes. While this is to be expected (because the open dialogue condition lends itself to greater engagement with the problem-topic) it may nonetheless represent a study limitation as the increased time individuals spent interacting with one another in the open dialogue setting may have influenced their perceived consensus, and their perceived efficacy of the IM methodology.

Another potential limitation of the current study is the fact that the self-report measures were used to assess trust, perceived consensus, objective consensus, and perceived efficacy of the IM methodology. Self-report measures are susceptible to issues of response bias and it is possible for participants to answer in ways which do not reflect their true beliefs. However, efforts were made to reduce the potential for response bias, as all measures were completed anonymously (i.e., student's names were not included in their completed measures), and students were assured that their data would be stored securely.

A further limitation of the current study relates to the fact that individuals with high and low trust were mixed in the open and closed voting groups. This may have influenced the nature of interaction in the open dialogue condition in unique ways and it would be useful for future research to examine separately and more closely the style of interaction of participants high versus low in trust, in addition to groups that include a mix of participants both high and low on trust.

Finally, it should be acknowledged that the sample size of 30 participants was below the suggested sample size of 34 based on *a priori* calculations in G*Power. Future research should seek to replicate these findings with a larger sample size.

3.6. Conclusion

This study adds to the existing research literature by highlighting the impact of dialogue, and trust, on key social processes and outcomes in collaborative learning. While it has long been recognised that dialogue has significant positive effects on learning and collaboration, little research has addressed the effects of dialogue on other critical social processes which, in turn, may impact on the collaborative learning process itself. This study adopted a

process-oriented approach to collaborative learning research by manipulating a key component of the systems model-building task, the presence or absence of dialogue. It was shown that open dialogue and discussion in the group led to significantly higher perceived consensus and perceived efficacy of the IM methodology in comparison with a condition where dialogue and discussion were restricted. Participants with higher levels of trust also reported significantly higher perceived consensus and perceived efficacy of the IM methodology.

3.7. Implications for the next study

These results have implications for the application of IM in the classroom environment, suggesting that great care should be taken to facilitate open dialogue among students. With this in mind, Study 2 seeks to further explore the role of the facilitator in supporting open and effective dialogue, by investigating the effects of different kinds of prompts on the nature and complexity of students' argumentation in a collaborative, dialogue-based, systems model-building task.

Chapter 4 - Study 2: Investigating the effects of task-level versus process-level prompts in collaborative argumentation

Note: an earlier version of this chapter was published in *ijCSCL*:

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4.1. Chapter overview

Study 1 highlighted the importance of providing opportunities for open dialogue in collaborative learning. Building upon these results, Study 2 examines the role of facilitator prompting in supporting effective dialogue and collaborative argumentation. More specifically, this study investigates the effects of task-level versus process-level prompts on the style and complexity of argumentation engaged in by students in a systems model-building task. Study 2 also seeks to investigate the effects of task-level versus process-level prompts on levels of perceived and objective consensus, and perceived efficacy of the IM methodology, while further extending this line of research by investigating the effects of prompting style on team orientation.

4.2. Introduction

Analyses of collaborative teams in work and educational settings have led to a number of important conclusions regarding the requirements for effective collaboration. For example, when left to their own devices, teams often fail to reach their full potential, and they may consider collaborative work to be too time-consuming and thus fail to sustain quality interactions and exchanges (Dickinson & McIntyre, 1997; Rummel & Spada, 2005). As such, in educational settings, successful collaboration requires the careful design of the learning environment for group interaction and the provision of instructional support, facilitation and prompts to promote meaning-making, problem-solving, and consensus among students (Pea, 2004; Strijbos et al., 2004). This need is echoed by Gabelica et al. (2012), who highlight the necessity to provide students with skilled facilitation and instructional support, which includes prompts designed to sustain quality interactions during the collaborative learning process (Gabelica et al., 2012). Notably, while the literature regarding the benefits of individual level instructional support in learning contexts is well-established (Gabelica et al.,

2012; Hattie & Gan, 2011), less research has been devoted to the analysis of prompts and facilitation effects in collaborative learning settings and the specific types of prompts that promote collaborative argumentation and consensus-building in this context. Furthermore, although the importance of good facilitation in collaborative learning environments is often highlighted by expert facilitators (Hmelo-Silver, 2002), there has been limited experimental research focused on the effects of facilitator prompting styles on processes and outcomes in CSCL.

4.2.1. Instructional support in collaborative learning environments

As described in Chapter 2 Section 2.4.3., prompts are a commonly used means of instructional support and scaffolding (e.g., Stevenson, Hickendorff, Resing, de Boeck, & Heiser, 2013; Gamlem & Munthe, 2014) and come in many forms, including guiding questions, sentence openers, or question stems which provide learners with hints, clues, suggestions or reminders that help them to complete a task. Prompts act as scaffolding that support and inform the learning process (Gan & Hattie, 2014), and may also be considered as “strategy activators” which “induce productive learning processes” (Berthold, Nückles, & Renkl, 2007, p.566). Prompts may be used to elicit explanations (Chi, 2000, Chi, deLeeuw, Chiu, & LaVancher, 1994), elaborations (Brown & Palincsar, 1989) or collaborative thinking aloud (Hogan, 1999).

Prompts have been used across a variety of instructional domains with diverse student groups. Studies have focused on increasing reflection and knowledge integration in middle school science students (Davis, 2003), increasing knowledge representation, problem-solving, evaluation, and monitoring skills in undergraduate information technology students (Ge & Land, 2003), and improving the quality of written peer feedback in secondary school student’s chemistry reports (Gan & Hattie, 2014). Such feedback and scaffolding protocols can take various forms, utilising various forms of prompts, for example: task-level prompts, process-level prompts, and self-regulatory prompts, amongst others (Hattie & Timperley, 2007). In their study, Gan and Hattie (2014) provided students with prompts designed to elicit peer feedback, such as “What other questions can he/she ask about the task?”. These types of questions provided learners with a type of process-level prompt that facilitated collaborative learning in the context of a written chemistry task. The current study uses similar prompts, modelled on the work of Hattie and Timperley (2007), and Gan and Hattie (2014).

Notably, many reviews and meta-analyses have demonstrated the benefits of task-level instructional support for individual learning outcomes (e.g., Alvero, Bucklin, & Austin,

2001; Balcazar, Shupert, Daniels, Mawhinney, & Hopkins, 1989; Denson, 1981; Guzzo, Jette, & Katzell, 1985; Ilgen, Fisher, & Taylor, 1979; Kluger & DeNisi, 1996; Mento, Steel, & Karren, 1987; Neubert, 1998). Task-level prompting provides information on how well a task is being performed. For example, task-level prompts may focus on: distinguishing correct from incorrect answers, acquiring more or different information, and building more surface knowledge (Gabelica et al., 2012; Hattie & Timperley, 2007). Importantly however, research suggests that such task-level prompting does not always have beneficial effects on individual learners, and can result in negative performance effects in some situations (see Kluger & DeNisi, 1996 for a review).

According to Hattie and Timperley (2007), one of the main shortcomings of task-level instructional support is that it often does not transfer well to other tasks or problems and is therefore limited in its value beyond the specific task at hand. One explanation for this is that when prompts, or other instructional support, are heavily focused on immediate task goals, individuals may not reflect upon the cognitive strategies involved in the learning or problem-solving process. For example, in a LOGO-based angle and rotation mathematics tasks, Simmons and Cope (1993) found that students (aged 9-11) who were provided with immediate, visual, task-level feedback by being able to see their rotation on a computer, spent less time developing strategies for solving the problem, and engaged in more simple trial and error, than students who performed the task via pen and paper.

Process-level prompting, on the other hand, seeks to address the shortcomings of task-level prompting. At the process-level, prompts may be used to address key processes and strategies which are necessary to complete the task (Ketelaar, den Brok, Beijaard & Boshuizen, 2012). Process-level support targets procedural knowledge and can provide support for error detection, information searching, and steps for revision of work done (Gan & Hattie, 2014, Gan (2011). Schoenfeld (1985), for example, found that prompting students to provide justifications for their learning was effective for knowledge use in mathematical problem-solving tasks. Process-level prompts which promote reflection on learning have also been found to have positive effects on writing-to-learn tasks (Hübner, Nückles, & Renkl, 2010), teacher education (Harford & MacRuairc, 2008) and e-learning (Krause, Stark, & Mandl, 2009). The design of the task-level and process-level prompts used in the current study was informed by both the prompting, and feedback, literature in relation to types of instructional support.

As noted above, while prompting has been argued to be powerful and effective in shaping team learning and team performance (Kozlowski & Ilgen, 2006; Woolley, 2009), the

application of these methods to CSCL settings has not been explored as extensively as in individual learning settings. Importantly, results and insights from studies of instructional support at the individual level cannot simply be transferred and applied to teams or other collaborative groups (Gabelica et al., 2012; Barr & Conlon, 1994; Dewett, 2003; Nadler, 1979). For example, Barr and Conlon (1994) suggest that the unique effects of instructional support in a team environment may be due to the distribution of prompts among team members, a process which is dependent on the interaction of a number of individual level and team-level variables including: the interaction between team members; the nature and efficacy of group communication; and individual perceptions of information. The potential discrepancy between individual and group level support may be especially relevant in the case of process-level prompting. In a collaborative context, process-level prompting may address individual and group behaviours, actions and strategies during team learning, however, research examining the impact of process-level support in teams is still in its infancy (Gabelica et al., 2012; Hattie & Timperley, 2007). As such, the current study describes an investigation of the effects of task-level versus process-level prompting in the context of a group decision-making process that involves collaborative argumentation, consensus-building and the development of a systems-based understanding of a common problem.

4.2.2. Process-level prompting and collaborative argumentation

As noted in Chapter 2, learning to argue is considered an important educational goal (Andriessen & Baker, 2014), particularly given research showing that people often demonstrate limited argumentation skills (Kuhn, 1991; Stark, Puhl & Krausse, 2009; Tannen, 1998). It is therefore imperative that research attend to the methods by which collaborative argumentation can be supported and facilitated in the classroom. Importantly, however, collaborative argumentation is not a simple process whereby individuals merely provide a series of reasons and objections in relation to a set of claims - it may involve many and diverse types of dialogue moves that are coordinated in a more or less coherent manner. The Conversational Argument Coding Scheme (CACS; Seibold & Meyers, 2007), which is used in the current study, identifies 16 conversational codes grouped under 5 argumentation categories, with codes representing different levels and types of argumentation (see Chapter 2 Section 2.4.1. for further detail).

Given the potential complexity of collaborative argumentation, the use of prompts to enhance argumentation skills is an increasingly common approach in collaborative learning

settings (Scheuer, Loll, Pinkwart & McLaren, 2010). As noted previously, prompts can come in the form of questions, question stems, or sentence openers to, for example: prompt students to check each other's information, prompt the provision of further explanation, encouraging justification of assertions (Webb, 1995); elicit explanations and justifications (King 1990); promote frequency of information exchange and constructive activities (Veerman et al., 2002), or probe and evaluate information for relevance and justification (Yiong-Hwee & Churchill, 2007). Across a variety of studies, prompting has been found to have positive effects on students' argumentation (e.g., Chiu, 2004; Gillies, 2004; Graesser et al., 1993; King, 1990; Veerman et al., 2002; Webb et al., 2008; Webb, 2009; Yiong-Hwee & Churchill, 2007). As such, informed by the previous prompting research (e.g., Hattie & Timperley, 2007; Gan & Hattie, 2014), a focus on prompting at different levels of complexity is central to the design of the current study, which seeks to investigate the effects of task-level versus process-level prompts on the variety and complexity of collaborative argumentation in the context of a systems model-building task.

More specifically, it is hypothesised in the current study that process-level prompts will result in greater variety and complexity of argumentation, as measured by the CACS. Further, if as hypothesised, the process-level prompts cultivate more diverse, sophisticated forms of argumentation, then it follows that this may lead to more complex and differentiated relational thinking, and thus result in more complex representations of the relationships between ideas in the systems structuring phase. With a more diverse pattern of voting, the matrix structures are likely to be more differentiated and thus result in more complex systems models.

4.2.3. Social psychological factors in collaborative settings

Importantly, facilitator prompting styles may have different effects on different people within a group. As demonstrated in Study 1, variables such as trust amongst group members may impact on the collaborative efforts of groups. As outlined in Chapter 2, higher levels of trust in groups have been implicated in a range of behaviours associated with more effective collaboration, including social negotiation, critical thinking and solution finding (Kreijns et al., 2002). Furthermore, trust is relevant in collaborative contexts as those with high trust have been found to generally assume that others are trustworthy, and presume that trusting others leads to positive outcomes (McKnight, Cummings, & Chervany, 1998). Therefore, building upon the results of Study 1, Study 2 also investigated the role of trust in these social processes and outcomes. Specifically, the results of Study 1 found that groups higher in trust

reported higher levels of perceived consensus, and perceived efficacy of the IM methodology, when compared with groups where levels of trust were lower and where open dialogue and discussion was restricted. The results of Study 1 are also consistent with previous research showing that trust is positively associated with levels of perceived satisfaction in group learning, and motivation to engage in group work in the future (Ennen et al., 2015; Huff et al., 2002). In light of the above, Study 2 seeks to extend this line of research, by investigating the effects of task-level versus process-level prompts, on processes and outcomes in a CSCL environment, while also analysing the role of trust as a covariate.

Building upon the design and results of Study 1, Study 2 also included an investigation of perceived and objective consensus, and perceived efficacy of the IM methodology. Notably, the results of Study 1 suggested that the opportunity to engage in dialogue plays an important role in the development of both perceived consensus, and perceived efficacy of the IM methodology. Furthermore, given that previous research found that the highest levels of consensus were evident in groups in which the members questioned each other's suggestions, accepted legitimate suggestions and incorporated others' viewpoints into their own perspective (Mohammed & Ringseis, 2001), and research reporting significant associations between both cognitive conflict, argumentativeness and levels of consensus (Anderson & Martin, 1999; Sambamurthy & Poole, 1992), an investigation of the effects of different kinds of facilitator prompting on levels of consensus is warranted. Finally, given research by Liaw et al., (2007) and Volery and Lord (2000) highlighting the role of the instructor in students' perceived satisfaction in group learning scenarios (as described in Section 2.6.4.), the effects of different kinds of facilitator prompting on levels of perceived efficacy of the IM methodology also warrants further exploration in Study 2.

The current study also introduces an additional social variable to the investigation, team orientation. As described in Chapter 2 Section 2.6.2., team orientation refers to an individual's propensity for functioning as part of a team, and the degree to which they prefer to work in a group or team, rather than as an individual, to accomplish tasks. Team orientation has been found to be associated with a number of positive behaviours and outcomes in the context of group work, including: team member exchange (Wang et al., 2014), cooperative behaviours (Eby & Dobbins, 1997), and team performance (Bell, 2007). Given that team orientation has been found to be influenced by an individual's previous positive experience of group work, Study 2 examined whether different kinds of facilitator prompting influenced levels of team orientation before and after the systems model-building task.

4.2.4. *The current study*

The current study investigates the effects of task-level versus process-level prompts on perceived and objective consensus, perceived efficacy, variety and complexity of argumentation, and collaborative systems model complexity in the context of an IM session. In light of the evidence reviewed above, it was hypothesised that prompting style during collaborative dialogue and argumentation is a critical factor in shaping key outcomes of collaborative learning. Specifically, it was hypothesised that:

1. Process-level prompts will produce higher levels of perceived and objective consensus.
2. Process-level prompts will produce higher levels of perceived efficacy of the IM methodology.
3. Process-level prompts will produce higher levels of team orientation.
4. Process-level prompts will produce more complex and varied forms of argumentation in groups.
5. Process-level prompts will result in the development of more complex systems models.

4.3. Method

4.3.1. *Design*

A one-way ANCOVA was used to assess the effects of prompting style (task-level versus process-level) on the perceived efficacy of the IM methodology, with trust included in the analysis as a covariate. Two 2 (condition: task-level versus process-level) x 2 (time: pre-intervention versus post-intervention) mixed ANCOVAs were used to assess the effects of task-level versus process-level prompts on perceived consensus, and team orientation, again with trust analysed as a covariate. A coefficient of concordance test was used to assess the statistical significance of differences in objective consensus across conditions before and after the experimental manipulation (i.e., differences in Kendall's W). Last, a series of chi-squared tests were used to examine frequency differences in argumentation codes across prompting conditions using the CACS coding system.

A priori sample size calculations were conducted using G*Power. Based on a review of feedback and prompting literature which reported predominantly large effect sizes for interventions similar to process-level prompting (Hattie & Timperley, 2007), a Cohen's d of 0.4 was used to calculate an appropriate sample size for the current study. This calculation

suggested a minimum sample size of 52 was required to yield adequate power at a desired power level of 0.8 and a probability level of 0.05. Given the inherent challenge in recruiting groups of students for research participation, the decision was made to aim for approximately 50% above this minimum required sample size.

4.3.2. Participants

Participants were first and second year psychology students ($N = 75$) comprising 28 males and 47 females, aged between 18 and 27 years ($M = 19.60$, $SD = 3.15$), from the National University of Ireland, Galway. Participants were offered research participation credits in exchange for their participation. Participants were recruited via a university research participation platform. Four groups of 17-20 participants, matched in terms of both mean and variance on the trust scale, were assigned at random to either the task-level or process-level condition.

4.3.3. Measures and materials

Trust. The same trust measure as used in Study 1 (Jarvenpa et al., 1998) was used in the current study. Items included, for example, “Most people tell the truth about the limits of their knowledge”. The scale had good internal consistency in the current study ($\alpha = .78$).

Perceived efficacy. The same measure of perceived efficacy of the IM methodology as used in Study 1, which was developed for this thesis, was used in the current study. Items included, for example, “I believe that Interactive Management can be used to solve problems effectively”. The scale had acceptable internal consistency ($\alpha = .62$).

Perceived consensus. As in Study 1, perceived consensus was measured by means of the method used by Kenworthy and Miller (2001). Participants were asked to rate how representative their opinions were in relation to others in the group e.g., “Generally speaking, my peers and I approach online social media in a similar manner”. The scale had good internal consistency ($\alpha = .76$).

Objective consensus. As in Study 1, objective consensus was measured using Kendall’s coefficient of concordance (Kendall’s W) in relation to likert scale judgement across a random set of ten relations from the full set of propositional interdependencies. Items included, for example “Not wanting personal details to be seen by everyone significantly impacts on the desire to share information and experiences with your network of contacts, family and friends”.

Team orientation. Team orientation was measured using the 21-item Team Orientation scale (Mohammed & Angel, 2004). Item responses were rated on a 5-point likert scale (1 = strongly agree, 5 = strongly disagree; e.g., “All else being equal, teams are more productive than the same people would be working alone;” “I generally prefer to work alone than with others” (reverse scored); and “I find that other people often have interesting contributions that I might not have thought of myself.” The scale had good internal consistency ($\alpha = .80$)

Variety and complexity of argument. Variety and complexity of argument was assessed using the CACS (Seibold & Meyers, 2007). As described in Chapter 2 Section 2.4.1., the CACS was developed to investigate argumentative micro processes in group interaction (Beck et al, 2012). The five argument categories, containing a total of sixteen argument codes, are presented in Table 5, along with an example of each code from transcription of the current study. Multiple Episode Protocol Analysis (MEPA; Erkens, 2005) was used to facilitate the CACS analysis. MEPA is computer software designed for interaction analysis, in which transcribed data can be coded several dimensions or levels. This data was transcribed from audio-visual recordings. Cohen's κ was run to determine the level of agreement between coders. There was strong agreement between the two coders, $\kappa = .85, p < .005$.

Table 5. *Conversational argument coding scheme and examples from Study 2*

Code	Example from transcript
I. Arguables	
A. Generative mechanisms	
1. Assertions: Statements of fact or opinion	“I just suggested increased feelings of anger towards yourself and others”
2. Propositions: Statements that call for support, action, or conference on an argument-related statement	“Wouldn’t this just be related directly to being self-conscious about your image anyways?”
B. Reasoning activities	
3. Elaborations: Statements that support other statements by providing evidence, reasons, or other supports	“..because, you know, sometimes you’re emotionally affected and a lot of the time people will feel angry”
4. Responses: Statements that defend arguables met with disagreement	“..but then whoever has been left out just ends up being paranoid about people that they thought they could trust and things”

5. Amplifications: Statements that explain or expound upon other statements to establish the relevance of the argument through inference	“Em, I guess what’s been suggested is that you might have less time to engage in other activities and from the range of interests you might have, you might not have time for them anymore”
6. Justifications: Statements that offer validity of previous or upcoming statements by citing a rule of logic (provide a standard whereby arguments are weighed)	“Just putting yourself in that situation like, if you just put yourself in the shoes of a person who wouldn’t be invited and just think about what they would feel?”
<hr/>	
II. Convergence-seeking activities	
7. Agreement: Statements that express agreement with another statement	“Yeah, I think what she said is right”
8. Acknowledgement: Statements that indicate recognition and/or comprehension of another statement but not necessarily agreement with another’s point	“I think that it could be, for some people, but I’ve never experienced guilt from Facebook”
<hr/>	
III. Disagreement-relevant intrusions	
9. Objections: Statements that deny the truth or accuracy of an arguable	“I don’t think it’s significant”
10. Challenges: Statements that offer problems or questions that must be solved if agreement is to be secured on an arguable	“Is it increased perception of being judged in a positive way though? You change your personality to be judged in a positive way, because you think you were being judged in a negative way?”
<hr/>	
IV. Delimiters	
11. Frames: Statements that provide a context for and/or qualify arguables	“Em, it’s probably within themselves, that they doubt themselves so much more.”
12. Fore stall/secure: Statements that attempt to forestall refutation by securing common ground	<i>No examples in transcript</i>
13. Fore stall/remove: Statements that attempt to forestall refutation by removing possible objections	<i>No examples in transcript</i>
<hr/>	
V. Nonarguables	
14. Process: Non-argument-related statements that orient the group to its task or specify the process the group should follow	<i>No examples in transcript</i>

- | | |
|--|-------------------------------------|
| 15. Unrelated: Statements unrelated to the group's argument or process (tangents, side issues, self-talk, etc.) | <i>No examples in transcript</i> |
| 16. Incompletes: Statements that do not contain a complete, clear idea because of interruption or a person's discontinuing a statement | “I don't know, eh...(discontinued)” |
-

Complexity of IM problematiques. IM complexity scores are based on total activity of the paths of influence in the structure. This involves computing the sum of the antecedent and succedent scores for each element. The antecedent score is the number of elements lying to the left of an element, which influences it. The succedent score is the number of elements lying to the right of an element in the structure, which influences it (Warfield & Cardenas, 1994).

Interpretive structural modelling. As in Study 1, Interpretive Structural Modelling (ISM) was used for systems model-building. The ISM programme was run on a PC by a co-facilitator. The relational statements which groups were asked to consider and vote on were displayed on a large screen via an overhead projector.

4.3.4. Procedure

During recruitment, prospective participants were presented with information in relation to the nature of the study, including details of the topic for discussion, which addressed the personal and social consequences of using online social media. The choice of topic in the context of collaborative argumentation is an important design consideration. The chosen topic must, for example, be sufficiently substantive so as to promote discussion. With this in mind, Asterhan and Schwarz (2016) suggest the use of ill-structured problems, which do not have a clear solution or correct answer. In this way, students are not expected to generate empirical answers in order to contribute to the discussion, but rather the topic is open to a sharing of opinions and questions from various perspectives based on students' own knowledge and experiences. Similarly, a second consideration in choosing a topic for discussion is that of relevance to students. That is, the topic should be one which is relevant to students in their personal, social, or academic lives, such that they will be sufficiently engaged by the topic. In line with these considerations, the topic of the potential negative personal and social consequences of social media usage was chosen for these IM sessions.

Participants were invited to register their intention to take part online via SurveyGizmo, and were required to complete the trust scale as part of the registration process. Participants were then randomly allocated to one of four groups, two in the task-level prompt condition ($n = 20$, $n = 20$) or process-level prompt condition ($n = 17$, $n = 18$).

4.3.5. Interactive Management sessions

A total of 4 IM sessions were carried out, with no more than 20 students in any session. Each session lasted approximately 180 minutes. Participants in each of the 4 sessions were directed to a room in which chairs were arranged in a circle, such that all of the group members could see each other. Before the IM session began, each participant was given a document which contained a participation information sheet, a perceived consensus scale, an objective consensus scale, and a team orientation scale. The participants were asked to read the information sheet, which contained an introductory paragraph about online social media. Participants were then required to complete the aforementioned scales. Once all scales had been completed, participants were given a list of potential negative consequences of social media usage, which were compiled based on a review of the literature. Next, the IM process was explained to participants and then the session began.

The design of the prompting conditions was informed by the work of Hattie and Timperley (2007) and Hattie and Gan (2011). The task-level prompt condition consisted primarily of simple, task-level prompts, while the process-level prompt condition consisted of task-level prompts, with the addition of process-level prompts. In each condition, the facilitator, trained in the use of the IM methodology, was given a specific set of prompts or instructions which could be used as part of the systems model-building process. A co-facilitator was present to oversee the process, and assist with the input of ideas into the ISM software, but did not engage in prompting or interact with students during the session. In both conditions, participants were asked to silently generate a set of ideas in addition to the idea set provided, which they felt had a significant impact on the problem at hand, in response to the question “What are the negative effects of online social media?”. This is referred to as the *Idea Generation* phase of IM. Specifically, the *nominal group technique* (NGT) was used as a method of idea generation. The NGT (Delbeq et al., 1975) described in detail in Chapter 1 Section 1.2.2., is a method that allows individual ideas to be pooled and discussed.

Once the initial silent idea generation was complete, and each participant had their own list of ideas to offer, the facilitator went around the room, to each participant asking them to present their idea to the rest of the group. They were asked to explain one idea clearly

and succinctly. The facilitator would then open the discussion up to the group, by asking “Does anyone have any other ideas?” While these guidelines were also followed by the facilitator in the process-level prompt condition, there was also the addition of some further prompts. In the process-level prompt condition, the facilitator could ask for further clarification, suggest that some ideas offered may be similar in nature and require further examination, suggest merging of ideas, suggest breaking down of ideas which appear to have multiple components, suggest considering the relevance of the idea offered in the problem-context, and suggest considering the generalisability of the idea offered (see Figure 2).

The next, and final, phase entered was the *Idea Structuring* phase. This is the phase during which the primary computer-supported collaboration took place, using the ISM software. In an effort to reduce cognitive load, facilitate focus, and build the components of the systems model, the ISM software presents two elements at a time on screen, asking the question “Does A significantly influence B?” As each of these relational statements is presented on the screen, the facilitator would open the discussion to the room, and ask if anyone has a “yes” or “no” preference at this stage. As participants indicated their preference, the facilitator would ask why they had this stated preference, and then request other opinions from the group. The facilitator would then request a show of hands from the group, and a vote would be taken and recorded by the ISM software. Again, these guidelines were also followed by the facilitator in the process-level prompt condition, but with the addition of further prompts and instructions. In the process-level prompt condition, for example, the facilitator would ask for contrary opinions, ask for support or evidence, ask the group to further consider the relevance of arguments provided, and suggest considering the generalisability of the reasons and evidence offered (see Figure 5).

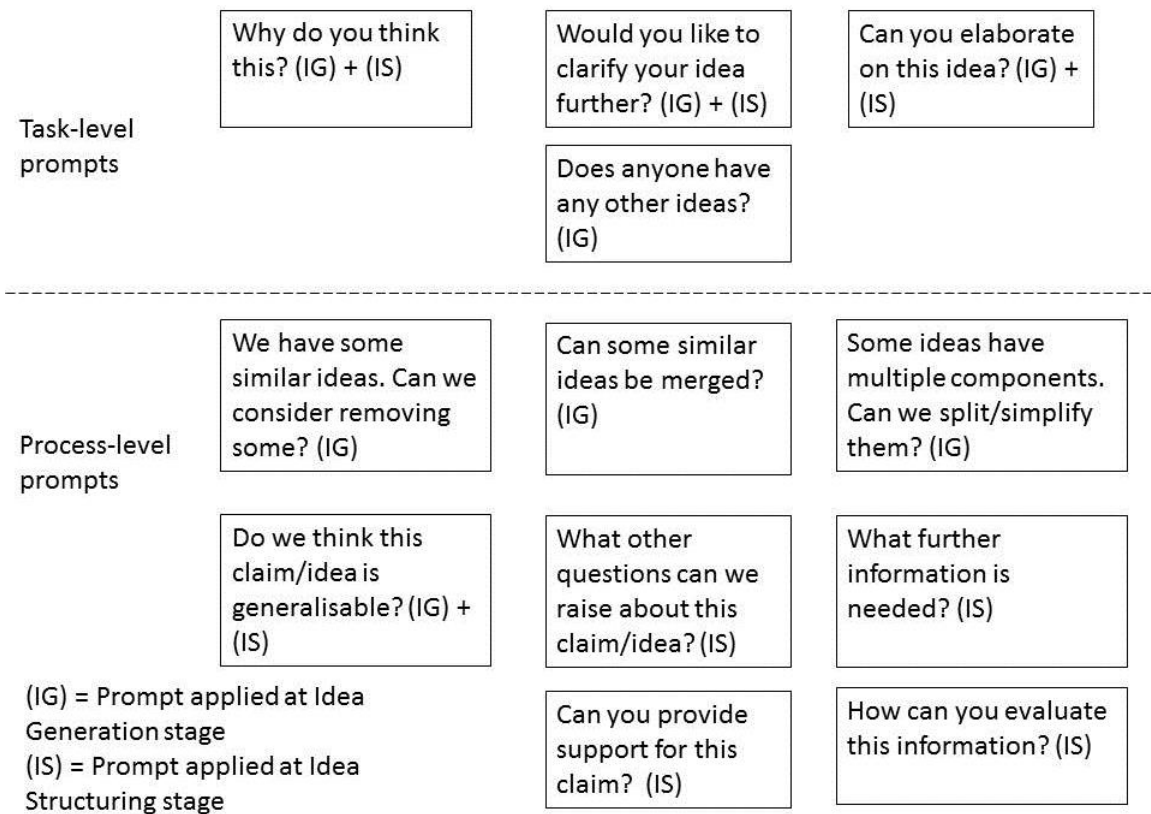


Figure 5. Task-level and process-level prompts in Study 2

In each condition, the process continued until all of the relational statements had been addressed, at which point the software had completed the systems model. In each group, the facilitator presented and described this systems model to the students, before asking them to complete the post-intervention measures of perceived consensus, objective consensus, perceived efficacy of the IM methodology, and team orientation.

4.4. Results

As prompts were delivered at the group level, and perceived efficacy, perceived consensus, objective consensus, and team orientation, were measured at the individual level, intra class correlations were calculated to assess any clustering by group status. These analyses were conducted separately for each prompt condition, and each outcome. The analyses indicated that the intra-class correlations ranged between 0 and 0.0022 ($p = .49$). As such, it was deemed that further multi-level analysis was not necessary. The results of ANCOVA testing of perceived efficacy, perceived consensus, and team orientation is presented below.

4.4.1. Perceived efficacy

Perceived efficacy of the IM methodology was assessed at post-test only. A one-way ANCOVA was used to assess the effects of prompting style (condition: task-level versus process-level) on perceived efficacy of the IM methodology, with trust analysed as a covariate. The ANCOVA revealed a significant main effect of condition, $F(1, 72) = 38.00, p < .001, \eta p^2 = .35, d = 1.51$, with higher perceived efficacy in the process-level prompt condition ($M = 24.38, SD = 2.71$) than in the task-level prompt condition ($M = 22.98, SD = 2.63$). No other effects were observed.

4.4.2. Perceived consensus

A 2 (condition: task-level versus process-level) x 2 (time: pre-intervention versus post-intervention) mixed ANCOVA was used to assess the effects of task-level versus process-level prompts on perceived consensus, with trust analysed as a covariate. The ANCOVA revealed a significant time x condition interaction, $F(1, 72) = 8.91, p = .004, \eta p^2 = .11, d = 0.83$, with a significant increase in perceived consensus in the process-level prompt condition from pre ($M = 18.06, SD = 2.22$) to post ($M = 20.54, SD = 2.55; t = 4.33, p < .01$) but not in the task-level prompt condition from pre ($M = 17.95, SD = 2.83$) to post ($M = 18.10, SD = 2.34; t = .18, p = .86$). The results also revealed a significant main effect of the covariate, trust, on perceived consensus, $F(1, 72) = 6.48, p = .01, \eta p^2 = .08, d = 0.82$, with higher trust associated with higher levels of perceived consensus.

Table 6. Means and standard deviations for perceived consensus

Condition	Time		Perceived Consensus
Task-level	Pre	<i>M</i>	17.95
		<i>SD</i>	2.83
	Post	<i>M</i>	18.10
		<i>SD</i>	2.34
Process-level	Pre	<i>M</i>	18.06
		<i>SD</i>	2.22
	Post	<i>M</i>	20.54
		<i>SD</i>	2.55

4.4.3. Objective consensus

Kendall's coefficient of concordance (Kendall's *W*) was used to measure concordance (i.e., agreement of ratings in relation to specific ISM paths of influence) within groups before and after the experimental manipulation. While there was a trend for objective consensus to increase in all groups, these differences were not statistically significant ($p > .05$ for both comparisons; see Table 7).

Table 7. *Objective consensus scores (Kendall's W)*

Condition	Pre	Post
Task-level	.23	.25
Process-level	.21	.23

4.4.4. Team orientation

A 2 (condition: task-level versus process-level) x 2 (time: pre-intervention versus post-intervention) mixed ANCOVA was used to assess the effects of task-level versus process-level prompts on team orientation, with trust analysed as a covariate. No significant findings were revealed. The ANCOVA revealed no time x condition interaction, $F(1,72) = 0.10$, $p = .75$, nor any effect of the covariate, trust, on perceived consensus, $F(1,72) = .03$, $p = .18$.

Table 8. *Means and standard deviations for team orientation*

Condition	Time	Team Orientation	
		<i>M</i>	<i>SD</i>
Task-level	Pre	<i>M</i>	70.78
		<i>SD</i>	3.64
	Post	<i>M</i>	71.00
		<i>SD</i>	3.31
Process-level	Pre	<i>M</i>	70.57
		<i>SD</i>	2.49
	Post	<i>M</i>	70.74
		<i>SD</i>	2.44

4.4.5. Variety and complexity of argumentation

A series of chi-squared tests were used to assess the statistical significance of differences in argumentation codes (as per the CACS) across prompting conditions. Of the 16 possible CACS argument codes which comprise the five argument categories, 12 were observed in the process-level prompt condition at least once, 8 were observed in the task-level prompt condition at least once, and 4 were not observed in any condition. Significant differences were observed across conditions for 3 argument codes, with higher frequency occurrence in the process-level prompt condition in each case, specifically, for *Propositions* ($\chi^2(1) = 6.27$, $p = .01$, $V = .11$, $d = 0.61$), *Amplifications* ($\chi^2(1) = 9.99$, $p = .002$, $V = .123$, $d = 0.76$), and *Challenges* ($\chi^2(1) = 7.45$, $p = .006$, $V = .12$, $d = 0.67$). In each of the remaining codes, with the exception of *Objections*, higher incidence was also observed in the process-level prompt condition than in the task-level prompt condition, however, these differences were not statistically significant. Descriptive data are presented in Figure 6.

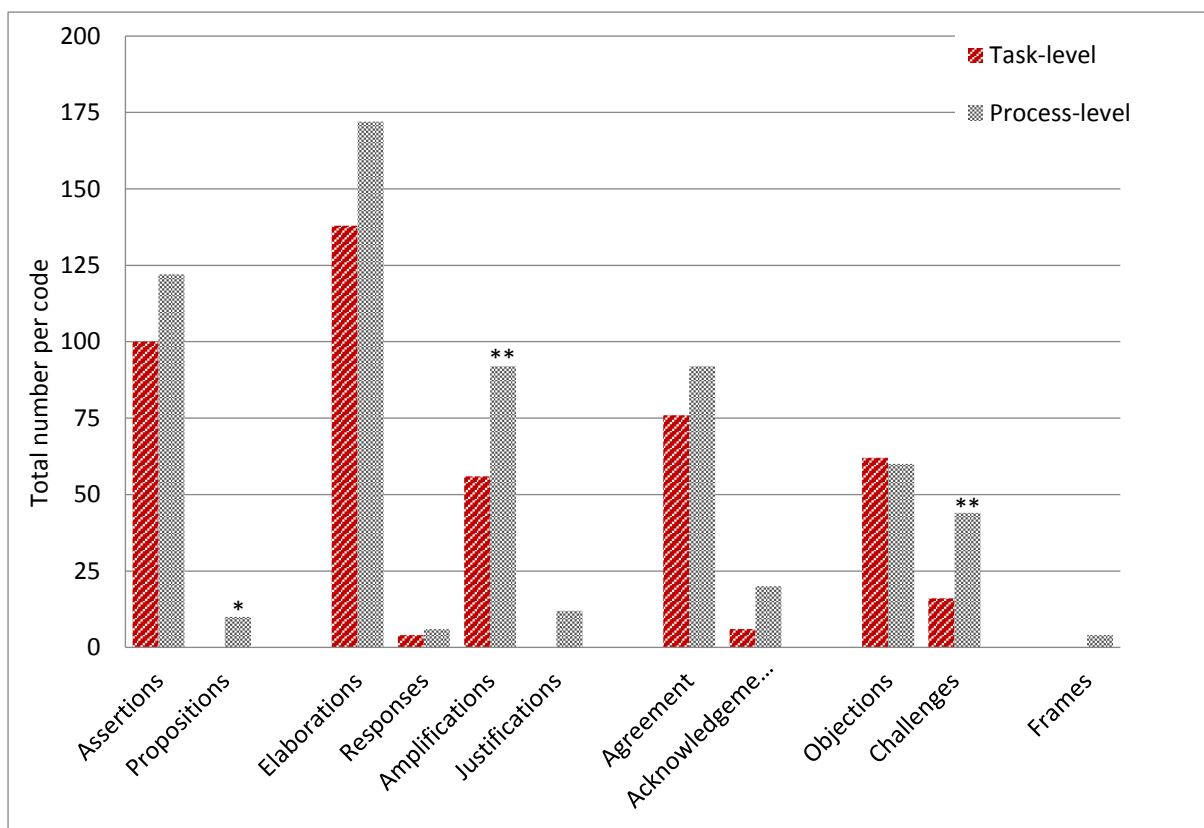


Figure 6. Incidence of CACS codes across prompting conditions

(Total of codes in task-level condition = 458; total of codes in process-level condition = 634;

* = significant at .05 level, ** = significant at 0.01 level)

Finally, analysis of the IM-generated problematques (see Figures 7-10), shows higher complexity of argument structures across conditions. The average complexity score for the problematques generated by the process-level prompt groups was 43. The average complexity score for the problematques generated by the task-level prompt groups was 35.5.

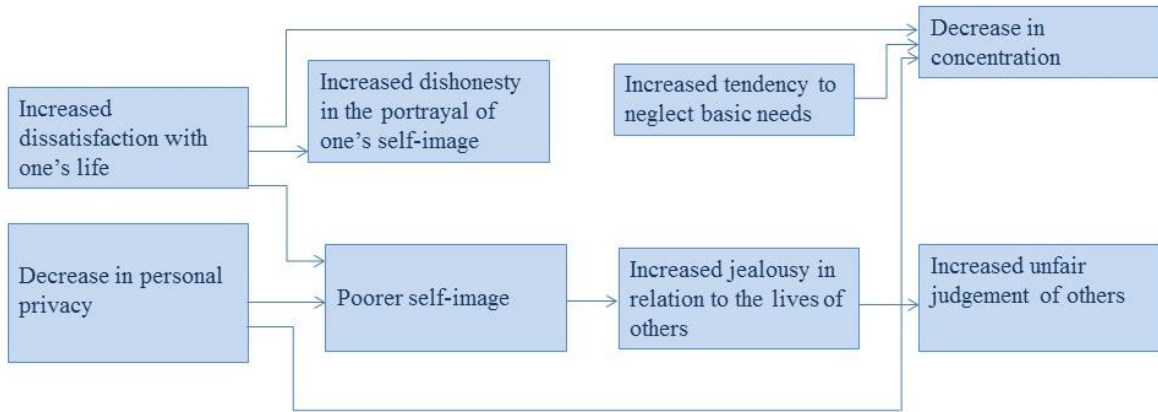


Figure 7. IM problematque generated in the process-level prompt condition

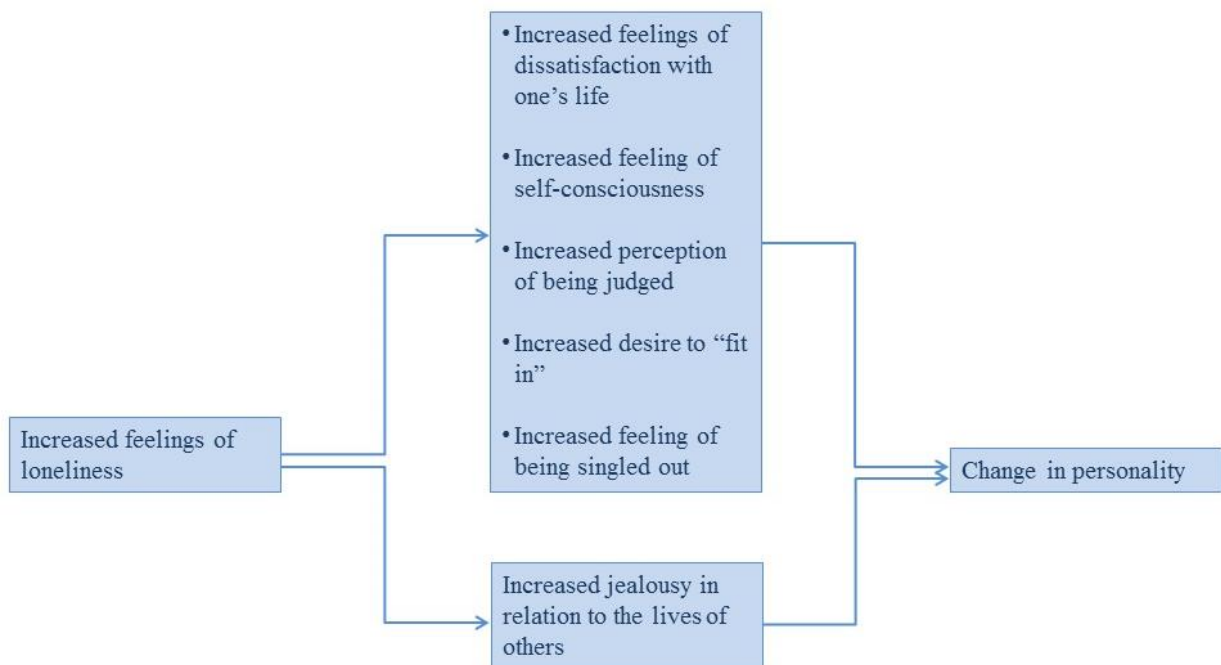


Figure 8. IM problematque generated in the process-level prompt condition

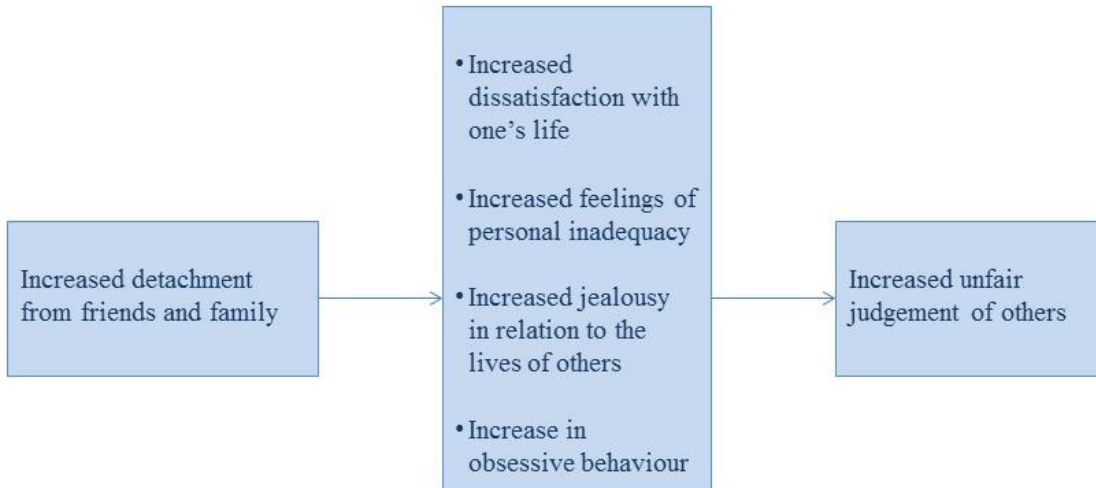


Figure 9. IM problematique generated in the task-level prompt condition

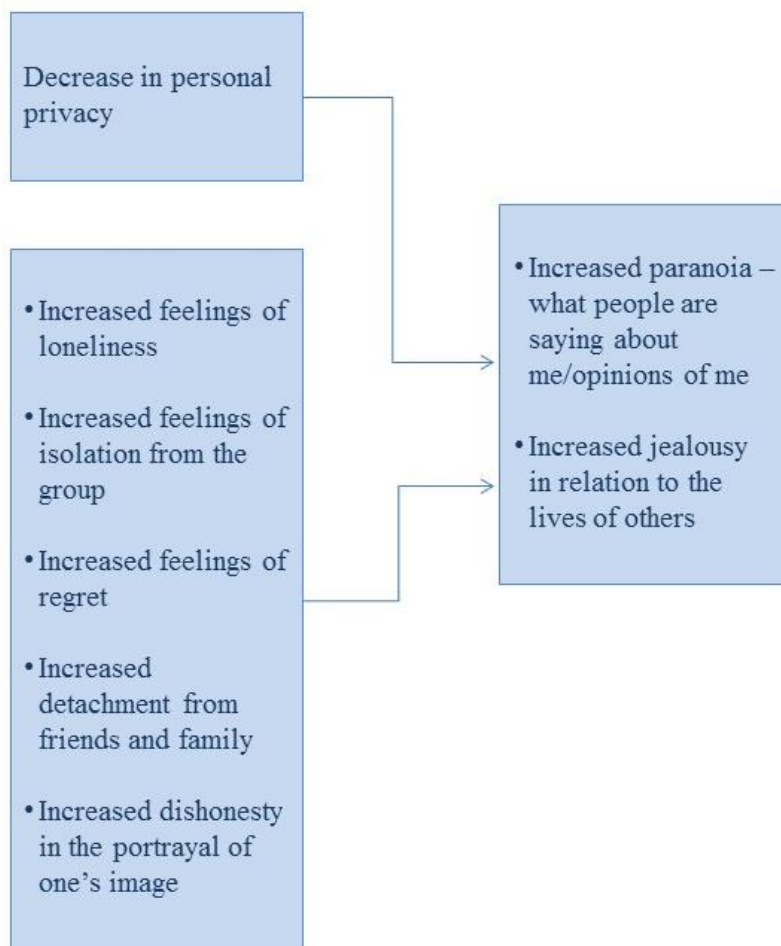


Figure 10. IM problematique generated in the task-level prompt condition

4.5. Discussion

Study 2 examined the effects of task-level versus process-level prompts on perceived consensus, objective consensus, perceived efficacy of the IM methodology, team orientation, variety and complexity of argumentation, in the context of an IM session. Results indicated that, compared to those in the task-level prompt condition, those in the process-level prompt condition reported higher levels of perceived consensus in response to the group design problem. Furthermore, those in the process-level prompt condition also reported higher levels of perceived efficacy of the IM methodology. No significant differences, however, were observed for either objective consensus or team orientation. Last, analysis of the dialogue from the IM sessions revealed that those in the process-level prompt condition exhibited higher levels of sophistication in their arguments, as revealed by their CACS scores and the complexity of their IM-generated problematques.

As noted in Study 1 (Chapter 3), achieving higher levels of consensus and promoting more coherent collective action was a core objective of John Warfield when he first developed the IM methodology (Warfield & Cardenas, 1994). Importantly, in the current study, while perceived consensus levels increased in both prompting conditions, only the increase in the process-level prompt condition was statistically significant. This suggests that while the IM method itself is effective in promoting consensus in a collaborative group, the role of the facilitator, and in particular the instructional support provided by the facilitator, has a significant impact on the consensus-building process. This increase in consensus in the process-level prompt condition is consistent with research on cognitive conflict and argumentativeness in consensus-building. Sambamurthy and Poole (1992), for example, found that confrontiveness in cognitive consensus - the extent to which groups addressed their differing perspectives during a decision-making process - was positively associated with levels of consensus. Similarly, Anderson and Martin (1999) found that argumentativeness - a person's willingness to argue issues with another - was positively associated with perceived consensus. Thus, it seems likely that process level prompts such as "What other questions can we raise about this idea?", may have made differing perspectives in the process-level group more salient, thereby opening channels for exploration and argumentation, and promoting the kind of cognitive conflict which ultimately contributes to perceptions of consensus. That the process-level condition demonstrated higher levels of challenges, supports this conclusion.

Furthermore, the observed link between higher trust and higher perceived consensus in the current study is consistent with previous research which suggests that trust can

influence critical social processes that may impact on levels of consensus in a collaborative group. As noted in Chapter 2, research suggests that trust is associated with increased quality of knowledge sharing (Chiu, Hsu, & Wang, 2006), and has been found to mediate the relationship between task conflict (also known as cognitive conflict) and relationship conflict (Simons & Peterson, 2000; Peterson & Behfar, 2003), with higher levels of trust buffering against the effects of relationship conflict and promoting cognitive conflict. These factors may have influenced the positive relationship between trust and perceived consensus in relation to the collaborative efforts of the group in the current study.

As noted previously, these results represent significant findings in relation to collaborative learning, and CSCL in particular, as higher levels of perceived consensus are likely to lead to higher levels of endorsement and engagement by the group in any action or response to a shared problem. For example, if a group feels strongly that there is a strong level of consensus in relation to the understanding and conception of a problem that they are working on together, they are more likely to be committed to, and satisfied with, any plan which comes from the newly-formed collaborative understanding (Mohammed & Ringseis, 2000).

It is noteworthy that, consistent with the results of Study 1, a significant increase in perceived consensus did not coincide with a significant increase in objective consensus. Again, it appears that while process-level prompting resulted in a greater sense of understanding and agreement among students, this was not reflected in their actual levels of agreement as measured using the likert scale index of agreement/disagreement across a subset of relational statements. The implications of one form of consensus being higher than the other are open to interpretation. However, it might be expected that, in the early stages of collaboration at least, it may be more beneficial to have high perceived consensus rather than objective consensus as groups are developing a sense of themselves as a cohesive group. Conversely, if objective consensus is high, but perceived consensus is low, this may suggest that although the level of objective agreement in the group is high, they may not be aware of this level of agreement, or do not feel that their interactions and discussions reflect such levels of agreement. As such, the group may not be optimally functioning in a way that reflects a cohesive pattern of openness and information sharing that fosters shared understanding. On the other hand, if perceived consensus is higher than objective consensus, it may be expected that the group would continue to openly share information and work toward shared understanding, as previous research suggests (e.g., Mohammed & Ringseis, 2001).

The effect of process-level prompts on perceived efficacy has further implications for CSCL. Results showed that, broadly speaking, participants across both prompting conditions found the computer-facilitated group design methodology to be a useful and valid method of mapping and structuring the interdependencies between problem relations. For example, on average, between 80 - 90% of participants across both conditions agreed or strongly agreed with the statement “*I believe that Interactive Management can be used to help a group achieve consensus about a problem*”. Importantly, however, those in the process-level prompt group reported significantly higher levels of perceived efficacy in relation to the IM process. Therefore, the prompts provided by the facilitator may be important for the overall success of the process, and for the level of support for the methodology by the group. This support for, or endorsement of, the methodology may be important in the context of efforts to sustain the ongoing use of a collaborative methodology as part a problem-solving strategy, adopted by students or other working groups.

It is also worth noting that, contrary to hypothesis 3, no effect of prompting on team orientation was observed. While previous research has found that levels of team orientation may be influenced by previous experiences of working in a group context, it may be that, despite students in the process-level condition reporting higher perceptions of consensus, and higher perceived efficacy of the IM methodology, in the short-time available for collaboration, this did not translate into a growth in team orientation. It is also possible that more explicit or direct interaction with group members or peers is needed for the cultivation of team orientation. In both the task-level and process-level prompt conditions, students’ attention was frequently directed to the facilitator, who delivered the prompts and directed their attention to various components of the task. Thus, students may not have spent enough time, in either condition, working directly with their peers, to foster a greater sense of team orientation.

4.5.1. Variety and complexity of argumentation

With regard to the types of argumentation coded by reference to the CACS coding system, overall, reasoning activities accounted for 37% of coded utterances, generative mechanisms accounted for 20%, disagreement-relevant intrusions accounted for 15%, convergence-seeking activities accounted for 14% and delimiters accounted for only 0.5%. The remaining 13.5% of coded utterances were nonarguable. This suggests that the argumentation across groups was reasonably complex, as the arguments did not rely heavily on generative mechanisms (assertions and propositions) as is typically the case in simple argumentation

(Canary, Brossmann, & Siebold, 1987). While these figures suggest that, in general, the argumentation was reasonably complex, the results of the CACS analysis in MEPA showed that the process-level prompt condition displayed higher levels of argument sophistication. In addition, when compared with those in the task-level prompt group, participants in the process-level prompt condition demonstrated significantly more frequent usage of propositions, amplifications and challenges. This suggests that the process-level prompt condition was engaging at a higher-level with the claims presented during the IM structuring work, and made more effective moves towards reaching a level of understanding and consensus within the group prior to voting. For example, while elaborations (i.e., statements that support other statements by providing evidence, reasons or other support e.g., “*Because of peer pressure, you know, people trying to get you to do things*”) were similarly evident in both groups, amplifications (i.e., statements that explain or expound upon other statements to establish the relevance of an argument through inference e.g., “*I think they are related because change in personality would be more, kind of, self-conscious I suppose, but not perception of being judged.*”) were observed more often in the process-level prompt condition. In this way, those in the process-level prompt condition were moving beyond accumulation of evidence and support in their reasoning activity - they were working further to establish how this reasoning relates to the problem at hand, and more specifically the relevance of their reasoning.

Similarly, while the frequency of objections (i.e., statements that deny the truth or accuracy of an arguable e.g., “*No, I think it would be the other way around*”) were almost identical across the two prompt conditions, challenges (i.e., statements that offer problems or questions that must be solved if agreement is to be secured on an arguable e.g., “*Well it kind of depends, on whether your self-consciousness affects your ability to socialise*”) occurred more often in the process-level prompt condition. This suggests that those in the process-level prompt condition engaged more critically with the information at hand, and engaged in more productive argumentation.

Finally, of the 16 types of argument codes which comprise the CACS, 12 were observed at least once in the process-level prompt condition, whereas only 8 were observed at least once in the task-level prompt condition, again highlighting the greater diversity and variation of argumentation demonstrated by the process-level prompt groups.

4.5.2. Systems-model complexity

In the current study, the students were tasked with developing a consensus-based model of the negative consequences of online social media usage. The process of model building involved the generation of ideas in relation to the problem, rank-ordering and voting on the most critical ideas, and discussion and decision-making regarding the interdependencies between these ideas. Overall, when examining the relational complexity of the models or structural hypotheses generated by students, the current study revealed that those in the process-level prompt condition arrived at a more complex, consensus-based understanding of the relations between the negative consequences of online social media usage. While each group began with the same initial set of ideas, added an almost equivalent number of additional ideas, and ultimately structured the same number of ideas during the model building process, the results of the groups' collaborative efforts differed in important ways. A closer look at the models or problematiques generated by groups reveals variations in complexity, which are in line with the varying degrees of argument complexity measured by the CACS. For example, while "decrease in personal privacy" appears as a primary driver in two of the problematiques (that is, there is one in each prompt condition, see Figures 7 and 10), the paths of influence stemming from this idea are more elaborate in the process-level prompt condition (see Figure 8). In both the task-level prompt and process-level prompt models referred to above, "decrease in personal privacy" had a significant aggravating effect on "increased jealousy in relation to the lives of others". However, in the process-level prompt condition, this path of influence is mediated by "poorer self-image". This suggests that the process-level prompt groups, through more complex and varied argumentation and exploration, further developed this relationship, and reached a consensus on a potential mediating factor. The additional complexity in these problematiques is consistent with, and representative of, the statistically significant differences in the prevalence of more complex and varied CACS codes. In other words, the consequence of different patterns of argumentation is reflected in the models generated by the groups. Crucially, when taken alongside the finding that students in the process-level prompt condition reported higher levels of consensus and perceived efficacy of the IM methodology, this suggests that the use of effective process-level prompting not only enhances the quality of students' interactions with the CSCL tool, but may also their positive perceptions of this interaction.

4.5.3. Limitations and future research

In relation to argumentation, it must be noted that the IM sessions were conducted in an educational environment, with discussions focused on a problem that may not have been considered critical to the participants. Despite the fact that many CACS studies have adopted a similar approach (e.g., Beck et al., 2012), the nature of the problem selected may have had an effect on the nature and level of complexity of argumentation in each group. Future research should examine the effects of prompting and facilitation in a variety of real-world problem-solving and decision-making contexts with groups that are working to resolve more critical problems that impinge upon their adaptive success as a group. Students in the current study however, did appear to engage with the topic in a way that reflected their interest in the personal and social consequences of social media usage.

Second, the groups in this study consisted of between 17 and 20 participants. These groups may be considered to be quite large relative to other collaborative learning groups. However, the group size is consistent with standard IM procedure, with groups typically consisting of 12 to 20 participants. Also, the size of the group is consistent with tutorial class sizes in the National University of Ireland, Galway. As such, the group size reflects a classic IM systems model-building session and contributes to the ecological validity of the findings, which demonstrate that students in classic tutorial size groups can work collaboratively to develop systems models in relation to complex problems. It is possible however, that variations in group size may influence collaborative dynamics and the effects of prompts and facilitation on group deliberation and decision-making. Future research should attempt to replicate these effects using a combination of both smaller groups and larger groups in the same experiment, that is, to test directly for the effects of group size on outcomes.

Third, there was a gender imbalance in the sample of this study with a ratio of approximately 3:2 females to males. This is a common sampling issue in university samples, particularly with regard to psychology-based research (Skinner & Louw, 2009). In relation to the results of this study, while some research has found that, in CSCL settings, females are more likely to qualify and justify their assertions (Fahy, 2003, Smith, McLaughlin & Osbourne, 1997) whereas males tend to assert opinions as facts (Fahy, 2002), other studies (e.g., Ding & Harskamp, 2009), have found that gender differences are diminished when hints (i.e., prompts) are provided.

Fourth, while the topic of the potential negative consequences of social media was chosen as the focus of the IM sessions as it represents a topic which may be problematized,

but yet has no clear answer and thus allows for open discussion of various perspectives and viewpoints, it is possible that this topic was more or less salient or relevant for some participants than others. As participants' level of interest in, or motivation to discuss, the topic was not measured, it is possible that this may have impacted upon the discussion within groups. While this concern may be countered by the fact that participants signed up to participate in this study knowing that it would involve discussion of this topic, and thus was likely of interest to them, it remains a potential limitation.

4.6. Conclusion

While the importance of good facilitation is often highlighted by expert facilitators (e.g., Hmelo-Silver, 2002), the current study provides one of the first experimental demonstrations of the effects of facilitator prompt style on outcomes in the application of IM. The results of this study suggest that adequate facilitation, in particular the use of process-level prompts to support reflection and deliberation, plays a vital role in the outcomes of collaborative argumentation in CSCL. The positive effect of process-level prompting was evidenced by the supporting and enhancing levels of consensus, by the harnessing of a positive sense of perceived efficacy of the IM methodology, and by supporting productive, varied, and complex forms of argumentation. These results are consistent with the views of Pea (2004), and Strijbos, Kirschner, and Marten (2004), who highlight that in order to cultivate successful collaborative learning, attention must be paid to the design of the collaborative environment, including the provision of scaffolding, and instructional support by the facilitator, as well as other studies which have reported positive effects of prompting in other collaborative learning scenarios (e.g., Chiu, 2004; Gillies, 2004; Graesser et al., 1993; King, 1990; Veerman et al., 2002; Webb et al., 2008; Webb, 2009; Yiong-Hwee & Churchill, 2007). Furthermore, when considered alongside research findings suggesting that teams may not operate at optimal levels on their own, or that they may fail to achieve and sustain quality interactions (Dickinson & McIntyre, 1997; Rummel & Spada, 2005), the results of the current study highlight the importance of effective facilitation and instruction in CSCL settings for a variety of outcomes. In order to optimise the power and efficacy of CSCL, it is necessary to both create the optimal conditions for key social processes such as consensus, and to provide the right support and framework for effectively harnessing a groups' collaborative efforts.

4.7. Implications for the next study

The results presented in this study, which suggest that process-level prompting can be used to enhance collaborative argumentation in the classroom, are promising. However, consideration of these results alongside the growth of peer learning as a pedagogical approach (e.g., Cho & MacArthur, 2010; Prins et al., 2006; Yang et al., 2006), and research reporting the efficacy of peer-to-peer prompting in collaborative writing tasks (Hattie & Gan, 2014), suggests that the use of prompts for enhancing collaborative argumentation in the context of peer learning represents a potentially important avenue for future research. This line of enquiry is further supported by research which reports that teacher-dominated discourse continues to be prevalent in classrooms and, more crucially, that this approach often limits student learning opportunities and outcomes (Alexander, 2004; Cazden, 2001; Lemke, 1990; Nystrand, Wu, Gamorgan, Zeiser, & Long, 2003; Strayer, 2012). With this in mind, Study 3 (Chapter 5) seeks to further explore the role of prompts on learning outcomes, by investigating the effects of facilitator-driven versus peer-to-peer prompts, on the style and complexity of students' argumentation in a collaborative systems model-building task, as well on key social-emotional processes.

Chapter 5 - Study 3: Investigating the effects of facilitator-driven versus peer-to-peer prompts in collaborative argumentation

Note: an earlier version of this chapter was published in *ijCSCL*:

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5.1. Chapter overview

Study 2 reported that process-level prompting may be used to support collaborative argumentation in the classroom. Study 3 seeks to extend these results by investigating the effects of prompts in the context of peer learning. In a society which is calling for more productive modes of collaboration to address increasingly complex scientific and social issues, greater involvement of students in dialogue, and increased emphasis on collaborative discourse and argumentation, become essential modes of engagement and learning. As such, Study 3 investigates the effects of facilitator-driven versus peer-to-peer prompts on the variety and complexity of argumentation in a collaborative systems model-building task. Furthermore, building upon the results of Studies 1 and 2, Study 3 also investigates the effects of this prompting manipulation on levels of perceived and objective consensus, perceived efficacy, and team orientation, while introducing the additional measure of discomfort in group learning.

5.2. Introduction

As noted in Chapter 2 Section 2.5., peer learning, as a unique form of collaborative learning, involves “the acquisition of knowledge and skill through active helping and supporting among status equals or matched companions” (Topping, 2005, p. 631). The literature on peer learning includes a variety of terminologies, approaches and methodologies including peer assessment (van Gennip, Segers, & Tillema, 2010), peer feedback (Gielen, et al., 2010a) and peer revision (Cho & MacArthur, 2010). Peer assessment refers to a combination of peer learning behaviours and can include collaborative development of criteria for student success, peer discussion of learning and task completion strategies, peer reading, and peer feedback. Peer revision can involve a subset of these learning behaviours, with a primary focus on revision of previous work with the aim of improving quality. Peer feedback includes

behaviours which peers engage in to provide insight or input on the performance of a peer on a given task, and may include strategies such as prompting and question asking. Kollar & Fischer (2010) argue that while these various terminologies, approaches and methodologies of peer learning may refer to different sub-processes, the central activity focus remain conceptually similar, reflecting one pedagogical approach, falling under the broader approach of peer learning.

As highlighted in Chapter 2 Section 2.5.1., numerous studies have compared the effects of peer learning versus teacher-driven learning, reporting that peer learning can be equally as effective (e.g., Cho & Schunn, 2007; Gielen et al., 2010b) or can provide additional benefits (e.g., Cho & MacArthur, 2010; Cho & MacArthur, 2011; Hartberg et al., 2008; Prins et al., 2006; Yang et al., 2006). Cho and MacArthur (2011) for example, reported on the benefits of students giving peer feedback, such that engaging in the provision of peer feedback enhanced student's own writing ability. In this study, 61 undergraduate students were assigned to one of three conditions: reviewing, reading, or a control condition. In the reviewing condition, students rated and commented on a peer's written paper. In the reading condition, students read a peer's paper but did not comment. In the control condition, students did not review or read another student's paper. The results of this study revealed that students in the reviewing condition outperformed all other groups on a subsequent writing task which involved writing a report on a new topic. Notably, further analysis of the nature of comments provided by students in the reviewing condition, revealed that comments coded as *problem detection* and *solution suggestion* were correlated positively with the quality of writing displayed by students in the reviewing condition. As such, the author suggest that these results are consistent with previous findings highlighting the benefits of providing explanations (e.g., Webb, 2009; Webb et al., 2008) as students in the reviewing condition not only rated their peer's work, but provided comments which explained both problems in their work, and potential solutions.

The findings of such studies indicate the potential of peer learning as a pedagogical approach. However, significant gaps in the peer learning literature remain. For example, the majority of studies have focused on investigating the effects of peer learning on written tasks (e.g., Cho & Schunn, 2007; Cho & MacArthur, 2010; Cho & MacArthur, 2011, Gielen et al., 2010a; Hartberg et al., 2008; Patchan, Schunn, & Correnti, 2016; Novacovich, 2016). The effects of peer learning approaches in the context of collaborative argumentation, or more broadly in computer-supported problem-solving, are not well understood. It is necessary

therefore, to investigate whether or not peer learning strategies, including the use of peer-to-peer prompts, can also be effective in the context of dialogue-based collaborative tasks.

One approach to understanding the benefits of peer learning and peer feedback is investigating the collaborative dialogue (i.e., the interactive talk) between peers in the classroom (e.g., O'Donnell, 2006; O'Donnell & King, 1998; Nussbaum, 2008). Webb et al. (2008) found that the prevalence and development of explanations among students in collaborative groups predicted individual learning in mathematics, with the highest growth observed in students who generated more explanations in exchanges with peers. This is consistent with research conducted by Chinn, O'Donnell and Jinks (2000), who found that more complex explanations given by students working in small groups correlated with individual learning gains. In a recent review of collaborative discourse and argumentation, Nussbaum (2008, p. 345) coined the term "critical, elaborative discourse", which emphasises the importance of students' "considering different viewpoints" and "generating connections among ideas and between ideas and prior knowledge". As such, peers can provide feedback to each other through such elaborations and purposeful discussions. In this way, they are not merely providers of correct or incorrect feedback, they can interpret the usefulness of feedback, and they can deliver feedback in turn based on these interpretations.

It must be noted, however, that not all students provide such elaborations or quality feedback (Lockhart & Ng, 1995; Strijbos, Narciss, & Dünnebier, 2010). Generally, the more able, more committed, and more vocal students provide greater elaboration and critical feedback and thus, are more advantaged in peer interactions. This suggests that it is crucial that teachers demonstrate, facilitate, and cultivate these skills. In practice, this may involve providing specific interventions, including instructional support designed to ensure all students can benefit from peer interactions.

There can also, however, be resistance to the implementation of peer feedback in the classroom. Reservations about the use of peer feedback often relate to concerns about the reliability of students' grading or marking of peers' work, power relations among peers and with teachers, and social loafing (Gan, 2011). As a result, efforts are often made to train or support students in their delivery of feedback. This can be done in various ways, including ensuring that peer feedback is clearly integrated into a lesson, or providing feedback guides or rubrics to the students to help them in their provision of feedback (Cho & MacArthur, 2010; Lundstrom & Baker, 2009; Min, 2005; Prins et al., 2006; Rollinson, 2005; Zhu, 1995). In this context, the facilitator is providing metafeedback, which empowers students to engage in peer learning processes (Prins et al., 2005). However, teachers cannot be expected to

intuitively understand and design the delivery of guidance and instruction for peer learning in various scenarios, and further research is needed to support the development of teacher practice in this regard. While research in the area of peer learning focused on written tasks is well advanced, more research is needed to ascertain the benefits of peer learning for other forms of collaboration, including collaborative discourse and argumentation.

5.2.1. Instructional support for peer learning

In studies of peer feedback, Prins et al. (2006) suggested that “feedback instruments such as performance scoring rubrics with criteria, or structured feedback forms that force feedback providers to ask reflective questions and give suggestions for improvement, could be valuable instruments for increasing the quality of the peer feedback” (p. 300). However, as noted above, one of the primary reasons for resistance to adopting peer feedback approaches in the classroom relates to concerns regarding the quality of feedback provided by peers, which may be perceived as lacking in quality and depth of content (Gan, 2011). This may be exacerbated by ineffective feedback interactions between the feedback provider and the feedback receiver (Prins et al., 2006). A common cause of poor peer feedback quality is a lack of information and skills concerning how to provide, receive, and use peer feedback. Crucially, however, this problem can be overcome through the use of instructional support, which may take the form of facilitation tools such as guiding sheets with prompts, peer review sheets with criteria, and graphic organisers. For example, Gan (2011) provided students with a graphic organiser, informed by the framework developed by Hattie and Timperley (2007) to help them to provide feedback to each other. In one condition, second-level chemistry students were taught to use a graphic organiser with prompts to formulate feedback to their peers, while students in a control condition received instruction about chemistry investigation skills, but no training in the delivery of peer feedback. Results revealed that students who were instructed in the use of the graphic organiser formulated higher quality written peer feedback.

Similarly, in a study also informed by Hattie and Timperley (2007), Gielen and De Wever (2015) provided students with one of three levels of structural support for peer feedback on a written task. These levels of structure were: 1) a peer feedback template alone, which addressed key components of the written task; 2) a peer feedback template plus basic structure, which consisted of two additional questions designed to prompt feedback and feed forward (“What was good about your peers’ work?”, and “What would you change in your peers’ work?”); or 3) a peer feedback template plus elaborate structure, in which students received a feedback template which was divided into sections for feed up, feedback, and feed

forward (Hattie & Timperley, 2007), with the criteria again listed in each section. This study took place over three feedback cycles, during which students wrote and received feedback on an abstract, which was the focus of their written task. The results of this study found that, while peer feedback improved significantly in all conditions, students in the elaborate condition displayed significantly greater increases in peer feedback quality when compared with both the template only, and the template plus basic structure conditions. As such, these results are consistent with the work of Gan (2011) in that they suggest that additional instructional and structural support, beyond the provision of a feedback template alone, is necessary for optimal peer feedback delivery by students.

Peer feedback interventions can also take the form of explicit training. Sluijsmans et al. (2002), for example, conducted a study of the effects of peer assessment training on the performance of student teachers (N = 93). This intervention involved defining performance criteria, giving feedback, and writing assessment reports. Results of this study showed that students in the experimental group, i.e. those who received training in feedback, outperformed students in the control group in terms of quality of assessment skills, as well as across the end products of the course. Specifically, students in the experimental group were more likely to use the performance criteria and to provide more constructive comments (i.e., specific, direct, accurate, achievable, practicable, and comprehensible comments) to peers than the students in the control group. This study provides further evidence that training in peer feedback skills positively affects students' ability to provide peer feedback.

Feedback skills can also be developed through demonstration and simulation. van Steendam et al., (2010), for example, found that training students through modelling of peer feedback behaviour followed by emulation of this behaviour, led to more correct and explicit feedback when evaluating a peer's text. In this study, which consisted of 247 university students who were learning English as a foreign language, compared two methods of instruction (observation versus practising) and two methods of emulation (dyadic versus individual), on quality of peer feedback in a writing revision task. Students were assigned to one of four groups: observation-dyadic (OD), observation-individual (OI), practising-dyadic (PD), and practising-individual (PI). In the observation condition, students observed a video of two experts engaged in dyadic peer feedback interaction. The peers in the video identified higher order problems with the written text, reflected on those problems, and suggested strategies for revision. In the practising condition, students worked in pairs, using the same revision strategy and criteria from the video, and the same sample text. They were also presented with the same model answers as presented in the video. Thus, the instructed content

was the same in both conditions, but the method of instruction (observing or practising) was different. In both conditions, this stage was followed by emulation, during which students took part in an exercise in applying the feedback criteria, either in dyads or individually. Quality of peer feedback was assessed by (a) detection of errors, (b) quality of corrective feedback applied to these errors – such as additional information, removal of errors, or reordering of information, and (c) quality of comments provided on the peer’s work, including the exhaustiveness and explicitness or specificity of the comments. The results of this study found that dyadic emulation (that is, peer feedback at post-test) was most productive when it was preceded by observation. That is, peers were better able to deliver feedback on their peer’s work when they had observed the experts modelling the behaviours first, than when they had practised the behaviours without this modelling. Notably, this was not the case for the individual emulation of feedback at post-test. In that case, emulation of the criteria was equally effective whether it was preceded by observation or practice. This suggests that learning to deliver peer feedback may require a different kind of instructional support than the provision of individual feedback, to model the interactions which occur during the process. As such, in the peer-to-peer prompting condition in this study, the peer-to-peer prompting process was first modelled by the instructor, before the role of prompting was passed over to the peers themselves.

Overall, as highlighted in Chapter 2 Section 2.4.3., the efficacy of scaffolding by means of prompts and higher order questions is well-founded (e.g., King, 1990; King, et al., 1998; Yiong-Hwee & Churchill, 2007; van Steendam et al., 2010; Veerman et al., 2002). Furthermore, the research presented above suggests that, with the correct instructional support such as graphic organisers, training, or observation and modelling, peers can effectively deliver such prompts or questions (Gan, 2011; Sluijsmans et al., 2002). Building on this line of research, the current study used a graphic organiser, as well as modelling of peer-to-peer prompting by the facilitator, to support peer-to-peer prompting in groups of students in a collaborative systems model-building task using the IM methodology. The graphic organiser and the specific prompts modelled by the facilitators were comprised of prompts adapted from Hattie and Gan (2011). Based on the research described above, reporting benefits of peer feedback over teacher-driven feedback in written tasks (e.g., Cho & MacArthur, 2010; Cho & MacArthur, 2011; Hartberg et al., 2008) and research showing that students, when provided with instructional support, can effectively deliver peer prompts (e.g., Gan, 2011; Sluijsmans et al., 2002), it was hypothesised that peer-to-peer prompts, rather

than facilitator-driven prompts, would result in more varied and complex argumentation in the context of a collaborative systems model-building task.

5.2.2. Social psychological factors in collaborative settings

Consistent with Studies 1 and 2, Study 3 also includes measures of key social variables and outcomes in the context of collaboration. As was reported in Study 2, the type of facilitation provided by the instructor (task-level versus process-level prompts) had an impact on levels of perceived consensus, and perceived efficacy of the IM methodology, while no effects were found for objective consensus or team orientation. As this study introduces a new component to the collaborative systems model-building task (i.e., the addition of a peer-to-peer prompting condition) each of these variables warrants further investigation. For example, based on the results of Study 1 and Study 2, and the literature reviewed in Chapter 2 Section 2.6, is expected that facilitator-driven versus peer-to-peer prompting may have different effects on consensus, perceived efficacy, and team orientation. More specifically, consistent with research reporting significant associations between both cognitive conflict and argumentativeness, and levels of consensus (Anderson & Martin, 1999; Sambamurthy & Poole, 1992), Study 2 found that process-level feedback, which facilitated greater depth of engagement and questioning, produced higher levels of perceived consensus. However, effects of peer-to-peer prompting versus facilitator-driven prompting have not been previously investigated. Given that previous research has found that peers can effectively deliver peer-to-peer prompts or questions (Gan, 2011; Sluijsmans et al., 2002), and research showing that peer comments may be rated as more useful than expert comments (Cho et al., 2008), the effects of facilitator-driven prompting versus peer-to-peer prompting on consensus (both perceived and objective) warrants investigation. More specifically, given previous findings which suggest that groups who question each other's suggestions, accept legitimate suggestions and incorporate other's viewpoints into their own perspective achieve higher levels of consensus (Mohammed & Ringseis, 2001), it is hypothesised that peer-to-peer prompting will result in higher levels of perceived and objective consensus than facilitator-driven prompting.

In addition, and building upon the results of Studies 1 and 2, levels of perceived efficacy of the IM methodology requires additional examination, given that this study introduces a new element to the process, peer learning. While the process-level prompting condition in Study 2, for example, resulted in higher levels of perceived efficacy, it remains to be seen whether facilitator-driven prompting, or peer-to-peer prompting, impacts on

student's perceptions of the process. Notably, previous research, as described in Chapter 2, has highlighted the role of the instructor as a key factor in student's perceptions of teaching using educational technology (e.g., Liaw et al., 2007; Volery & Lord, 2000). The effect on perceived efficacy when reducing the role of the instructor in the process then, remains unclear. However, in the case of Volery and Lord's (2000) research, one of the key facilitator behaviours which impacted on students' perceptions related to the role of encouraging student interaction. As such, while the role of the instructor, previously found to be influential in students' perceptions of learning, is less-central in the peer-to-peer prompting condition, their role in facilitating student interaction, by encouraging and providing an environment for peer learning, may be beneficial in supporting perceptions of efficacy in student groups, particularly if students are empowered to provide effective prompts. As such, it is hypothesised that, compared to facilitator-driven prompting, peer-to-peer prompting will result in higher levels of perceived efficacy of the IM methodology.

While levels of consensus and perceived efficacy are important outcomes in the context of collaborative learning, it is also necessary to consider variables relating to teamwork. With this in mind, and consistent with Study 2, the current study also measured levels of team orientation both before and after the IM session. While no significant increase in team orientation was reported between prompting conditions in Study 2, the peer learning context may provide a more conducive environment for the cultivation of team orientation. According to a review by Boud et al. (2001), peer learning promotes team-skills such as working with others, and communication. In contrast to collaborative learning more broadly, peer learning, as a form of collaborative learning, emphasises more directly a participatory culture of learning (Kollar & Fischer, 2010), explicitly requiring peers to interact with each other in a constructive manner, via peer prompting, feedback, assessment or other forms of engagement. In other words, peer learning involves a greater focus on learning *from* one another, as opposed to *alongside* one another. Similarly, Study 3 also includes a measure of discomfort in group learning, which was not included in Studies 1 or 2. While high levels of team orientation are desirable in group learning contexts, it is not uncommon for students to be averse to group work, with many students reporting the experience to be discomfiting (Cantwell & Andrews, 2002). Such negative attitudes towards group work can have negative consequences for learning (Volet & Mansfield, 2006). As such, it is important to consider the impact that various types of interactions can have on individual students engaged in the process, and whether or not certain kinds of facilitation or prompting can be used to reduce levels of discomfort in the collaborative learning environment. Based on the available

research, it is hypothesised in the current study that peer-to-peer prompting will result in higher levels of team orientation and lower levels of discomfort in group learning.

Finally, as in Studies 1 and 2, Study 3 includes a measure of trust. Given the research described in Chapter 2 Section 2.6.5., including findings that trust is associated with supporting knowledge sharing (Chiu, et al., 2006), motivation to work and group satisfaction, (Ennen et al., 2015) and moderating the relationship between task conflict and relationship conflict (Simmons & Peterson, 2000), as well as the findings in relation to trust in Studies 1 and 2, trust was included for further investigation in Study 3.

5.2.3. The current study

The current study investigates the effects of facilitator versus peer prompts on perceived and objective consensus, perceived efficacy, discomfort in group learning, team orientation, variety and complexity of argumentation, and collaborative systems model complexity in the context of an IM session. In light of the evidence reviewed above, it was hypothesised that peer-to-peer versus facilitator-driven prompting during collaborative dialogue and argumentation is a critical factor in shaping key outcomes of collaborative learning. Specifically, it was hypothesised that:

1. Peer-to-peer prompts will produce higher levels of perceived and objective consensus.
2. Peer-to-peer prompts will produce higher levels of perceived efficacy of the IM methodology.
3. Peer-to-peer prompts will produce higher levels of team orientation.
4. Peer-to-peer prompts will produce lower levels of discomfort towards group learning.
5. Peer-to-peer prompts will produce more varied and complex forms of argumentation.
6. Peer-to-peer prompts will result in the development of more complex systems models.

5.3. Method

5.3.1. Design

A one-way ANCOVA was used to assess the effects of prompting style (facilitator-driven versus peer-to-peer) on perceived efficacy of the IM methodology, with the effects of trust

analysed as a covariate. A series of three 2 (condition: facilitator-driven versus peer-to-peer) x 2 (time: pre-intervention versus post-intervention) mixed ANCOVAs were used to assess the effects of facilitator-driven versus peer-to-peer prompts on perceived consensus, team orientation, and discomfort in group learning, with trust analysed as a covariate. A coefficient of concordance test was used to assess the statistical significance of differences in objective consensus across conditions before and after the experimental manipulation (i.e., differences in Kendall's W). A series of chi-squared tests were used to examine frequency differences in argumentation codes across prompting conditions using the CACS coding system. Last, complexity scores were calculated for each of the problematques across conditions, to analyse complexity of IM systems models.

A priori sample size calculations were conducted using G*Power. Based on effect sizes for peer tutoring reported in an extensive meta-analysis of different educational factors (Hattie, 2009) a Cohen's d of 0.40 was used to calculate an appropriate sample size for the current study. This calculation suggested a minimum sample size of 64 was required to yield adequate power at a desired power level of 0.8 and a probability level of 0.05. Given the inherent difficulties in recruiting groups of students for research participation, the decision was made to aim for approximately 50% above this minimum required sample size.

5.3.2. *Participants*

Participants were first year psychology students ($N = 101$) comprising 45 males and 56 females, aged between 17 and 31 years ($M = 20.7$, $SD = 4.5$), from the National University of Ireland, Galway. Participants were offered research participation credits in exchange for their participation. Participants were recruited via an online research participation platform within the university. Eight groups of 10-14 participants, matched in terms of both mean and variance on the trust scale, were assigned at random to either the facilitator-driven or peer-to-peer condition.

5.3.3. *Measures and materials*

Trust. The same trust measure as used in Study 1 and Study 2 was used in the current study. The scale had good internal consistency in the current study ($\alpha = .75$).

Perceived efficacy. The same measure of perceived efficacy of the IM methodology as used in Study 1 and Study 2 was used in the current study. The scale had good internal consistency ($\alpha = .70$).

Perceived consensus. The same method of measuring perceived consensus as used in Study 1 and Study 2 was used in the current study. The scale had good internal consistency ($\alpha = .75$).

Objective consensus. The same method of measuring objective consensus as used in Study 1 and Study 2 was used in the current study.

Team orientation. The same measure of team orientation as used in Study 1 and Study 2 was used in the current study. The scale had good internal consistency ($\alpha = .82$).

Discomfort in group learning. Discomfort in group learning was measured using the scale developed by Cantwell and Andrews (2002). The discomfort in group learning scale is one of three components of the Feelings Towards Group Work (FTGW) scale (Cantwell & Andrews, 2002). The other two components of the FTGW scale, preference for individual work and preference for group work, were not included due to their high levels of similarity to items on the Team Orientation scale. Discomfort in group learning however, was deemed sufficiently distinct to warrant inclusion. The scale had good internal consistency ($\alpha = .76$).

Variety and complexity of argument. Variety and complexity of argument, as in Study 2, was measured using the CACS. Table 9 below presents a sample of utterances for each code (where present in the transcriptions from the study). As in Study 2, MEPA was used to facilitate the CACS analysis. Cohen's κ was run to determine the level of agreement between coders. There was strong agreement between the two coders, $\kappa = .89, p < .005$.

Table 9. *Conversational argument coding scheme and examples from Study 3*

Code	Example from transcript
I. Arguables	
A. Generative mechanisms	
1. Assertions: Statements of fact or opinion	“I think yes on that one”
2. Propositions: Statements that call for support, action, or conference on an argument-related statement	“Well for good collaborative learning, wouldn't you want to be part of the team?”
B. Reasoning activities	
3. Elaborations: Statements that support other statements by providing evidence, reasons, or other supports	“..I think that if I am motivated to be part of the team, then I will want to know each individual's ability because if I know what they are able to do we can perform better”
4. Responses: Statements that defend arguables met with disagreement	“But your motivation might stop depending on the criticism you receive, do you know?”

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|---|---|
| 5. Amplifications: Statements that explain or expound upon other statements to establish the relevance of the argument through inference | “Ok, say coming in here today, I’m motivated to come in and do all of the work as part of a team, but that doesn’t mean that say, with <i>participant 5</i> that if he had more information than <i>participant 10</i> that I would necessarily recognise that” |
| 6. Justifications: Statements that offer validity of previous or upcoming statements by citing a rule of logic (provide a standard whereby arguments are weighed) | “But like I said earlier, you’re not motivated by other people’s ability, it’s up to them if they want to pull their weight” |

II. Convergence-seeking activities

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|---|---|
| 7. Agreement: Statements that express agreement with another statement | “Eh yeah.” |
| 8. Acknowledgement: Statements that indicate recognition and/or comprehension of another statement but not necessarily agreement with another’s point | “I would say it would enhance it to a certain extent, but I wouldn’t say it would significantly enhance it because, you know, you can encourage people all you want but if they’re not willing to put the work in and they’re not willing to work as part of a team - of a team it’s not going to motivate them to do so” |

III. Disagreement-relevant intrusions

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| 9. Objections: Statements that deny the truth or accuracy of an arguable | “I would disagree with that” |
| 10. Challenges: Statements that offer problems or questions that must be solved if agreement is to be secured on an arguable | “It’d kind’ve depend on how much criticism we’re talking about, do you know what I mean?” |

IV. Delimiters

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| 11. Frames: Statements that provide a context for and/or qualify arguables | “For me like, inclination to get to know everyone in the group, is like more about, for myself, if I get to know people I feel more comfortable in a group and I feel more like I want to be a part of a team and I want to learn” |
| 12. Foretell/secure: Statements that attempt to forestall refutation by securing common ground | <i>No examples in transcript</i> |

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|---|---|
| 13. Fore stall/remove: Statements that attempt to fore stall refutation by removing possible objections | “Just because you know what the topic is doesn’t mean you want to learn about it” |
|---|---|

V. Nonarguables

- | | |
|--|---|
| 14. Process: Non-argument-related statements that orient the group to its task or specify the process the group should follow | “Ok, in the context of good collaborative learning, does the willingness to accept criticism with humility significantly enhance the motivation be part of a team?” |
| 15. Unrelated: Statements unrelated to the group’s argument or process (tangents, side issues, self-talk, etc.) | “I can’t believe that inspired someone!” |
| 16. Incompletes: Statements that do not contain a complete, clear idea because of interruption or a person’s discontinuing a statement | “So I’d kind of say, you know.....” |
-

Complexity of IM problematiques. As in Study 2, complexity of IM problematiques was measured using complexity scores (Warfield & Cardenas, 1994). These complexity scores are based on total activity of the paths of influence in the IM structure. This involves computing the sum of the antecedent and succedent scores for each element. The antecedent score is the number of elements lying to the left of an element, which influences it. The succedent score is the number of elements lying to the right of an element in the structure, which influences it.

Interpretive Structural Modelling. Interpretive Structural Modelling (ISM) was again used for systems model-building, operated by co-facilitators, with relational statements projected onto a screen.

5.3.4. Procedure

During recruitment, prospective participants were presented with information in relation to the nature of the study, including details as to its focus on collaborative learning and critical thinking. Participants were invited to register online via SurveyGizmo, and were required to complete a trust scale as part of the registration process. Participants were randomly allocated to one of eight groups, four in the facilitator-driven condition ($n = 12, n = 13, n = 13, n = 14$) and four in the peer-to-peer condition ($n = 12, n = 13, n = 10, n = 14$). There were two topics of discussion across the eight groups, with students discussing key skills and dispositions associated with either a) good collaborative learning (four groups; $n = 51$) or b) good critical

thinking (four groups; $n = 50$). As in Study 2, careful consideration was given to the selection of topics for discussion. The chosen topics were in the form of ill-structured problems, with no definitive correct answer (Asterhan & Schwarz, 2016), and relevant to students in their academic lives.

Facilitators

The IM sessions were facilitated by four PhD candidates from the same university as the authors. Each of these facilitators had previous experience facilitating IM sessions. In advance of this study, they were provided with three hours of study-specific training in the use of the IM methodology, and were provided with specific training materials and detailed instructions for facilitation, within the confines of the study protocol, including the prompting protocol. This protocol is described in more detail in the following section.

Pilot

A small-scale pilot study was conducted in order to test the study protocol. One group of 8 students participated in the facilitator-driven pilot condition, and one group of 10 students participated in the peer-to-peer pilot condition. Reflection on the pilot study allowed for considerable refinement of the peer-to-peer prompting protocol, including the addition of a coordinating phase in the transition from modelling of prompts by the facilitator, to handing over of control of prompt delivery to peers (described in the following section).

Interactive Management sessions

The IM sessions took place over two weeks; each of the eight groups took part in two sessions, with no more than 14 students in any one session. Each session lasted approximately 120 minutes. In week 1, participants in each of the eight groups were directed to a room in which chairs were arranged in a circle, such that all of the group members could see each other. Before the IM session began, each participant was given a document which contained a participation information sheet, a perceived consensus scale, an objective consensus scale, a discomfort in group learning scale, and a team orientation scale. The participants were asked to read the information sheet, which contained an introductory paragraph about either collaborative learning, or critical thinking. Participants were then required to complete the aforementioned scales. Once all scales had been completed, a short introductory presentation on examples of dispositions associated with good collaborative learning, or good critical thinking, was delivered by the facilitator to provide additional

context for participants. Next, the steps in the IM process was explained to participants and the session began.

The Idea Generation phase of IM took place during week one. In both the collaborative learning and critical thinking groups, participants were asked to silently generate a set of dispositions which they felt had a significant positive impact on the topic at hand (collaborative learning, or critical thinking). To facilitate this stage, the nominal group technique (NGT) was used (Delbeq et al., 1975), as in the previous studies. As described in Chapter 1 Section 1.2.2., NGT involves five steps: (a) presentation of a stimulus question (b) silent generation of ideas in writing by each participant working alone (c) presentation of ideas by participants, with recording on flipchart by the facilitator of these ideas and posting of the flipchart paper on walls surrounding the group (d) serial discussion of the listed ideas by participants for the purpose of clarifying their meaning; and (e) implementation of a closed voting process in which each participant is asked to select and rank five ideas from the list, with the results compiled and displayed for review by the group. The method of facilitation was the same for both conditions during week 1, with the only exception being that the groups in the peer-to-peer condition were introduced to the concept of peer-to-peer prompting, and the graphic organisers for use in week 2 were distributed (see Figure 11).

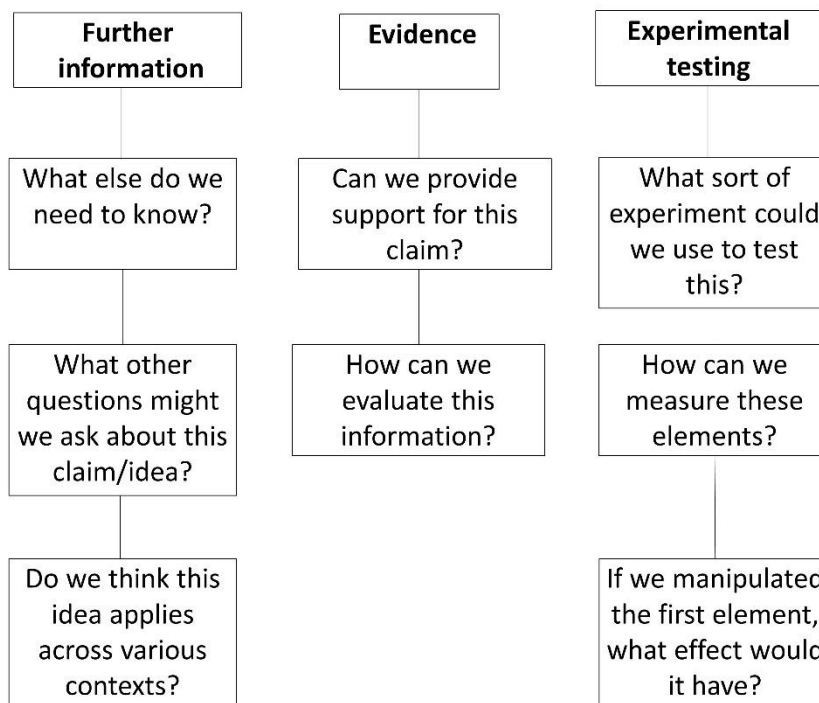


Figure 11. Graphic organiser of prompts

In week 2, each of the eight groups returned to structure the relationships between the ideas generated in week 1. The ISM software presents two elements at a time on screen, asking the question “Does A significantly influence B?”. As each relational statement is presented on screen, the facilitator opens the discussion to the room, and asks if anyone has a “yes” or “no” preference at this stage. This is also the stage during which the prompt manipulation was implemented. As participants indicated their preference, the facilitator would ask why they had this stated preference, and then request other opinions from the group, using a variety of prompts from Figure 11. After a period of discussion, the facilitator would request a show of hands from the group, and a vote would be taken and recorded by the ISM software.

This process took place during both the facilitator-driven and peer-to-peer conditions. However, during the peer-to-peer condition, participants were again introduced to the graphic organiser, and were encouraged to review and consider the prompt questions throughout the process, as they were told that they would be taking over control of the facilitation process during the course of the session. In the peer-to-peer condition, the role of facilitator was gradually transferred from the facilitator to the participants. This process involved three phases: modelling, coordinating, and handing over. In the modelling phase, the facilitation was conducted in the same manner as in the facilitator-driven condition, as the facilitator modelled the use of questions to prompt participants during the structuring process. This involved the facilitator directing students’ attention to the graphic organiser while selecting and delivering prompts to the group in response to the relational statement, and subsequently in response to ideas provided by other students. This phase lasted approximately 30 minutes.

Next, during the coordinating phase, the facilitator began to introduce peer prompts into the facilitation process. This was achieved by explicitly directing the attention of participants to the contributions made by others, via the questions on the graphic organiser (e.g., “John, we’ve heard an argument provided by Aoife, how could we provide some support for this claim?” or “Susan, what else do we need to know about Michael’s suggestion before we can make a decision?”). During this phase, participants were once again encouraged to review the graphic organiser and consider questions which would be relevant to pose to peers at any given time during the process. This coordinating phase lasted approximately 30 minutes, giving participants a chance to gain a clearer understanding of how peer prompts work, and to become more familiar with the process.

Finally, when beginning the handing over phase, the facilitator explained to participants they were now to facilitate each other, in a manner consistent with the process

which was initially guided by the facilitator in the modelling phase, and then further demonstrated in the coordinating phase. To begin this phase, the facilitator selected one participant to read out the next relational statement (e.g., “In the context of good critical thinking, does willingness to persevere significantly enhance willingness to take the ideas of others into account?”). Once the participant read out the relational statement, he or she invited input from the group of participants, as the facilitator did earlier in the process. The group was once again reminded to review and consider the graphic organiser when providing prompts to other peers, and the discussion was handed over to the group. Once an adequate level of discussion about the relational statement had been conducted (i.e., when participants discussed arguments for and against), the facilitator called for a vote, and the process continued with the next participant (sitting to the right of the previous reader of the relational statement), who in turn read out another relational statement, before calling for input. This process continued for approximately 60 minutes. Once all relational statements had been addressed, and the systems model generated, participants were asked to complete the post-intervention measures of perceived efficacy of the IM methodology, perceived consensus, objective consensus, team orientation, and discomfort in group learning.

5.4. Results

As in Study 2, intra-class correlations were calculated to assess any clustering by group status. Intra-class correlations were calculated for perceived efficacy, perceived consensus, team orientation, and discomfort in group learning. These analyses were conducted separately for each prompt condition, and each outcome. The analyses indicated that the intra-class correlations ranged between 0 and 0.036 ($p = .19$). As such, it was deemed that further multi-level analysis was not necessary. The results of ANCOVA testing of perceived efficacy, perceived consensus, team orientation, and discomfort in group learning are presented below.

5.4.1. Perceived efficacy of the IM methodology

Perceived efficacy of the IM methodology was assessed at post-test only. A one-way ANCOVA was used to assess the effects of prompting style (condition: facilitator-driven versus peer-to-peer) on perceived efficacy of the IM methodology, with trust analysed as a covariate. The ANCOVA revealed a significant main effect of condition, $F(1, 93) = 7.17, p = .009, \eta p^2 = .07, d = 0.53$, with higher perceived efficacy in the peer-to-peer condition ($M = 25.26, SD = 2.31$) than in the facilitator-driven condition ($M = 23.84, SD = 3.01$). No other effects were observed.

5.4.2. Perceived consensus

A 2 (condition: facilitator-driven versus peer-to-peer) x 2 (time: pre-intervention versus post-intervention) mixed ANCOVA was used to assess the effects of facilitator-driven versus peer-to-peer prompts on perceived consensus, with trust analysed as a covariate. The ANCOVA revealed a significant time x condition interaction, $F(1, 93) = 4.70, p = .03, \eta p^2 = .05, d = 0.27$, with a significant increase in perceived consensus in the peer-to-peer condition from pre ($M = 14.74, SD = 2.19$) to post ($M = 15.91, SD = 2.03; t = 2.18, p = .03$) but not in the facilitator condition from pre ($M = 14.88, SD = 1.95$) to post ($M = 15.20, SD = 2.12; t = .36, p = .72$). The results also revealed a significant main effect of the covariate, trust, on perceived consensus, $F(1, 93) = 11.63, p = .001, \eta p^2 = .11$, with higher trust associated with higher levels of perceived consensus.

Table 10. Means and standard deviations for perceived consensus

Condition	Time		Perceived Consensus
Facilitator-driven	Pre	<i>M</i>	14.88
		<i>SD</i>	1.95
	Post	<i>M</i>	15.20
		<i>SD</i>	2.12
Peer-to-peer	Pre	<i>M</i>	14.74
		<i>SD</i>	2.19
	Post	<i>M</i>	15.91
		<i>SD</i>	2.03

5.4.3. Objective consensus

Kendall's coefficient of concordance (Kendall's W) was used to measure concordance (i.e., agreement of ratings in relation to specific ISM paths of influence) within groups before and after the experimental manipulation. No significant effects were observed. ($p > .05$ for both comparisons; see Table 11).

Table 11. *Objective consensus scores (Kendall's W)*

Condition	Pre	Post
Facilitator-driven	.11	.08
Peer-to-peer	.06	.06

5.4.4. Discomfort in group learning

A 2 (condition: facilitator-driven versus peer-to-peer) x 2 (time: pre-intervention versus post-intervention) mixed ANCOVA was used to assess the effects of facilitator-driven versus peer-to-peer prompts on discomfort in group learning, with trust analysed as a covariate. The ANCOVA revealed a significant time x condition interaction, $F(1, 94) = 5.70, p = .02, \eta p^2 = .06, d = 0.64$, with a significant decrease in discomfort in group learning in the peer-to-peer condition from pre ($M = 12.52, SD = 2.79$) to post ($M = 10.78, SD = 2.95; t = 1.97, p = .04$) but not in the facilitator-driven condition from pre ($M = 12.50, SD = 2.79$) to post ($M = 11.90, SD = 3.02; t = .40, p = .69$). No other effects were observed.

Table 12. *Means and standard deviations for discomfort in group learning*

Condition	Time		Discomfort in Group Learning
Facilitator-driven	Pre	<i>M</i>	12.52
		<i>SD</i>	2.79
	Post	<i>M</i>	11.90
		<i>SD</i>	3.02
Peer-to-peer	Pre	<i>M</i>	12.50
		<i>SD</i>	2.79
	Post	<i>M</i>	10.78
		<i>SD</i>	2.95

5.4.5. Team orientation

A 2 (condition: facilitator-driven versus peer-to-peer) x 2 (time: pre-intervention versus post-intervention) mixed ANCOVA was used to assess the effects of facilitator-driven versus peer-to-peer prompts on team orientation, with trust analysed as a covariate. The ANCOVA

revealed a significant time x condition interaction, $F(1,66) = 8.23, p = .006, \eta p^2 = .11.$, with an increase of team orientation from pre ($M = 71.86, SD = 8.50$) to post ($M = 74.78, SD = 6.80; t = 2.78, p = .009$) in the peer-to-peer condition, but not in the facilitator-driven condition from pre ($M = 71.88, SD = 9.62$) to post ($M = 70.91, SD = 8.48; t = 1.2, p = .24$). The results also revealed a significant main effect of the covariate, trust, on team orientation, $F(1,66) = 10.07, p = .002, \eta p^2 = .13$, with higher trust associated with higher levels of team orientation.

Table 13. Means and standard deviations for team orientation

Condition	Time	Team Orientation	
		<i>M</i>	<i>SD</i>
Facilitator-driven	Pre	<i>M</i>	71.88
		<i>SD</i>	9.62
	Post	<i>M</i>	70.91
		<i>SD</i>	8.48
Peer-to-peer	Pre	<i>M</i>	71.86
		<i>SD</i>	8.50
	Post	<i>M</i>	74.78
		<i>SD</i>	6.80

5.4.6. Conversational argument coding scheme

A series of chi-squared tests were used to assess the statistical significance of differences in argumentation codes (as per the CACS) across prompting conditions. Of the 16 possible CACS argument codes which comprise the five argument categories, 15 were observed in the peer-to-peer condition at least once, 12 were observed in the facilitator-driven condition at least once, and 1 was not observed in any condition. Significant differences were observed across conditions for 4 argument codes, with higher frequency occurrence in the peer-to-peer condition in each case, specifically, for amplifications ($\chi^2(1) = 5.13, p = .01, V = .05, d = .50$), justifications ($\chi^2(1) = 7.08, p = .005, V = .06, d = .58$), acknowledgements ($\chi^2(1) = 4.68, p = .02, v = .05, d = .47$), and challenges ($\chi^2(1) = 6.79, p = .005, V = .06, d = .58$). In each of the remaining codes (with the exception of objections, forestall/secure, and forestall/remove) higher incidence was also observed in the peer-to-peer condition than in the facilitator-driven

condition, however, these differences were not statistically different. Descriptive data are presented in Figure 12.

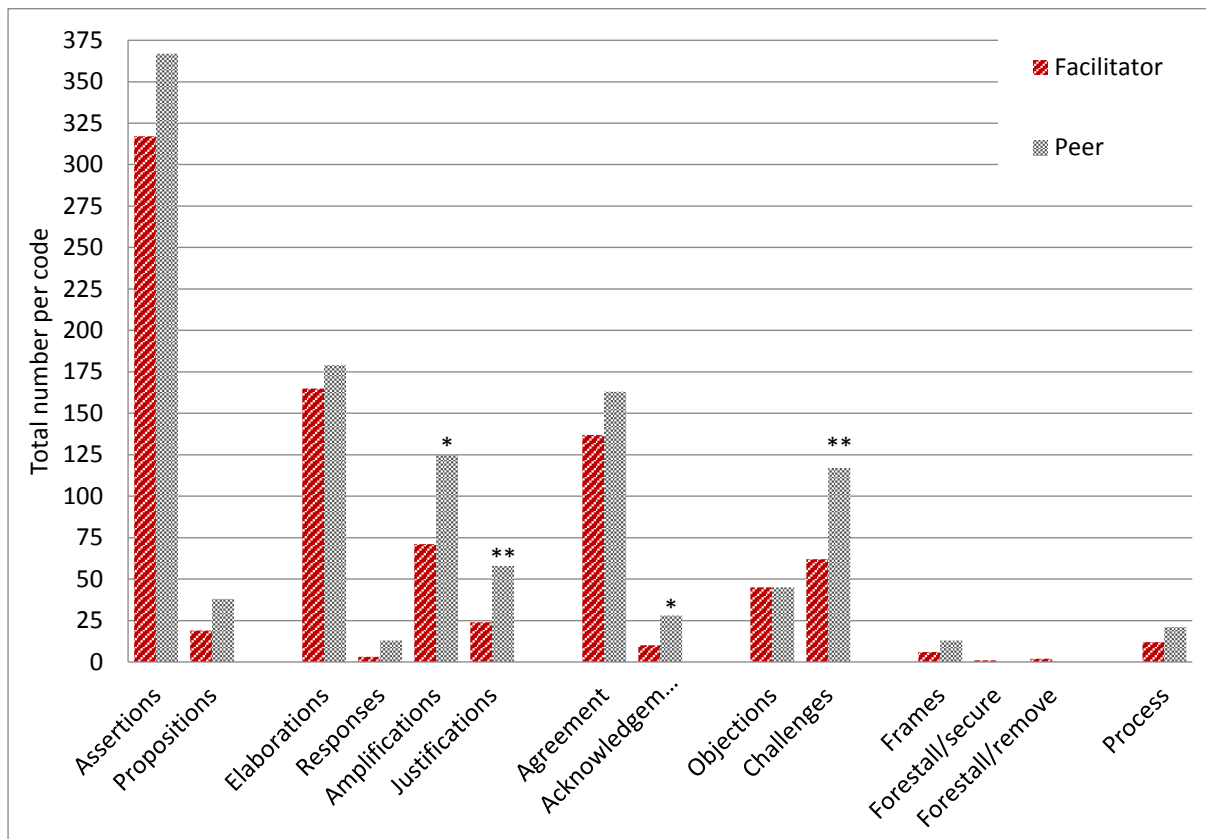


Figure 12. Incidence of CACS codes across conditions

(Total of codes in facilitator-driven condition = 874; total of codes in peer-to-peer condition = 1167; * = significant at .05 level, ** = significant at 0.01 level)

Finally, analysis of the IM-generated problematques (see Figures 13-16 for samples from each condition, with the remaining problematques in Appendix B) revealed no significant difference in complexity of argument structures across conditions. The average complexity score for the problematques generated by groups in the peer-to-peer condition was 36.75. The average complexity score for the problematques generated by groups in the facilitator-driven condition was 40.

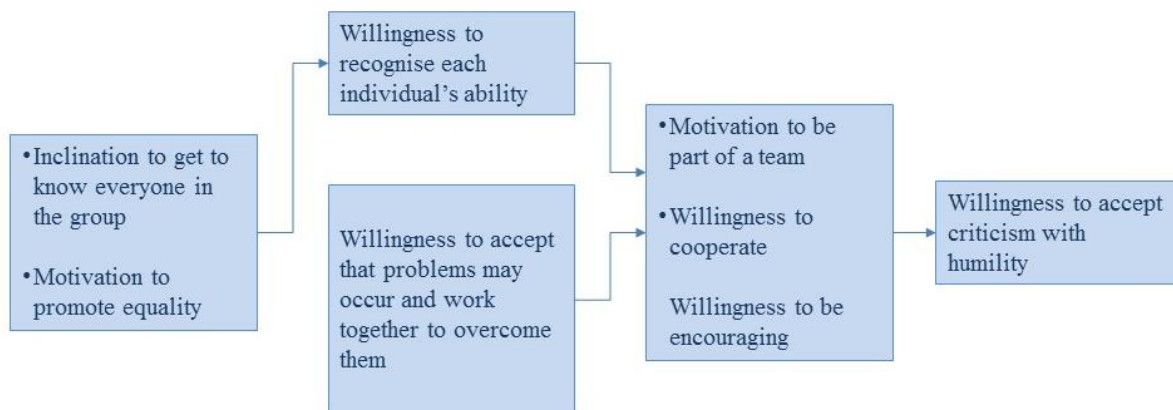


Figure 13. Problematique generated in the peer-to-peer condition

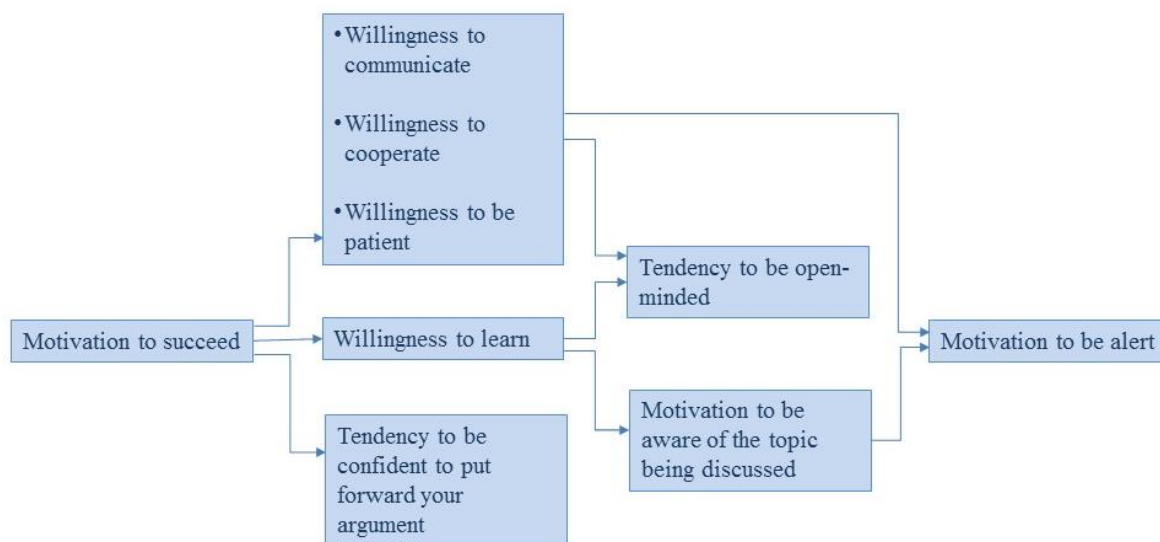


Figure 14. Problematique generated in the peer-to-peer condition

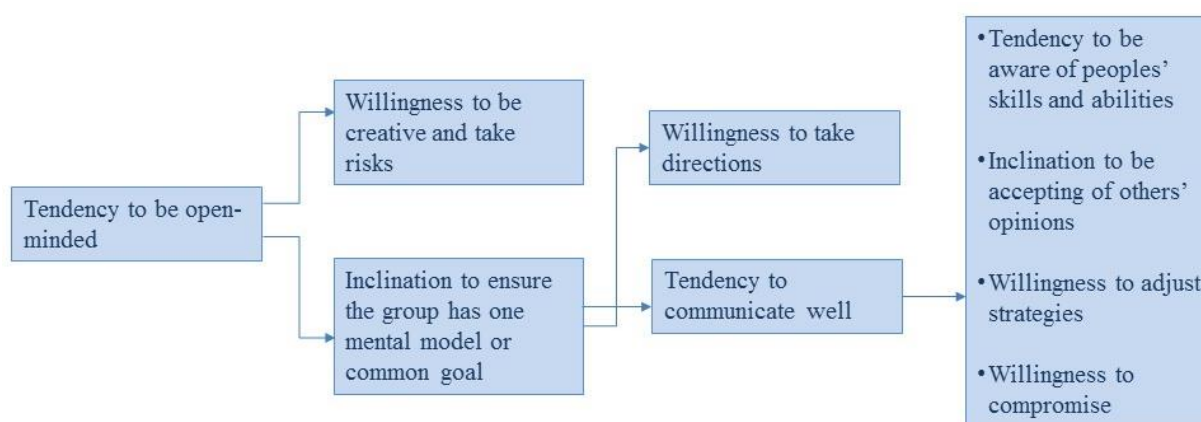


Figure 15. Problematique generated in the facilitator-driven condition



Figure 16. Problematique generated in the facilitator-driven condition

5.5. Discussion

Study 3 examined the effects of facilitator-driven versus peer-to-peer prompts on perceived and objective consensus, perceived efficacy of the IM method, team orientation, discomfort in group learning, and variety and complexity of argumentation. Results indicated that, compared to those in the facilitator-driven condition, those in the peer-to-peer condition reported higher levels of perceived efficacy of the IM methodology, but as in Studies 1 and 2, no significant differences were found regarding levels of objective consensus. In addition, those in the peer-to-peer condition reported higher levels of perceived consensus in relation to the topical focus of the IM sessions, lower levels of discomfort in group learning, and higher levels of team orientation after the IM sessions. Finally, analysis of the dialogue from the IM sessions revealed that those in the peer-to-peer condition exhibited higher levels of sophistication in their arguments, as revealed by their CACS scores, but no significant differences in the complexity of the systems models were found.

Building upon findings from Study 2, which found that process-level prompts were more effective than task-level prompts in generating perceived consensus, the current study extended the prompting research into a peer learning scenario. In the current study, while post-IM perceived consensus levels were relatively high in both conditions, a significant pre-post increase was only recorded in the peer-to-peer prompt condition. As noted in Studies 1 and 2, higher levels of perceived consensus, this time in the peer-to-peer prompting group, may have implications for students' overall levels of engagement in, and endorsement of, the IM process. Furthermore, as highlighted in Chapter 2 Section 2.6.1., previous research has found that if a group feel strongly that there is a high level of consensus in relation to the understanding and conception of a problem that they are working on together, they are more

likely to be committed to, and satisfied with, any plan which comes from the newly-formed collaborative understanding (Mohammed & Ringseis, 2001). These findings suggest that if teachers or facilitators want to promote a high level of consensus in a group, taking a step back and passing over the role of prompting to their students is a potentially powerful method, particularly if students have received structured training and understand how to use prompts in context. This finding is consistent with Boud et al.'s (2001) review of peer learning, which highlights benefits such as: working with others, communication and articulation of knowledge, and critical enquiry and reflection, all of which are conducive to consensus, as well as research which suggests that peer learning promotes motivation (Bloxham & West, 2004). Furthermore, given that the peer-to-peer prompt condition also displayed more varied and complex forms of argumentation, this result of higher perceived consensus is also consistent with research reporting significant associations between argumentativeness and levels of consensus (Anderson & Martin, 1999; Sambamurthy & Poole, 1992). Notably the covariate, trust, also had a significant effect on perceived consensus, consistent with research reporting the role of trust in information-sharing (Chiu et al., 2006), and moderating the relationship between task conflict and relationship conflict (Simmons & Peterson, 2000).

Also consistent with Boud et al. (2001) is the finding that peer-to-peer prompting has a positive impact on levels of team orientation, which represents another important finding in the context of peer learning, and collaborative learning more broadly. Given the demand for teamwork skills in the workplace (Koc et al., 2015), this result also has important implications beyond education. Considering research which has found that team orientation enhances decision-making, cooperation, coordination, and overall team performance (Eby & Dobbins, 1997), it follows that any educational intervention which promotes team orientation may have positive implications for a graduate's approach to teamwork beyond education. Notably, Fransen, Weinberger, and Kirschner (2013) highlight that choice of educational task is an important factor in understanding the effects of team orientation in a learning context, with the strongest, positive effects of team orientation seen for tasks which are authentic, complex, challenging, and collaborative (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; Kirschner, Paas, & Kirschner, 2009a, 2009b, 2011). In the current study, the tasks were authentic, as they focused on two components relevant to the student's education: critical thinking and collaborative learning. Similarly, in the context of the IM methodology, the tasks were inherently complex, challenging and, particularly in the peer-to-peer condition, highly collaborative. As such, the findings in relation to increased team orientation in the

peer-to-peer condition are consistent with previous research. Furthermore, the finding that the covariate, trust had a significant impact on team orientation is also consistent with previous research. For example, Ennen et al. (2015) reported a significant positive relationship between trust and motivation to work in groups in future.

The finding in relation to perceived efficacy of the IM methodology, again, represents another important finding for the application of IM in a learning context. While Studies 1 and 2 reported higher levels of perceived efficacy in the context of presence, as opposed to absence, of dialogue (Study 1), and process-level, as opposed to task-level, prompting (Study 2), this study highlights that peer-to-peer prompting, as opposed to facilitator-driven prompting, can also produce higher levels of perceived consensus. While, broadly speaking, students in both conditions found the process useful and engaging, those in the peer-to-peer condition reported significantly higher levels of perceived efficacy of the IM methodology, suggesting that the increased empowerment of students who were driving the deliberation and prompting process, contributed to a greater sense of value and perceived success of the process. Importantly, these findings are consistent with the findings of Volery and Lord (2000), who found that one of the key factors which impacted on student's perceptions of educational technology, related to the role of the instructor in encouraging student interaction. In the case of the peer-to-peer prompting condition in this study, the instructor more explicitly encouraged peer interaction, relative to the facilitator-driven condition, by first modelling peer-to-peer prompting behaviour, then coordination of peer interactions, before finally passing over control of prompting to peers themselves. Thus, this additional emphasis on peer-to-peer interaction may have contributed to the higher levels of perceived efficacy reported by students.

Furthermore, this finding is also consistent with research conducted by Cho and MacArthur (2007), who found that students who received feedback from multiple peers made greater improvements on written tasks than those who received feedback from a single teacher. They suggest that while peers may not have the same level of expertise as teachers, they may provide comments which are more accessible to fellow students, and may be better able to recognise difficulties in conceptualisation or understanding due to their own similar perspective. It seems plausible that, in the same way that peer engagement contributed to greater improvements in written tasks, receiving accessible, relevant prompts from a peer contributed to a greater sense of both perceived consensus, and perceived efficacy of the collaborative process in the case of this study.

As well as considering students' outcome-related perceptions of the process (including perceived efficacy, and perceived consensus), it is also necessary to consider how students respond emotionally to peer-to-peer prompting, particularly given that the experience of peer-prompting may be unfamiliar to students. In the current study, although the IM process was new to students, results highlighted a positive response to the peer learning experience. In addition to reporting higher levels of both perceived consensus and perceived efficacy of the process, those in the peer-to-peer group reported a significantly greater reduction in discomfort in the group learning process. This may be due to the increasingly open nature of the sessions, where the facilitator gradually models, simulates, and passes over control of the task to the students. More generally, these findings have implications for the adoption and sustained use of such collaborative methodologies by students or other working groups as, in effect, high levels of perceived consensus and perceived efficacy, and reduced levels of discomfort in group learning, suggest a significant level of endorsement of the methodology.

5.5.1. Variety and complexity of argumentation

With regard to the types of argumentation coded during the IM sessions, the results of the CACS analysis showed that students in the peer-to-peer prompt condition displayed higher levels of argument sophistication. More specifically, when compared with the facilitator-driven condition, participants in the peer-to-peer prompt condition demonstrated significantly higher levels of amplifications, justifications, acknowledgements, and challenges. This suggests that those in the peer-to-peer prompt condition were engaging at a higher level of consideration, analysis, and evaluation of the claims presented during IM work, and made more effective efforts towards achieving a level of understanding and consensus within the group, prior to voting. For example, in the category of reasoning activities, while elaborations (i.e., statements that support other statements by providing evidence, reasons or other support e.g., "Yes because if you're open minded you hear everyone's ideas") were similarly evident in both conditions, amplifications (i.e., statements that explain or expound upon other statements to establish the relevance of an argument through inference e.g., "I think it's a yes because if you put yourself in the situation, say, if you were in a group and you were set as the team leader you could be like right guys this is what we're doing and that's how it has to be done but if you have the patience you can take the time to listen and decide as a group, if you aren't patient you wouldn't do that") were observed more often in the peer-to-peer prompt condition. In this way, those in the peer-to-

peer prompt condition were moving beyond accumulation of evidence and support in their reasoning activity - they were working further to establish how this reasoning relates to the problem at hand. Similarly, in the category of convergence-seeking activities, while there was no significant difference between levels of agreements (i.e., statements that express agreement with another statement e.g., “Yeah that could happen too”) across the two conditions, the level of acknowledgements (i.e., statements that indicate recognition and/or comprehension of another statement but not necessarily agreement with another’s point e.g., “I think you can be motivated like to want to achieve the goal but it doesn’t necessarily mean that you’re going to try and encourage everyone like”) was significantly higher in the peer-to-peer prompting condition. This suggests that students in the peer-to-peer prompt condition, while engaging in convergence-seeking activities and moving towards consensus, remained open to the suggestions of others, while also remaining critical in their analysis. Importantly, these patterns of argumentation also suggest that students were not moving towards consensus for the sake of consensus, but rather they were engaging in a process of deeper analysis and evaluation of their peer’s arguments, before reaching a level of perceived consensus. From a learning perspective, this is an important distinction as dissent and critique are conducive to learning and reflection, both in the classroom (Johnson et al., 2007) and at a societal level (Sunstein, 2005).

5.5.2. *Systems-model complexity*

When examining the relational complexity of the models or structural hypotheses generated by students, the current study revealed no significant differences between the two experimental conditions. This suggests that, although those in the peer-to-peer prompt groups engaged in more complex patterns of argumentation, this was not reflected in the structural complexity of yes/no relationships in the IM matrix structures generated. This finding is in contrast to Study 2, where it was found that higher structural model complexity was coupled with differences in argumentation complexity in groups that received either task-level facilitator prompts or process-level prompts. In other words, while structural models may accurately reflect the consequences of more or less complex and varied patterns of argumentation when process prompting is compared with task-level prompting, in situations where process prompts are delivered by either a facilitator or by peers, while differences in argumentation complexity may be observed, these differences may not translate into differences in the structural complexity of systems models generated by groups.

5.5.3. Supporting peer-to-peer prompting

While the IM methodology is well established in the applied systems science literature and has been successfully applied in a wide variety of scenarios to accomplish many different goals (as outlined in Chapter 1 Section 1.2.1.), both Studies 2 and 3 emphasise that the manner in which it is facilitated is a crucial factor. Building upon the results of Study 2, which highlighted the effects of different levels of facilitator prompting, Study 3 suggests that control of the delivery of prompts in a collaborative learning exercise such as IM, can be passed over to students, with positive implications for learning. However, when considering the implications of these results, it is important to note that this passing over must be done in a methodical, controlled manner, in which the teacher or facilitator remains crucial. As detailed in the procedure, in the peer-to-peer prompt condition the teacher first models the use of the graphic organiser to deliver prompts (i.e., uses the prompts to elicit discussion), then coordinates peer-to-peer interaction, by using prompts from the graphic organiser to facilitate interaction and engagement (e.g., “John, we’ve heard an argument provided by Aoife, how could we provide some support for this claim?”), before finally handing over control of the prompting to the students. As such, these findings are consistent with previous research by van Steendam et al. (2010) who found that modelling of peer feedback behaviour, followed by emulation of this behaviour can improve the quality of peer feedback delivered by students. These results are also consistent with research by Sluijsmans et al. (2002), who found that students who received training in peer assessment and feedback outperformed a control group on peer assessment and feedback quality, in that the modelling and coordinating phases in the peer-to-peer condition in the current study provided instructional support for students before the role of peer-to-peer prompting was handed over to them.

Overall, this study highlights the potential value of peer-to-peer prompting in the context of collaborative systems model-building. These results, including findings that peer-to-peer prompting resulted in both positive perceptions of the learning process, and key indications of higher-level learning outcomes, highlight the potential for a range of benefits of peer-to-peer learning in CSCL going forward.

5.5.1. Limitations and future research

While considerable efforts were made to standardise the learning conditions in each group, the nature of collaborative learning research is that differences in interactions between group members is possible, and as such, the interactions between students within the four groups in

each prompt condition may have varied in ways beyond the control of the researchers. However, all efforts to minimise such variability were made, including the fact that trained facilitators operated within strict protocols at all times during the study.

Second, as in the previous studies, there was a gender imbalance in the sample of this study with a ratio of approximately 4:3 females to males. As discussed in Study 2, this is a common sampling issue when university student samples are used (Skinner & Louw, 2009). While there is limited evidence to suggest gender differences in peer learning, a study by Webb (1984) found that high level elaboration was more likely to be elicited by asking a question of a female peer, than a male. However, other studies have found that gender differences in peer learning are diminished when hints (e.g., prompts) are provided (e.g., Ding & Harskamp, 2009) or when students are given guidance in facilitating interactions (Gillies & Ashman, 1995).

Third, the participants in this study were predominantly students who received all of their education to date within the Irish education system, and as such may not be generalisable to students from other education systems. It is possible that these results would be more or less pronounced in the case of students who have differing levels of prior experience with methods of peer learning. As such, future research should seek to replicate these findings within the educational systems of other countries.

Fourth, as in Study 2, levels of students' interest in, or motivation to discuss, the topics chosen for the IM session were not measured. While the topics of collaborative learning and critical thinking are equally academically relevant to all participants in this study, it is possible that the extent to which participants in each group were engaged and motivated to discuss the topic was subject to some degree of variability. However, in practical terms this limitation may be less pertinent, as this reflects the nature of classroom discussions more broadly, wherein students in the same class may have varying levels of interest in any given topic.

5.6. Conclusion

The results of this study suggest that the positive effects associated with process-level prompts in collaborative learning can be extended to learning contexts which are driven by peers as opposed to expert facilitators or teachers. This is an important finding when one considers (a) that many studies have found that formative assessment (including feedback and prompting) is a vital component of education, and (b) resource constraints in many universities have led to a reduction in the quantity and quality of feedback received by

students (Gibbs & Simpson, 2004). One possible solution to the limited scope for instructor feedback, as a function of demands on teachers' time, is better use of in-class formative peer learning, designed to facilitate and accelerate learning for student groups. While the results of the current study may have positive implications for teachers, in terms of reducing the burden placed on them by diminished resources (time), critically, the positive effects of peer-to-peer prompting on students learning experiences was clear. Students were found to report a positive response to the peer learning experience, reporting higher levels of both perceived consensus, and perceived efficacy, suggesting that students found the process to be more efficacious and beneficial than a predominantly facilitator-driven learning process. Students reported lower levels of discomfort in group learning, with results showing that those in the peer-to-peer condition reported a significant reduction in discomfort in the group learning process. Students in the peer-to-peer condition also reported increased levels of team orientation, which may have positive implications for the development of teamwork skills in both educational and organisational contexts. Finally, students in the peer learning condition demonstrated more complex modes of argumentation, suggesting that supportive and structured peer learning conditions can facilitate the development of key critical, collaborative, and systems thinking skills that are highly significant educational outcomes in a world that is calling for more productive modes of collaboration across all sectors of society.

Chapter 6: The development of a pilot applied systems science curriculum

6.1. Chapter overview

John Warfield devoted much of his career to building a viable applied systems science, focusing in particular on developing and testing methods to support groups in tackling complex societal problems (Warfield, 2006). As part of his vision, Warfield recognised the importance of integrating applied systems science into education and highlighted the need to cultivate in students the skills of systems design, group deliberation, consensus-building, and critical thinking. The pilot applied systems science curriculum described in this chapter provides an initial attempt to implement Warfield's educational vision. Building on the findings of Studies 1-3, and incorporating their implications for teaching and learning, an applied systems science curriculum aligned with Warfield's vision was designed and piloted over the course of a 12-week semester, with 23 final-year undergraduate psychology students attending the National University of Ireland, Galway. Central to this pilot curriculum is an instructional focus consistent with the experimental studies described in the current thesis – including a focus on dialogue, argumentation, facilitation and prompting, consensus-building, as well as the application of the IM methodology. Aligned with the use of IM software for systems modelling, the module also included an instructional focus on critical thinking using Argument Mapping software (Rationale; van Gelder, 2007). Students also made use of Scenario-Based Design (SBD) methods (Rosson & Carroll, 2000) to translate options derived from IM work into design solutions. In communicating the focus of the module to students, Warfield's vision was described succinctly, and the 3Ts framework (Hogan, Harney, & Broome, 2015), which emphasises a focus on tools, talents, and teams, was also used to orient students to major learning objectives. More generally, the module was informed by the literature on collaborative learning, particularly with regards to curriculum design, as well as the literature on instructional support and peer learning reviewed in Chapter 2. This module culminated in groups of students using the tools and talents acquired during the module to tackle an applied problem from a systems science perspective, using (a) IM to explore and map the structure of the problem, (b) Rationale to build clear arguments for the casual pathways in the problem structure, and (c) SBD to develop potential solutions to these problems.

6.2. Introduction

As described in Chapter 1, Warfield recognised the importance of integrating applied systems science into university education. Warfield believed that, through developing shared understanding of complex problems, and supporting consensus-based design of solutions, it will be possible to tackle the many complex scientific and social problems which exist, and persist, in society today. Importantly, Warfield emphasised that appropriate methodologies and supports need to be developed and integrated into education systems, to harness skills of collaborative systems design thinking, critical thinking, and collective action (Warfield, 1976, 2006, 2010). With this in mind, he developed IM to provide groups with a structured approach to tackling complex problems (Warfield & Cardenas, 1994; Warfield, 2006). This approach to systems thinking and problem-solving focuses heavily on facilitation of collaborative discourse, consensus-building, and empowerment of the group and individual group members. The pilot applied systems science education curriculum described in this chapter, *An Introduction to Collaborative Enquiry and Applied Systems Science*, builds upon Warfield's work, by placing Warfield's tool, IM, and group methodologies such as *Ideawriting* and *Nominal Group Technique* (NGT), at the core of a teaching module. Furthermore, given Warfield's recognition of the importance of critical thinking skills, this module also incorporated the use of Argument Mapping, a tool which has been found to be successful in fostering critical thinking skill (Dwyer et al., 2011, as described in Chapter 2). Finally, to support the translation of systems thinking into design solutions, students made use of SBD methods as part of their project work (see Thompson Long et al., 2017).

As highlighted in Chapter 1 Section 1.4., Warfield's approach to collaborative systems design may be aligned with more recent approaches to CSCL in the Learning Sciences. For example, Stahl's (2015) perspective on current educational design needs complements Warfield's perspective on the necessary conditions for the application of systems science in an educational context. More specifically, Stahl highlights the need for development of curricula, which, in design and delivery, should incorporate a Learning Sciences emphasis on student-centred, collaborative, explorative, immersive, computer-supported problem-solving approaches. As described later in this chapter, these components identified by Stahl are central to the design and implementation of the current pilot applied systems science curriculum. Furthermore, Stahl's (2010) conceptualisation of *Group Cognition* (Chapter 1, Figure 3, p. 36), places *sequential small-group interaction* as the central component, linking the task, the individual, and the group. This sequential small-

group interaction, or “the dialogical interaction through which individual participants form into a collective knowledge-building agency” (2010, p. 255), is central to the development of shared understanding and learning at the group level. As such, consistent with both Warfield and Stahl, the learning activities which comprised this pilot curriculum were largely centred on small-group collaboration, in which group dialogue was facilitated by various instructional supports, tools, methodologies, and peer learning.

6.3. Curriculum design

Curriculum design has classically been described as a process “which identifies the elements of the curriculum, states what their relationships are to each other, and indicates the principals of organisation and the requirements of that organisation for the administrative conditions for which it is to operate” (Taba, 1962, p. 421). This definition is broadened by Ornstein and Hunkins (2009) to include the imparting of skills, attitudes, and essential concepts. As such, curriculum design may take into account intellectual development, as well as personal development, character development, and social development (Mitchell, 2016).

According to Ornstein and Hunkins (2009), the source of the design is a primary consideration in curriculum design. The source of the design may consist of various facets or have a number of foundations. A source may be based on a foundation of knowledge, a social or societal imperative, or some combination of the two. For example, the knowledge or skill which is most fundamentally important to, or needed by, the society at the time, may have significant influence on the design process. In the case of Warfield, the drive to create the *Horizon College* (as described in Chapter 1 Section 1.2.4.) stemmed from a perceived need at the societal level - a need to cultivate knowledge and skills which will better enable groups to solve complex problems.

Further, as noted by Mitchell (2016), the curriculum design process may involve consideration of both knowledge as a design source, and/or the learner as a design source. In particular, the design may reflect the needs of the student to learn and develop skills to meet the needs of the society in which they will work and interact. In other words, consideration of the learner as a design source may require consideration of the educational needs or requirements of students which will enable them to develop specific targeted knowledge or skills. This, according to Mitchell (2016), highlights the need for a student-centred approach to curriculum design, a call which echoes that of Stahl (2015). As such, drawing on both the learner and societal needs as design sources, a student-centred approach was central to the design and implementation of this pilot curriculum. More specifically, this pilot curriculum is

focused on providing an environment for the cultivation of skills such as collaborative argumentation, critical thinking, and systems design, all of which are called for presently at the societal level (Hogan et al., 2017) and thus represent core components of this curriculum.

A useful way of conceptualising and representing the core components of curriculum design is using a curricular spiderweb (van den Akker, 2003), as seen in Figure 17 below. This spiderweb, according to McKenney, Nieveen, and van den Akker (2006) illustrates the interconnectedness between components of a curriculum, and the vulnerability of the structure which connects them. According to McKenney and colleagues, this vulnerability is due to the interdependence which exist between components of the curriculum. In other words, balance across objectives and lines of curriculum design work is key, as a dramatic shift in any one direction will “pull the entirety out of alignment” (p. 68). This idea of vulnerability of curriculum structures and the spiderweb representation aligns with the challenges of orchestration described by Dillenbourg et al., (2009) as outlined in Chapter 1 Section 1.4.2. Dillenbourg and colleagues referred to, for example, the challenge of orchestrating scaffolding derived from multiple sources. In the context of collaborative learning, scaffolding or instructional support may be provided by the teacher, the learning materials, and peers. Dillenbourg highlighted the need to achieve consistency and complementariness across each source of scaffolding within a learning environment, such that each source is working in tandem towards the same goal, that is, supporting students to achieve key learning objectives when working through different aspects of the curriculum. Each of the components of the curricular spiderweb will be addressed in the context of the current module, and are presented in Table 14 below.

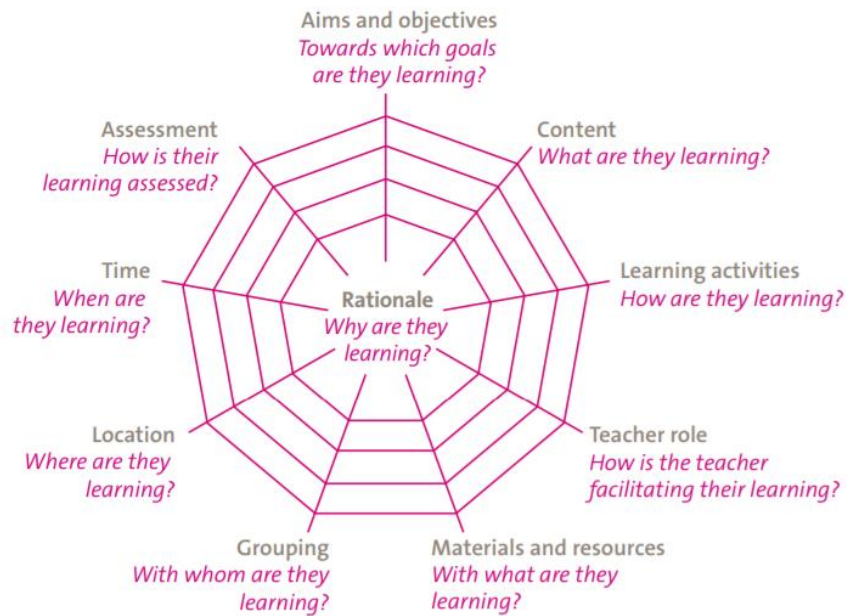


Figure 17. Curricular spiderweb (van den Akker, 2003)

Table 14. Components of curricular spiderweb

Components of curricular spiderweb	
Rationale	The rationale for this pilot curriculum stems from a growing recognition of the need to cultivate teamwork, collaborative enquiry, and systems design skills in undergraduate students, such that students can use these skills as part of a broader teamwork effort to resolve complex problems across various organisational and applied social contexts.
Aims and objectives	The module objectives and learning outcomes were presented to students in week 1 of the module. These include, for example: <ul style="list-style-type: none"> • To provide students with a grounding in collaborative enquiry skills and applied systems science, with a focus on real world applications. • To provide students with training in group facilitation, collective intelligence, and systems thinking techniques.

	The full set of objectives and learning outcomes are presented in Section 6.6.1., which outlines week 1 of the module.
Content	The topics addressed include: collaboration and teamwork, peer feedback and prompting, critical thinking, systems thinking, and, group problem-solving. This content was delivered by a combination of lectures, group discussion, and collaborative learning activities, and was weighted heavily towards collaborative group activities.
Learning activities	Group discussion; Cooperative reading; Peer prompting; Ideawriting; Collaborative argument mapping; Collaborative systems model-building; Collaborative scenario-based design; Reflective journaling; Report-writing.
Teacher role	To facilitate students' collaborative engagement in the application of applied systems science tools and methodologies.
Materials and resources	Powerpoint; ISM software; Rationale software; Graphic organisers (prompts); Scenario-based design materials (i.e., sketching and mock-up materials).
Grouping	Students work primarily in groups of 4 to 5.
Location	A large classroom, well-suited to small-group collaboration: plenty of wall space, as well as chairs and tables which can be rearranged into work stations for multiple groups.
Time	Friday 14:00 – 16:00.
Assessment	Weekly attendance and participation; Weekly reflective journal; Group project. Further detail is provided in Section 6.6.1.

Again, as noted above, Stahl (2015) highlights a number of key components which should be incorporated into collaborative learning curricula going forward. These components include a focus on student-centred, collaborative, explorative, and immersive

learning. Also, according to Stahl, curricula should involve a problem-solving focus, and make good use of CSCL methods. The module described in this chapter addresses each of these components, as described below, with detailed examples of how these components manifested in the week-by-week module design and delivery presented in Section 6.6.

Throughout the course of the module, a *student-centred* approach was adopted. Students were given the opportunity to contribute to a number of aspects of the module's organisation and implementation. For example, as described in more detail in Sections 6.6.2. and 6.6.3., students were directly involved in the development of a set of indicators for peer monitoring. Further, the broader approach to the module involved limited traditional lecture-style learning, and primarily involved high levels of student engagement through *collaborative* exercises (e.g., group discussions, group problem-solving, group design thinking, group presentations) as described in more detail in Sections 6.6.2. – 6.6.12. This *student-centred* approach is also demonstrated by the reflective journal entries which students submitted weekly (further detailed in Section 6.6.3.). These reflective entries allowed the instructors to review students' reflections on, and perceptions of, their learning and progress each week. As such, it was possible to anticipate student's needs ahead of the next class, which provided additional information to the instructors in relation to the *learner as a design source* (Ornstein & Hunkins, 2009).

The reflective journals also provide an example of the *immersive* nature of the module. In keeping a weekly reflective log, students were afforded the opportunity to reflect upon, and immerse themselves further, in their learning experiences. These reflective logs, which were reviewed by the module instructors, provide testimony from students about their levels of engagement with, and immersion in, the course content, and the collaborative processes. Examples of these reflections are provided in sections 6.6.3. – 6.6.10.

The *immersive* and *explorative* components of the module are most evident in relation to the *problem-solving* component. This module sought to enhance students' group problem-solving skills by guiding them through processes of collaborative argument mapping, collaborative systems model-building, and collaborative SBD exercises. Students were also guided through the process of facilitating a problem-solving group, and the use of peer-to-peer prompting. These skills were then employed by students in an applied group problem-solving project over the course of 7 weeks, as described in sections 6.6.6. – 6.6.12. This project required students to immerse themselves, in small groups, in an applied problem-space, and to use both *computer-supported* tools (IM and Rationale) and group work

methodologies (NGT, Ideawriting, Paired Comparison, SBD) to explore, analyse, and collaboratively develop solutions to the specific problem.

6.4. Design implications stemming from Studies 1-3

The results of Studies 1-3 have several implications for the design of this pilot applied systems science module. Notably, Study 1 highlighted the importance of dialogue for the development of consensus, and for students' perceptions of the efficacy of the IM methodology. Study 2 demonstrated the importance of providing adequate instructional support in the context of collaborative discourse tasks. More specifically, Study 2 reported that process-level prompts were more effective than task-level prompts in supporting varied and complex forms of collaborative argumentation, as well as harnessing higher levels of perceived consensus, and perceived efficacy of the IM methodology. Last, Study 3 reported that peer-to-peer prompts, as opposed to facilitator-driven prompts, are an effective means of supporting varied and complex collaborative argumentation, when delivered in conjunction with the provision of instructional support in the form of a graphic organiser, and a graduated approach to passing over control of prompting from the facilitator to students. Study 3 also reported on the benefits of peer-to-peer prompts for perceived consensus, perceived efficacy of the IM methodology, enhanced levels of team orientation, and reductions in discomfort in group learning.

Each of these findings has significant implications for a curriculum which focuses on collaborative learning in the context of applied systems science projects using the IM methodology. First, given that students were working in IM project groups for the majority of the semester, developing a capacity to build consensus was seen as advantageous to support on-going group activities. As highlighted in Chapter 2, consensus-building supports the development of positive expectations about the implementation of decisions reached by a group, and higher levels of overall satisfaction (Mohammed & Ringseis, 2001). As such, this module was designed in line with the conditions which promoted consensus in Studies 1-3, that is, by providing extensive opportunities for dialogue, providing process-level prompts during facilitated tasks, and supporting peer-to-peer prompting through the use of instructional supports and facilitator modelling.

Similarly, students' perceptions of the efficacy of the IM methodology was an important consideration in the design and implementation of the curriculum. Consistent with the results of Studies 1-3, providing opportunities for open dialogue, providing effective facilitator prompting, and supporting peer-to-peer prompting, was central to the learning

activities in the module and this, it was believed, would positively influence students' perceptions of the IM methodology during the module.

Further, the results of Study 3 suggest beneficial effects of peer-to-peer prompting for the enhancement of students' perceptions of team orientation, as well as reducing feelings of discomfort in group learning. As the module involves prolonged group interaction and learning, developing a sense of team orientation may have significant advantages for student groups, whereas feelings of discomfort may have significant disadvantages. Team orientation, as outlined in Chapter 2, is associated with positive cooperative behaviours such as team member exchange, empowerment, team performance, and team productivity (Bell, 2007; Eby & Dobbins, 1997; Wang et al., 2014). Also, while positive perceptions of group work are associated with feelings of achievement in students, negative perceptions are not (Volet & Mansfield, 2006). Therefore, creating a collaborative learning environment which cultivates team orientation in students while also reducing levels of discomfort in group learning, by providing students with the skill and opportunity to engage in peer-to-peer prompting, was an important consideration in the design and implementation of the module.

To summarise, the pilot curriculum reported on in this chapter, built upon the findings of Studies 1-3 in the following ways.

- 1) This module was heavily weighted towards student-student dialogue and interaction, as opposed to more traditional, teacher-centred approaches. During the first half of the module (Weeks 1 – 6), the second half of each 2-hour class was devoted to collaborative work. Towards the end of the semester (Weeks 7 – 12), when students were primarily focusing on their specific, group-selected IM projects, the amount of time spent on collaborative activities increased further.
- 2) Throughout the duration of the module, a strong emphasis was placed on the use of prompts as a means of instructional support for students' various collaborative activities. For example, students were presented with the graphic organiser used in Study 3, and were encouraged to engage in supportive peer-to-peer prompting during collaborative tasks.
- 3) Related to the above, training of students in the facilitation of IM systems model-building involved a graduated approach of modelling, coordinating, and passing over control of the process to students, as used in Study 3.

A more detailed description of the of module is presented in Section 6.6., which provides a weekly overview of in-class activities.

6.5. Method

6.5.1. Students

This module was offered as an elective module to third-year undergraduate psychology students. While all students studied psychology, among the 23 students who enrolled in this module, 22 studied a second degree subject also. These ranged from: English, French, Information Technology, Geography, Sociology, Political Studies, and Economics. Notably, Warfield in his *Horizon College* proposal, envisioned students from various disciplines learning together, and bringing their knowledge and experience from multiple domains together in a process of collaborative system design. For the purpose of group projects, students were divided into five groups of 4 or 5 students, beginning in week two, and an effort was made to include a diversity of second-subject expertise across each project group.

6.5.2. Facilitators

To provide sufficiently intensive instructional support and facilitation across the five groups, the module was co-delivered by two instructors, the primary author of this thesis, and his supervisor.

6.5.3. Tools used

Interactive Management

As described in Chapter 1, IM is a computer-supported systems science methodology, which involves a number of steps, including: (a) idea generation, clarification, and discussion, (b) voting on ideas to be carried forward for systems model-building, (c) systems model-building using ISM, (d) review and analysis of the resultant systems model (or problematique), and (e) generation of options or solutions to address the problematic situation. In this module, students were instructed in the use of the IM methodology, including the ISM software, for the purpose of completing their group project.

Rationale

Rationale is an Argument Mapping (AM) software which has been applied in a variety of educational contexts, including primary, secondary, and university education (van Gelder, 2007). Rationale has also been used in research on cultivating critical thinking skills (e.g., Dwyer et al., 2011). Rationale allows the user to generate a graphical representation of an argument in response to any position or *claim*. By means of a simple drag-drop function, users can position a central *claim* at the top of a blank map, and connect colour-coded

argument components including *supports* or reasons for the claim (green), *objections* or reasons against the claim (red) and *rebuttals* or counterarguments to *objections* (orange).

6.6. Weekly progression

The module was delivered in a 2-hour classroom session, once a week, for 12 weeks. The module was delivered in a large classroom, with tables and chairs which could easily transition from facing the front of the room (i.e., towards the facilitators and projector screen), to a series of smaller “pods”, each made up of two tables, forming a square work station for small group work (i.e., for 4 or 5 students). The weekly schedule for the module was as follows:

6.6.1. Week 1: Introduction to collaborative enquiry and applied systems science

In week 1, students were provided with an overview of the module including: module objectives, learning outcomes, weekly schedule, and assessment details.

The module objectives as set out in week 1 include:

- To provide an introduction to collaborative enquiry and applied systems science through the use of a number of different pedagogical approaches, including a combination of lectures, class exercises, class discussions, and collaborative exercises.
- To provide students with a grounding in collaborative enquiry skills and applied systems science, with a focus on real world applications.
- To provide students with training in group facilitation, collective intelligence, and systems thinking techniques.
- To provide students with an opportunity to work collaboratively on an applied system design challenge.

The learning outcomes specified that, by the end of the semester, students should be able to:

- Describe the role of collaborative enquiry in applied settings such as: education, health, business, technology, community, and science.
- Discuss the role of dialogue, critical thinking, systems design, and teamwork in collaborative enquiry.
- Gain skill in the use of computer-supported collaborative learning tools, including Rationale and IM.

- Develop collaborative systems models describing problematic situations.
- Apply IM to an applied problem.

As regards assessment, the module was continuously assessed, with the division of marks as follows:

Table 15. *Assessment: Division of marks*

<i>Assignment</i>	% of total mark
Weekly attendance	10
Weekly participation (as rated by peer monitoring)	10
Weekly reflective journal entries	30
Group project (group report & individual reflection)	50 (35 & 15)

As such, week 1 primarily involved “setting the scene” for the semester. In keeping with the *student-centred* approach to the module, students were also given a chance to introduce themselves to the wider group, and share their motivations for selecting this elective module, including the skills they hoped to develop, and how they hoped to apply these skills in their future career. The responses from students regarding potential future applications of the skills to be learned on this module ranged from: applying collaborative problem-solving skills in NGOs, to bringing a systems perspective into organisational settings, to applying CSCL technologies in a teaching capacity.

6.6.2. Week 2: From collaboration to collective intelligence

In the first half of this class, students were given an introduction to the concept of collaboration, with a focus on both theoretical and applied understandings. Students were also introduced to the concept of Collective Intelligence, including an introduction to John Warfield and Systems Science. Students were also introduced in to the 3Ts model of Applied Systems Science Education (Hogan et al., 2015). This model, presented in Figure 18 below, highlights three key layers of applied systems science education: *Tools*, *Talents*, and *Teams*. The *Tools* layer includes a focus on tools that support group deliberation and systems

thinking, specifically in this module, IM and AM tools. The *Talents* layer includes a focus on individual competencies that support collaborative systems design work, including critical thinking, and systems thinking. The *Teams* layer includes a focus on group dynamics and key factors associated with successful teamwork as presented in Salas et al.'s (2005) Big 5 in Teamwork model.

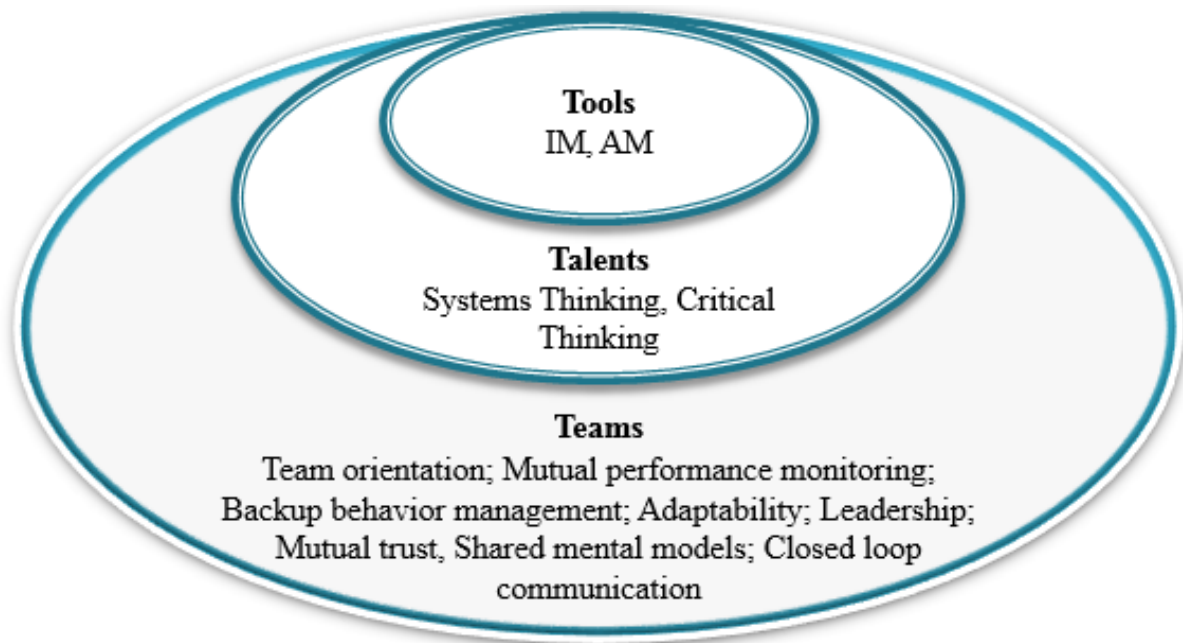


Figure 18. 3Ts model (Hogan, Harney & Broome, 2015). IM = Interactive Management; AM = Argument Mapping

In the latter half of the class, students were also allocated to their groups for the remainder of the semester. At this stage, students were briefed on the peer monitoring component of the course. Students were reminded that group work is central to the module, and that they would work with their group on a number of in-class exercises, follow-up exercises between classes, and a group project. As such, students were given the opportunity to generate, discuss, and agree upon, a set of criteria for peer monitoring of their participation within their groups. In particular, students were asked to generate a set of potential indicators of teamwork which could be used to monitor progress and engagement of their group during their shared tasks. Students were requested to submit potential indicators by means of a Google Spreadsheet, in advance of their week 3 class, and be ready to engage in a discussion about these potential indicators during the class.

6.6.3. Week 3: Introduction to Argument Mapping

At the beginning of the week 3 class, the instructor facilitated dialogue in relation to the peer monitoring criteria generated by students. Each criterion was clarified and discussed by the group. This was followed by a vote, completed anonymously via Google Spreadsheet, to decide on 5 key indicators to be used throughout the semester. Each student was given a link via email to a separate Google Spreadsheet, which contained all of the proposed peer monitoring criteria generated by students. Each student was asked to rank the five criteria which they believed to be most important for inclusion in the peer monitoring task. These criteria were applied at both the group level (e.g., My group is dependable) and in relation to each individual in the group (e.g., Peer X is dependable). After an agreed upon deadline for this rank-ordering, the votes and ranks were compiled by one of the instructors. The 5 criteria which emerged were:

- Peers in my group do their share of the work/ Peer X does their share of the work
- My group is dependable/ Peer X is dependable
- My group provides support (e.g., information, advice, resources) to each other /Peer X provides support (e.g., information, advice, resources) to others
- My group as a whole participate in conversations /Peer X participates in conversations
- My group contributes ideas/Peer X contributes ideas

During the remainder of the class, students were introduced to AM, including an overview of the Rationale AM software. This class guided students through a series of AM and critical thinking exercises, which they completed in their groups. The AM exercises, the instructional validity of which have been reported by Dwyer et al. (2011), involved learning how to graphically structure an argument, as in the exercise (Figure 19) below. This exercise, one of the first AM exercises which students completed, introduced students to the process of graphically representing arguments for and against a claim. For example, in Figure 19, students are provided with the central claim, “People should only work a 35-hour week”, as well as the two supports (green) “because working for longer causes stress” and “because a 35- hour week maximises work efficiency”. To complete the task, students had to add objections (red) to each of the existing supports, as well as develop a new line of argument, beginning with an objection to the central claim, followed by a support for this objection.

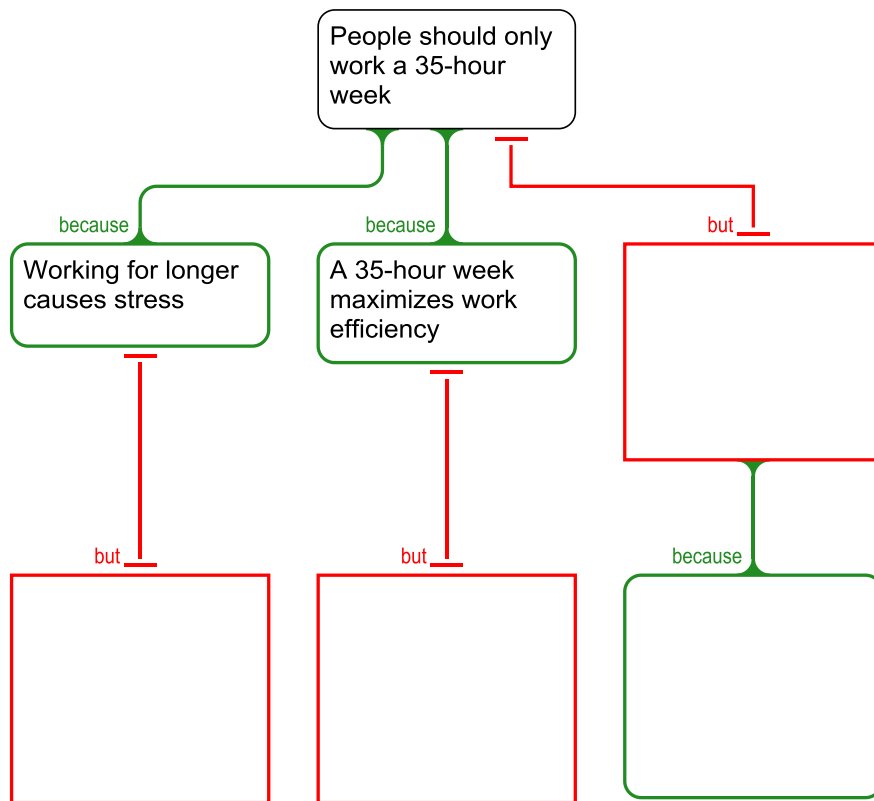


Figure 19. Sample AM exercise

As such, this exercise was primarily aimed at teaching students about argument structure. Later exercises, involved evaluation and analysis of the credibility of an argument based on its source, as in Figure 20 below. In this case, students were presented with the central claim, “Aggression is biologically caused”, as well as series of supports and objections. The task for students here was to identify the type source of the argument (e.g., research, personal experience, common sense belief) and discuss its credibility.

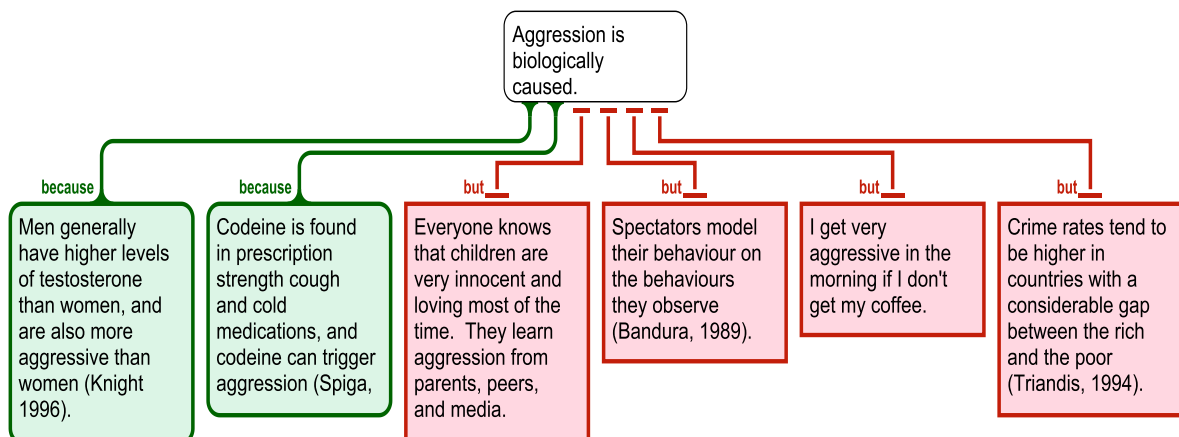


Figure 20. Sample AM exercise

Week 3 ended with students being introduced to the weekly reflective log exercise, which was to be completed from weeks 3-10. Specifically, after each class, students answered a set of reflective questions, in no more than 150 words (for each question). A separate Google Document was set up for each student to complete their weekly entry. The weekly questions were:

- What did I do to advance my learning this week? (e.g., What did I read/write/watch/listen to? What did I think about?)
- What did I learn? (e.g., How does this relate to my previous understanding/experience of the topic? How can I apply this knowledge in future?)
- What other reflections, opinions or observations can I offer on what I have learned this week?

Sample of student reflections from week 3:

“For me, the most significant aspect of the class was working together as a team, and getting the opportunity to explore and challenge each other, and our thoughts and ideas on different topics. Initially, I noticed that each member of my group had great ideas for each topic we discussed, yet all our ideas were different. However, when we put them all together, they worked well as an overall structure for the maps and led to a very fun, easy group discussion. This meant we did not argue over the same point, and we all took our chance to explain and interpret our own points.”

“What I learned this week is that with the right incentives and good communication group collaboration can work as well if not better than working on a project on you own. I think this is as a result of us in the group sharing ideas and discussing them in an open-minded way. This is in contrast to other group projects I have worked on in the past which for the most part did not go as well.”

6.6.4. Week 4: Peer Feedback and Prompting, and Introduction to Interactive Management.

Week 4 began with a presentation and discussion of the concepts of feedback and prompting in the context of collaborative learning, covering material from the theoretical and empirical literature on feedback and prompting, and also a summary of the experimental results from Studies 2 and 3 in the current thesis. Students were introduced to the prompts used in the process-level condition in Study 2, and the graphic organiser used in the peer-to-peer condition in Study 3. Students were also introduced to the CACS and how prompts may be

used to elicit varied and complex forms of argumentation. Following this, students engaged in an AM exercise, in which they used peer-to-peer prompts from the graphic organiser, while engaging in collaborative argument mapping. This AM task was followed by a discussion of the use of prompts, and the types of arguments generated during their AM task, with reference to the CACS codes.

In the second half of the week 4 class, students were introduced to the IM methodology. This involved an overview of the steps in the process, from idea generation to structuring. To make this process more concrete for students, students engaged in a mock IM session, facilitated by the instructor, around the trigger question, “What are barriers to effective group problem-solving?”. Students were guided through the process of generating ideas, voting on ideas, and structuring interdependencies between ideas. As this was conducted as a learning exercise, the focus was not to complete a structuring session, or generate a complete systems model, but rather to work through six to eight relational questions, while providing guidance and instruction to students on key aspects of the process from the perspective of a facilitator. Students were also presented with sample complete systems models from previous projects, and provided with guidance on how to interpret these structures.

Sample of student reflections from week 4:

“A lot of the work focused on during this class was based on groups, and how groups should not have a team leader, but contributors. This is very important I think, and it should be used in many different ways throughout the university.”

“While I’ve always understood the utility of feedback, I had never considered that there were discrete types before. With my newfound understanding of the intricacies of feedback, I hope to be able to provide even more effective feedback to my group members and on teams I will likely be a part of in the future, either in school or in my career. I will also have a better understanding of the meaning and motivation of others who are providing feedback to me.”

6.6.5. Week 5: Introduction to Collaborative Scenario-Based Design

In week 5, students were introduced to the process of SBD (see Figure 21). It was noted that all of their group projects would involve the development of technological solutions to systems problems. This involves connecting the IM methodology with SBD methods (Rosson & Carroll, 2000) used in technology design projects. The first 30 minutes of the class was delivered in lecture format. Students were presented with examples of SBD in applied

projects, and the many uses of the approach, including a variety of EU projects the instructors had worked on. Following the lecture, the remainder of the class consisted of a collaborative exercise in which students worked together to design a mock interface for assisting authors in designing children’s e-books. This aligned with one of the EU projects the instructor team were working on at the time, the Q-Tales project. This process involved students considering the needs of various potential users, and mocking up a design with affordances which could assist authors in creating children’s e-books. Students worked with A1 paper, and mock wireframe templates, coloured pens and sticky notes, to complete their design. Students were also asked to work on their design with their group outside of class, and present the completed version at the beginning of the week 6 class.

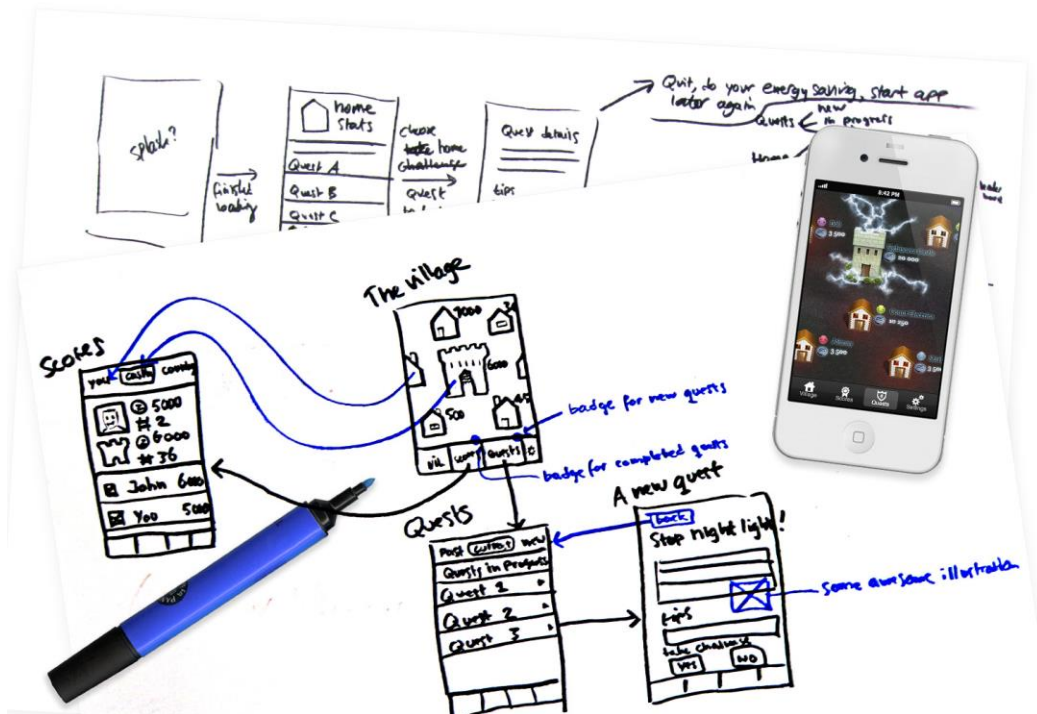


Figure 21. Example image of a scenario-based design activity

Student reflections from this week 5:

“This experience really aided in connecting the group and also in helping us to better communicate with each other on another level. This task taught me the importance of communication and how best to get my point across as well as taking others’ thoughts and opinions into consideration and how to work together as a team to develop one idea.”

“The task was very enjoyable as the group had the opportunity to brainstorm and work together, with everyone giving their own ideas and suggestions. We all worked well together

as a group with this task which made it more enjoyable. For me personally this was a new experience, developing the framework for an interactive book, which made it very interesting. We also could include drawings and pictures to our pages which made the task fun. Initially I was confused as to what the task was exactly, but I found my group helpful and approachable, therefore I quickly understood what we had to do. Having experienced this kind of task, I now feel confident in brainstorming with a group and given input and ideas to them. I feel this week has improved my ability to brainstorm and to help me feel confident with given my own ideas to a new task.”

6.6.6. Week 6: Scenario-based design presentations, and introduction to group projects

Week 6 began with student presentations of their collaborative SBD for a children’s e-book design ecosystem. The remainder of the class was devoted to students choosing the topic for their group project. Students were given a description of the basic requirements of the group project, which were as follows:

- Develop a systems model depicting the interdependencies of barriers influencing this problem.
- Engage in scenario-based design to propose a solution to the problem.
- Write a report detailing the steps in the process, and present the results of your collaborative enquiry.

Each group was then given a brief overview of three potential projects, each of which addressed a different problem. They were asked to individually read each project overview, including two short journal articles relating to the topic. Following this, each individual was asked to generate a set of reasons for and against choosing each project. Once they had done this individually, each group was asked to engage in a discussion before collectively choosing their group project.

The three potential project topics are presented below, and the number of groups who chose each topic is provided in parentheses:

- Topic 1: This project involves the development of a systems model describing the barriers to adherence to contraception among university students, and subsequent scenario-based design of a technology-mediated solution that will enhance adherence to contraception among university students (2).
- Topic 2: This project involves the development of a systems model depicting barriers to the development of literacy skills in children and adolescents, and subsequent

scenario-based design of a technology-mediated solution that will enhance literacy skills in children and adolescents (0).

- Topic 3: This project involves the development of a systems model describing barriers to transparent, open democracy and government, and subsequent scenario-based design of a technology-mediated solution that will enhance transparent, open democracy and government (3).

Sample of student reflections from week 6:

“In the second half [of the class] we were introduced to the topics in which we could choose for our project. This was really enjoyable as we all got really involved. In order to make the best decision we decided to look at each of them objectively. Unfortunately, we didn’t have the time to run through them all and so we plan to meet up to discuss this further before next week’s class.”

“We took most of the class to each read through articles given to us and then discuss those articles with one another. This exercise was very helpful in not only giving us a clear idea of what we would be studying more in depth for our project, but also in allowing us to practice analysing articles and being able to discuss them with each other in an effective way.”

6.6.7. Week 7: Cooperative reading

Students arrived to class in week 7 having chosen their topic for their group project. Thus, week 7 began with an overview of the steps each group would take in completing their projects, including:

- Researching their topic by reading journal articles.
- Compiling a set of barriers (e.g., to government transparency) based on their reading.
- Categorising this set of ideas.
- Prioritising the 12 most crucial barriers for IM systems model-building.
- Engaging in collaborative systems model-building.
- Generating options for overcoming key barriers.
- Using SBD to develop a mock-up of a solution to address the problem.
- Writing a report, as a group, on their project, including a detailed account of each of the above activities.

Students were also reminded of the importance of effective teamwork, and engaging in productive, supportive, peer feedback and prompting throughout their collaboration.

Following this overview, students engaged in cooperative reading in their groups. Each group was assigned two project-relevant journal articles to read, with two group members reading each paper. Once each student had read their paper, they took turns to summarise the key themes which emerged from their reading, such that by the end of the process, each group member had a clear understanding of the scope of the paper. During this task, the two instructors observed each group, offering guidance on the cooperative task where necessary.

Students were instructed that such cooperative reading is critical to their groups' ability to read, analyse, and assimilate the depth and breadth of information needed to inform their project. As such, for the remainder of the class, students were instructed to engage in a search for relevant journal articles, during which they collaboratively compiled a set of relevant papers using the library database, and assigned two journal articles to each group member to read ahead of the next class. Further, each student was instructed by the facilitator to highlight 5-10 critical points from their reading relevant to the problem situation they were addressing, and arrive in week 8 ready to discuss these critical points with their group, and collaboratively develop a shared understanding of the problem field.

Sample of student reflections from week 7:

"I really enjoyed this week, between meeting up with my group to discuss the project topics to then, choosing the topic we will work on. I think the exercise we did in class of two people reading the one paper and sharing their opinions was very beneficial. I think I will even suggest it to my group that we try it again in our future work."

"This activity proved to be very beneficial, as I did in fact bypass some information that was relevant to our question. I also found it very helpful because with some information I found difficult to understand, my partner could share some light and vice versa which made the process less daunting and quicker. I also found it beneficial that two others in our group had a separate reading, as they could share further light on our reading and vice versa, overall our group not only extracted the most of one reading by having two dissect it but we also collaborated knowledge with the two readings, therefore shared knowledge helped singular knowledge grow."

6.6.8. Week 8: Idea generation

Each group arrived into class on week 8, having read eight (or ten) papers which related to their project topic. Further, each student arrived ready to discuss a set of 5-10 key points raised by these papers. As such, the class began with students in each group taking turns to present these key points, and engaging in discussion with their group. The purpose of this discussion, as instructed to students, was to allow each group to begin the process of idea generation, i.e. generating a comprehensive set of barriers which influence their problem focus in their project. Therefore, following this initial open discussion, each group engaged in *ideawriting* as a means of generating a set of barriers. Ideawriting, as described in Chapter 1, involves a number of steps: (a) presentation of a stimulus question to participants, based on their project focus (e.g., what are barriers to adherence to contraception?); (b) silent generation of ideas in writing by each participant working alone; (c) exchange of written sheets of ideas among all group members, with opportunity for individuals to add ideas as they read others' papers; and, (d) discussion and clarification of unique ideas. Thus, by the end of this exercise, each group had generated a set of key barriers which influence the problem focus of their project.

Students were again asked, ahead of week 9, to engage in further reading and idea generation, in order to develop an exhaustive set of barriers in the context of their problem focus.

Sample of student reflections from week 8:

“What I continue to find striking in this process is just how complex the systems are that underlie societal problems. When we first began brainstorming barriers, they seemed simple and discrete, but as we move forward it becomes clear that they are all interconnected. A lack of education about contraception makes discussing it more taboo, which in turn leads to embarrassment, which in turn results in a lack of communication, etc. Determining the proper entry point in the long chain of barriers will require some finesse, but I think that taking the time to understand the system fully will result in a more effective intervention, rather than using an availability heuristic to decide what the most obvious barrier is and only focusing on that.”

“To comprehend the task more clearly and efficiently required an intense level of commitment and work from each member of the group, both individually and collaboratively. Individually we had to understand our readings and prepare our notes, but I found my

deepest level of learning came from the collaborative element; in that my efforts to convey the fundamental concepts I identified in my assigned readings allowed me to understand them more clearly myself. The discussion and constructive criticism that evolved from what I proposed allowed me to clarify and elaborate on my own thinking, which I feel I would not have been able to achieve through reading alone.”

6.6.9. Week 9: Categorisation and systems model-building

Students arrived to class in week 9 with a full set of barriers generated in response to their stimulus question for their chosen topic, owing to efforts during the week 8 class, and also their collaborative efforts outside of class. The next step in the project process then, was for each group to arrange their barriers into distinct categories. This process began with the facilitator, demonstrating the *paired comparison method*. This method involves initially writing each of the barriers on separate A4 pages, and posting these on a wall. Then, the facilitator selects one barrier at random, and places the selected barrier, in turn, next to each barrier on the wall, asking the same question in each case: “Do you see any commonality between this barrier [in hand] and this one on the wall?”. If the group perceived the barrier to be similar to one of the ideas on the wall, they are grouped together, one idea below another, as part of a potentially emergent category. If the selected barrier is not in any way similar to any another barrier statement, it is placed into a column of its own on the wall, and may at a later point be placed into an emergent category. This process proceeds until a set of clear categories emerges. As this is a rather complex task, the facilitator initially demonstrated the process with one group, while each of the remaining groups observed. Once the facilitator had demonstrated four or five rounds of comparison with each group, group members took on the role of facilitator in turn. Categorisation continued for the remainder of the first half of the class, as each of two instructors observed and offered guidance where necessary.

The second half of the class involved the beginning of students’ collaborative systems model-building. First, however, it was necessary to reduce the overall set of barriers, to a set of 10 which would be carried forward to the IM structuring stage. As such, each member cast votes on their barriers by placing red stickers on the five barriers which they believed to be most critical. These votes were then counted in each group, and a set of ten distinct, top-ranked barriers emerged, which were carried forward to the systems model-building stage. In each case, for each group project, these barriers represented critical components of the problem that needed to be understood further, specifically, by reference to their interdependencies as part of a broader systems problem.

As with the paired comparison stage, the systems model-building stage began with a demonstration from the instructor. This involved the instructor facilitating the first three relational questions for one of the groups, while the other groups observed. Again, at this stage, the instructor reminded the groups of the kinds of prompts which may be useful during this exercise (see Figure 22 below.) Then, the instructor took a step back, and observed the first student facilitator from this group, offering guidance where necessary, before moving on to observe the remaining four groups, with the aid of the second instructor, as students in each group took turns in adopting the role of facilitator.

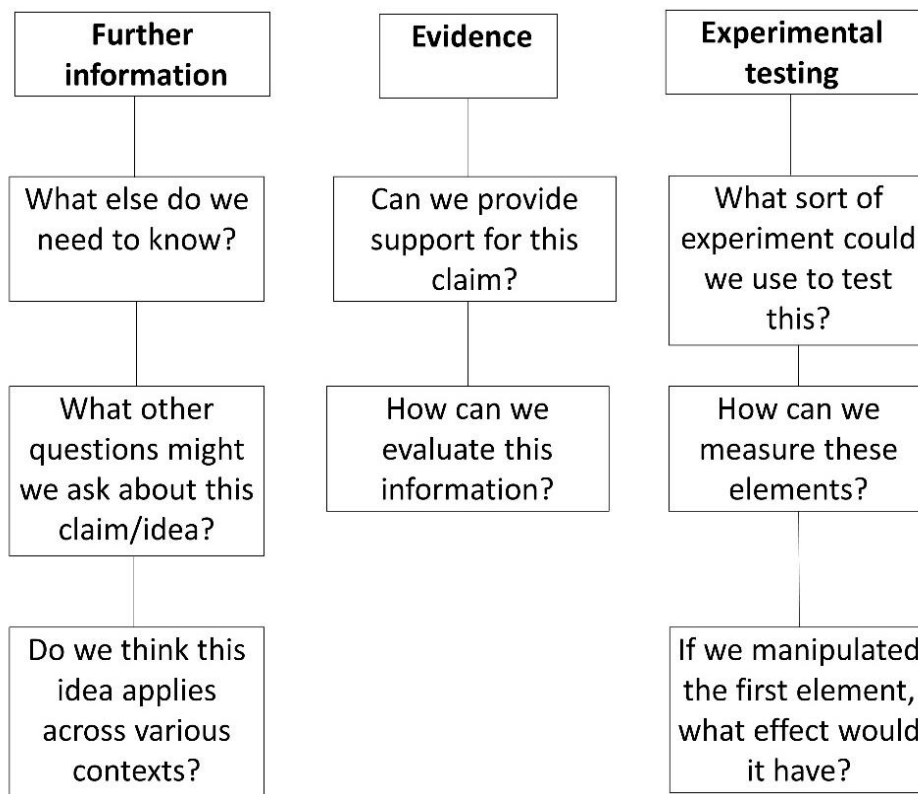


Figure 22. Process-level prompts used by students during systems-model building

During systems model-building, students were also engaged in another, complimentary task. As a means of displaying their rationale for decisions regarding the relationships between barriers, each group was asked to generate argument maps for a selection of three relational decisions. An example of such an argument map can be seen in Section 6.8.2.

Students proceeded with this task until the end of the class, but given the time-consuming nature of systems model-building this task was not expected to be completed in-class. Rather, students were informed that they could complete this process during the week 10 class.

Sample of student reflections from week 9:

“This [categorising task] was extremely time-consuming, however, I began to notice how much our categories which we had already developed changed. This gave us all an insight into how to break down huge tasks properly, ensuring that each aspect was considered properly. This method can be applied in future tasks that involve a large cognitive load.”

“The important role of the facilitator was brought to my attention within this class. The facilitator not only has to accurately interpret what individual members of the group are saying they must also ensure that all members understand the points being made. They also are responsible for probing questions to the group to generate more discussion and develop a deeper understanding about specific ideas.”

6.6.10. Week 10: Systems Model-Building (continued), and generation of options

During the week 10 class, students completed their systems model-building, while the instructors observed and offered guidance where necessary. Students were again reminded to engage in prompting during this task, to support their collaborative argumentation. Once this systems model-building task was completed, students were encouraged to discuss the emergent model with their group, and begin considering options which would help to overcome the problem at hand, based on the model and the relationships between barriers within it. After using *ideawriting* to generate a set of high impact, feasible options that would help to overcome key problems in the problem field, students were advised to consider these options in light of the final stage of their project – scenario-based design – during which they were required to develop a mock-up of a potential social-technological solution to the problem at hand. To assist student in their design thinking, mock scenarios were provided for each project, to serve as prompts for the generation of solutions. These scenarios are presented below.

Transparency and e-governance scenario:

“Sean is a public administrator in the Galway City Council. Sean holds a town hall meeting about some proposed changes in the city. He quickly realised that citizens feel left out of the process, and don't feel listened to by the council. Sean decides he wants to make decision-making in government more transparent, and get citizens more engaged in the process. Sean decides to work with Amanda, a programmer, to develop a technological innovation to

increase transparency and citizen engagement. Sean wants this platform to be as accessible as possible, allowing people with limited computer skills to use it.”

Adherence to contraception scenario:

“Sharon is a Public Health Officer. She often visits schools as part of her work to talk to students about sexual health. Sharon notices that many students have limited, and often incorrect, knowledge about contraception. She also notices that students and teachers alike are reluctant to have an open discussion about this. Sharon decides to work with Tom, a programmer, to develop a technological innovation to increase adherence to contraception.”

Sample of student reflections from week 10:

“I found this class beneficial as I had the chance to be the facilitator; this gave me the opportunity to show my group the work I had focused on prior to the class. I had the chance to ask probing questions which my group found helpful as it generated information that was not initially thought of and it helped our group generate further ideas on some barriers we had to discuss.”

“I believe our group worked really well this week. The software that was used in class is extremely beneficial. ISM allowed our group to focus on the relationship between 2 barriers at a time. This was a great way to generate more ideas and good discussions within the group. Using Rationale was also extremely beneficial. Once our ideas were mapped out in front of us we were able to see the links between certain barriers. These two software tools are also very adaptable, they can be used within any problem-solving based project and so I know that they will help with future projects.”

To provide further support for their design thinking, students were instructed in the use of *user stories* as a means to translate key design ideas into specific functionalities of a technological solution that would help to overcome barriers in their problem situation. All the user stories generated by students were generated in the form:

As User Type _____, I want _____, so that I can _____.

Students again used the *ideawriting* method to complete this task, adding distinct user stories to a user story template sheet containing the phrase above, before swapping their *ideawriting* sheets with one another. For example, a student completing the adherence to contraception project, may have suggested:

As a student health nurse, I want accurate and accessible information dispelling myths about contraceptives, so that I can provide it to students

Students were also provided with A1 paper, coloured pens, wireframe templates and sticky notes, to complete their SBD mock-ups, informed by the user stories. This task was to be completed before the end of the week 11 class.

6.6.11. Week 11: Scenario-based design

During the week 11 class, each group was given time to complete their SBD mock-up of a potential solution to their problem focus. Figure 23 below presents an example of a scenario-based design from one student group. This example depicts functions of a mobile application which could be used to address *barriers to adherence to contraception*. As can be seen in the first two frames, users can create an account on the app, and log-in to access information relating to health and relationships. The second two frames provide examples of such information-related functions, which includes information on side effects of contraception, as well as addressing common myths about contraception, and access to a community forum for discussion and further engagement. This app is an example of a solution which, by providing information on common myths about contraception, may address the needs of the student health nurse in the sample user story provided in week 10.

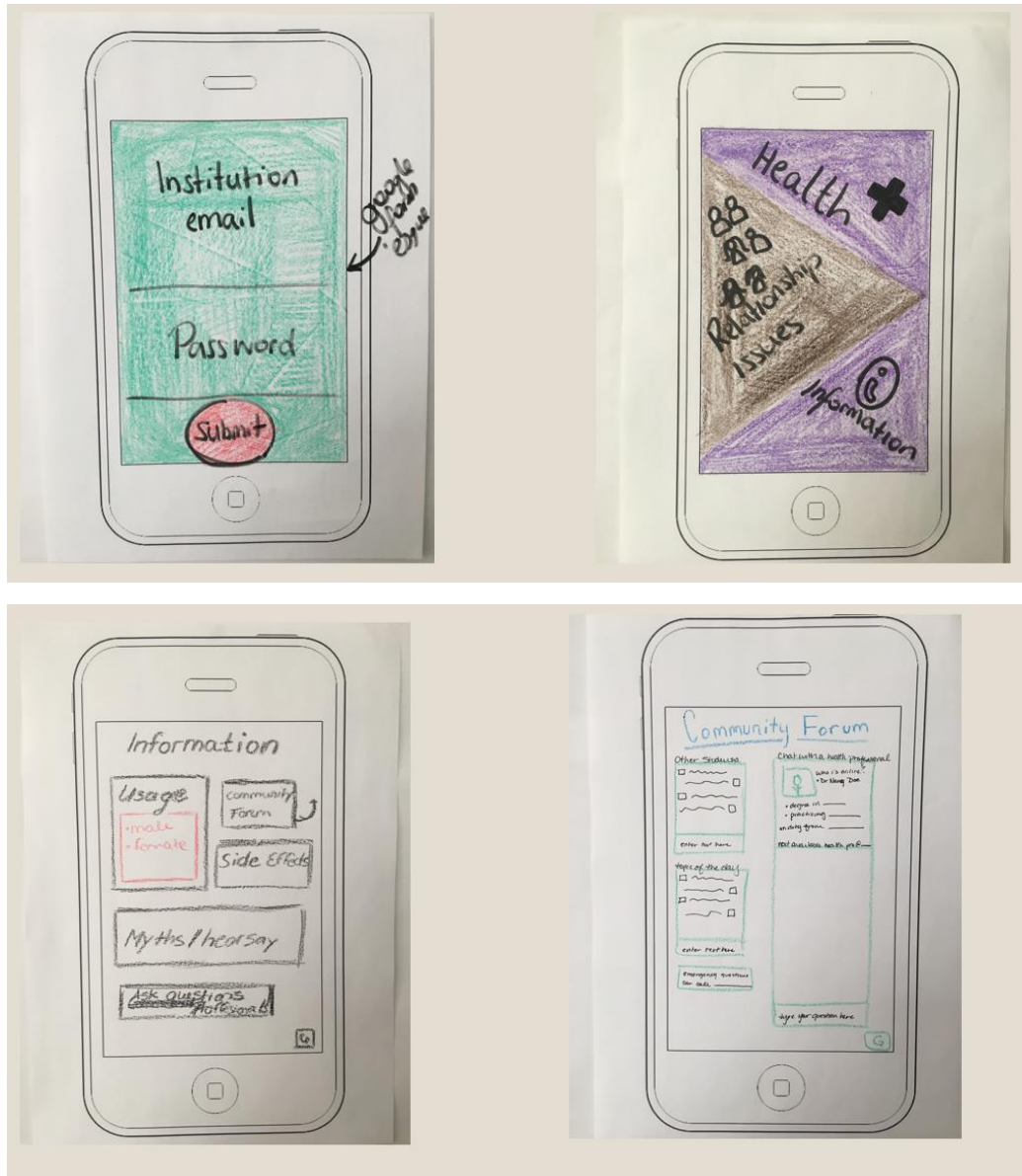


Figure 23. Sample mock-ups from a group completing the barriers to adherence to contraception project

6.6.12. Week 12: Project presentations

During week 12, each group presented the results of their project. This included an introduction to the problem focus, an overview of the methodology used, presentation of key results such as critical barriers and the developed systems model, as well as a presentation of the outcome of their SBD.

6.7. Design of group projects

As detailed above, students participating in the module spent seven of the twelve weeks engaged in group project work. Each project involved the exploration of a specific applied problem using an applied systems science approach grounded in Warfield's IM method, while also integrating Warfield's method with other collaborative methods including AM and SBD. Three of the five groups addressed the problem of *barriers to transparent, open democracy and government*, while the two remaining groups addressed *barriers to adherence to contraception among university students*. Each project involved several key collaborative tasks, including: researching and identifying barriers in the problem field, the development of a systems model which depicts the relationships between barriers, the development of options in response to barriers, and the scenario-based design of a technology-supported solution to address the problem. The project culminated in the writing of (a) a 4000-word group project, as well as (b) an 800-word reflection on the collaborative process from each individual. Below is an outline of the requirements of each of these tasks.

a) Group project write-up

- Introduction to problem area, including:
 - i. Defining the problem
 - ii. High level problem issues identified in the literature
 - iii. Gaps in the literature
 - iv. Focus of current group project
- A description of the project methodology, including:
 - i. Cooperative reading
 - ii. Idea generation
 - iii. IM structuring
 - iv. AM
 - v. SBD
- Results, including:
 - i. Journal articles reviewed (by whom)
 - ii. All categorised barriers generated (with citations for each barrier)
 - iii. Prioritised barriers (with number of votes received for each)
 - iv. ISM systems model (including description of the problem structure and core logic, drawing upon AM work)

- General discussion, including:
 - i. Main findings
 - ii. Interpretation of findings
 - iii. Implications
 - iv. Conclusions
- b) Individual reflection on the collaborative process, including:
 - Quality of deliberation by the group (e.g., arguments, evidence, conversational dynamics)
 - Quality of facilitation and peer-to-peer support
 - Time management, delegation, process management
 - Overall impressions on the group process and applied systems science methodology

6.7.1. Sample group project output

Figure 24 below presents an example of a systems model developed by one group in response to the *barriers to transparent, open democracy and government* topic.

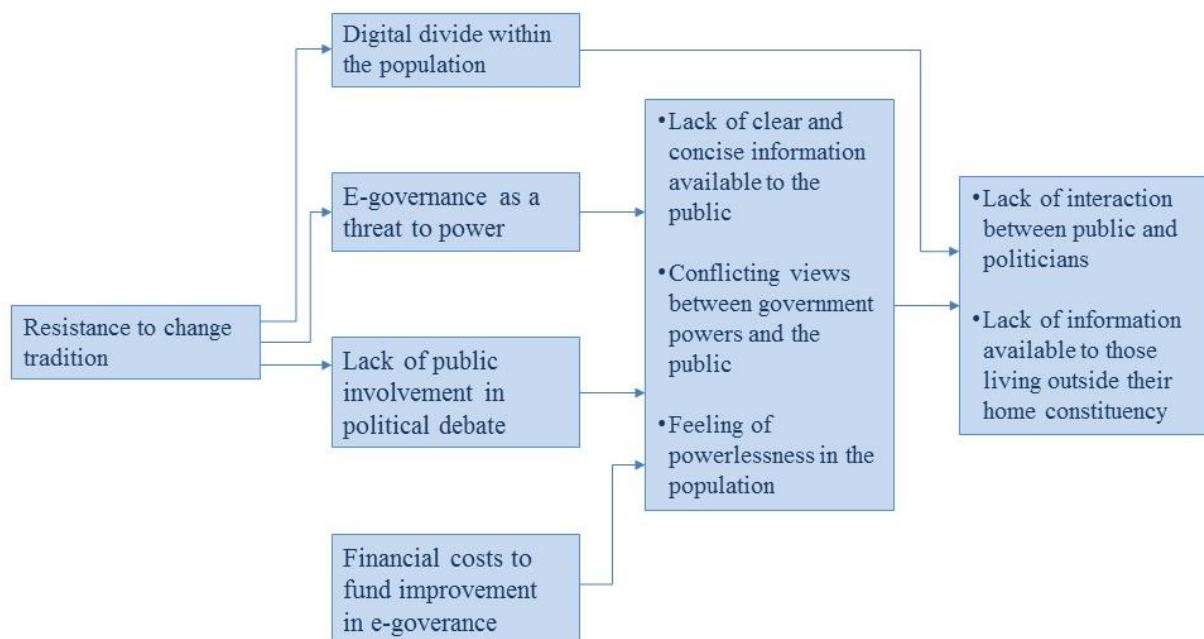


Figure 24. Sample problematique from a group project

In this case, the group in question identified 41 barriers to transparent and open e-governance, through multiple rounds of cooperative reading, discussion, and idea generation, before prioritising the 10 barriers in the structure above. As can be seen in the systems model,

resistance to change tradition was identified as a primary driver in this barrier structure. As such, *resistance to change tradition* was deemed to negatively impact *digital divide with the population*, *e-governance as a threat to power*, and *lack of public involvement in political debate*. *Digital divide with the population*, in turn, was deemed to negatively impact both *lack of interaction between public and politicians* and *lack of information available to those living outside of their home constituency*, both of which are in a cyclic relationship i.e. influencing each other. Both *e-governance as a threat to power*, and *lack of public involvement in political debate* were deemed to negatively impact *lack of clear and concise information available to the public*, *conflicting views between government and the public*, and *feeling of powerlessness in the population*, each of which are in a cyclic relationship, and subsequently negatively impact both *lack of interaction between public and politicians* and *lack of information available to those living outside of their home constituency*. Finally, another path of influence begins with *financial barriers to fund improvement in e-governance*, which was also deemed to influence the cyclic relationship between *lack of clear and concise information available to the public*, *conflicting views between government and the public*, and *feeling of powerlessness in the population*. This model demonstrates that students, taking turns acting as facilitator engaging in peer-to-peer prompting, are capable of generating complex systems-models in response to an applied problem.

6.8. Evaluating the module

From a curriculum evaluation perspective, this pilot applied systems science curriculum was designed and delivered with the following objectives in mind:

- To provide a "trial run" of an applied systems science education module consistent with the vision of John Warfield, centred on collaborative learning, IM-based systems design, and, more generally, skill in the use of tools, the cultivation of key talents, and the facilitation of teams (i.e., the 3Ts).
- To design and deliver a module which involves a student-centred, collaborative, explorative, immersive, problem-focused, and computer-supported approach to applied systems science education, consistent with the synthesis of Stahl (2015).
- To apply the prompting findings from Studies 2 and 3, to support collaborative argumentation during key phases of group work (i.e., idea generation, systems model-building).

- To provide a positive and engaging group work experience for students culminating in efforts to address a group-selected applied systems design challenge.
- To learn from the delivery of this applied systems science module, and support further design considerations and recommendations for future iterations of the module, and ongoing programme developments in the field of systems science education.

Evaluative insights in relation to these objectives, from both the perspective of students (gathered from weekly reflective journals and anonymous end-of-semester module feedback) and the instructor, are presented below. In the first instance, a number of high-level evaluative comments are organised around the dimensions of the 3Ts model.

6.8.1. Tools

Overall, observing students during the course of the pilot module, as well as reviewing their group projects and individual reflections, suggests that students developed proficiency in the use of core module tools, IM and Rationale, and they also perceived the tools to be effective in supporting their group projects. In general, students demonstrated a high-level of engagement with the both the IM and AM tools during the module. Notably, in the students' reflections, one student highlighted two distinct perceived advantages of the IM methodology: *“I feel that this stage of the process [ISM] has two distinct advantages. The first is that it allows you to put your barriers or solutions to a problem in a form of hierarchical structure so that they can be approached in an efficient manner. Secondly, I found that through the process of deliberation and voting at this stage the group can become stronger as a team as a result”*. This comment addresses benefits at the level of both *talents* and *teams*, stemming from the use of the IM structuring *tool*. Furthermore, the important role of prompting during this process was highlighted by another student: *“Question asking was an important dynamic that was included in the process and I think we used it very well to clarify our ideas.”*

Students also reflected positively on the IM methodology as a whole. It was frequently noted in students' reflections that the structured nature of the methodology, as well as the facilitation and instructional support, enhanced their capacity to focus on the project content as opposed to deliberating over the steps which needed to be taken next. Importantly, students' reflections suggested this structured process was instructive, but not overly restrictive. For example, one student reflected: *“Particularly useful was the presence of a structure or plan that guided the group through the realisation of the project. This led the*

group to be more creative and relaxed, because the members knew what they needed to focus on at each stage. Moreover, this step-by-step process facilitated a mindful and careful approach to work; without falling into the temptation of skipping stages. There were some fixed steps that the group was asked to take, such as the processes of idea generation, and categorisation of barriers. Nonetheless, each group was free to creatively enrich these basic structures with their ideas. It was as if the group had all of the instructions to build the project, but the project itself would not have been realised without the group. The applied systems science methodology was the empty vessel waiting to be filled with the members' ideas." Notably, this reflection is consistent with Soter et al. (2008), who propose that a constructive environment for collaborative discourse is one which provides structure and focus, while not being so rigid as to be prohibitive to generative learning.

6.8.2. Talents

Figure 24 above, depicting a systems model developed by one of the student groups, is also illustrative of their engagement with systems thinking, one of the key talents identified in the 3Ts model. Generating a systems model of the relationships between barriers in a problematic situation is a demanding task. However, in their reflections, students highlighted the facilitation provided by instructors, as well as their own developing facilitation skills, as key to supporting this systems thinking process: *"The quality of facilitation within the class was very high. During each discussion the instructor would join the group and add content, probe a specific question or ask for an evaluation of points being made. This encouraged a higher level of thinking within the group. In-group facilitation also occurred naturally, if two members had conflicting views on a certain issue one of the other members naturally assumed the role as a facilitator and mediated discussions."*

Furthermore, the critical thinking skills employed by students during the process of working on their group project is reflected in the argument maps which they developed when thinking about key claims relevant to the problem they were addressing. For example, the argument map presented below (Figure 25) was used by a group to explore the topic of oral contraceptive pill usage, during their project on *barriers to adherence to contraception*. In the argument map presented below, students provide supports, objections, and rebuttals in relation to the claim that, "The oral contraceptive pill is a safe and effective method of contraception". Notably, the students include references to research to support their

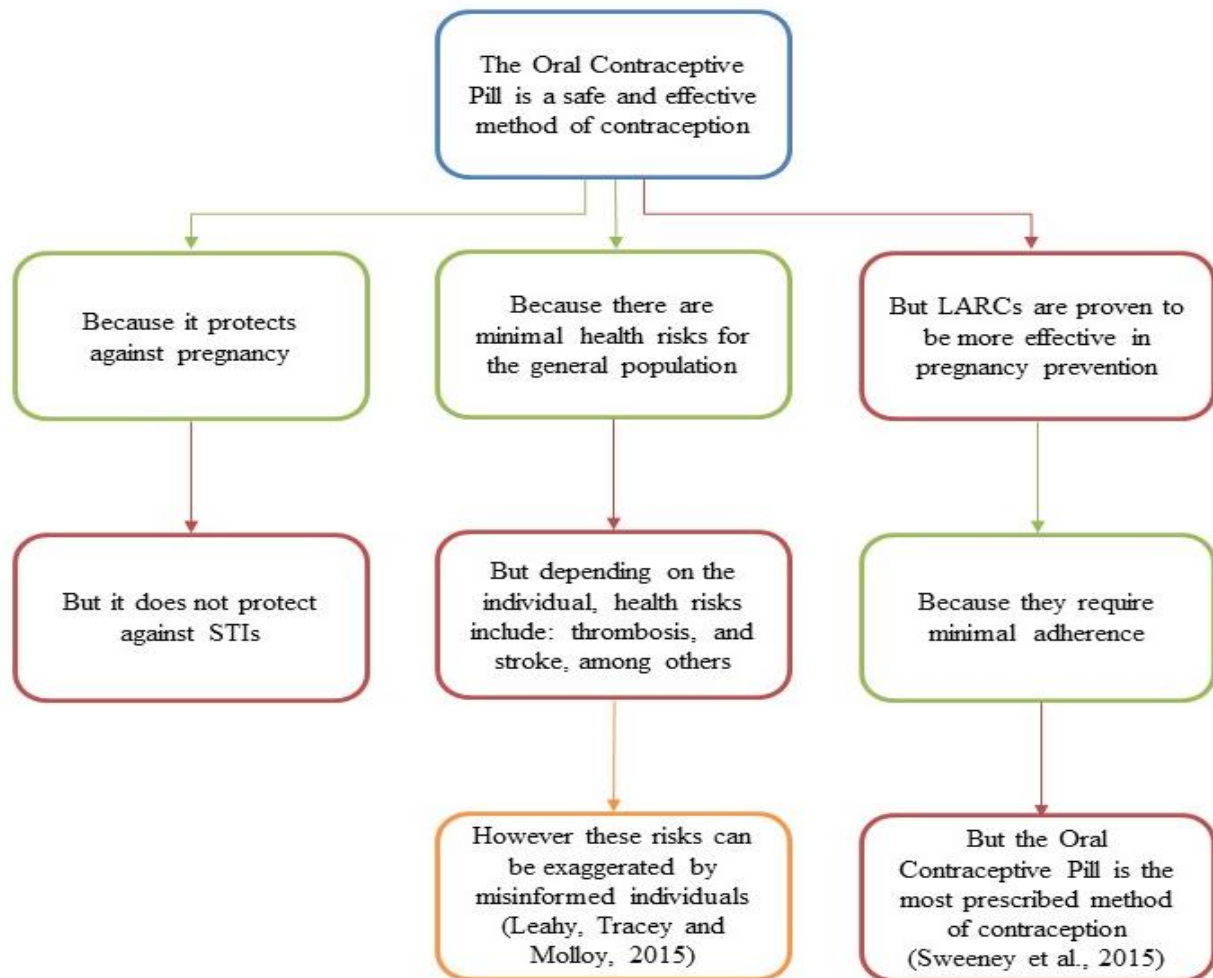


Figure 25. Sample argument map from a group project

arguments, and further elaborate on this research in their project report, showing that they have critically engaged with the literature during their deliberations.

6.8.3. Teams

A review of students' weekly reflective journal entries, as well as their end of semester reflection on the collaborative process, suggests that positive group dynamics and effective teamwork featured strongly throughout their work together inside and outside of class, and developed over the course of the semester. For example, a number of students drew contrasts between their experience of group work in this module, versus previous experiences. For example, *"I usually tend to avoid group projects, but I really enjoyed this group process. I found that I was gaining information and learning a lot from observing members in my group's behaviour. I felt that our combined strengths really came together each week, and we*

ended up being quite a strong team. I haven't really experienced that before in a group project".

Furthermore, students noted that the group project process, as laid out in weeks 6-12, helped to harness the teamwork in the group, by supporting their ability to communicate and provide feedback to each other. As one student noted: *"I think that the process encouraged the group's teamwork abilities in that it provides us with new ways to communicate our ideas and structure our feedback."*, and their ability to engage in team processes more broadly *"I feel that this module has been an invaluable experience and has taught me many skills that can be applied to all of my future endeavours both as a student and possibly a practitioner. Having learned the importance of sharing, supporting, participating and contributing I feel I can now offer and instil these qualities in group situations to come. Furthermore, the practical skills I have had the opportunity to experience have improved my ability to communicate efficiently to others. A skill that will undoubtedly be a positive attribute despite the challenge that is being undertaken."*

6.8.4. Student reflections on overall design and implementation of the module

Students also provided a number of comments which represent reflections on the module as a whole. These comments were predominantly positive. For example, a number of students commented that the module provided them with practical skills above and beyond their other modules. As noted by students: *"One of the best things about this class, is unlike many of my other modules, the real-world applications of the theories are highly practical"* and *"Overall I feel that this module was an invaluable experience and has equipped me with practical skills that I have yet to find as motivating and functional in any other component of the curriculum"*.

Interestingly, the process of recording weekly reflections itself was highlighted by students as a beneficial task. It was noted by students that completing these reflections each week helped them to recognise and incubate the learning gains from week to week, as well as maintain motivation. For example, *"The reflective log was interesting, not only to reflect on my own learning, but to motivate me to work hard for my group too, and to ensure I was doing a fair amount of work. It also helped me to understand the benefits of each class. I love the fact that I can now use these skills in many aspects of life. I feel quite interested in this line of psychology now"* and *"By having weekly assignments and tasks, I felt that I was focused and motivated, in contrast to other subjects, whereby it is easy to fall behind."* This perceived benefit of the reflective journal practice is interesting and resonates with research

which suggests that students often fail to realise how much they have learned in team-based learning (Michaelsen & Sweet, 2008). Thus, it may be that taking the time to reflect on each week's learning helps students to recognise key learning gains.

6.8.5. Additional instructor reflections

From an instructor perspective, the process of facilitating, modelling, and observing students' systems model-building activity using the IM tool prompts several points of reflection. First, the observation of students' interactions within their groups was revealing as regards the social process of developing consensus and the emergent team orientation that arose within groups over time. It should be noted that, in general, instructor observations of key teamwork behaviours did not involve sitting at the work station with a group, thereby occupying the same workspace and influencing group processes; but rather, after prompting students, the instructors would typically observe from the top or bottom of the room during critical teamwork activities, and only directly join a group sporadically, or upon request for guidance. This approach sought to allow students to interact within their groups more naturally, and reduce the occurrence of socially desirable behaviours in the presence of the instructor.

One of the most revealing aspects of these observations, which relates to the emergence of consensus and team orientation, was the increase in the level of inclusion and collective participation evident in the groups over time. More specifically, as the semester progressed, the levels of input from each member of a group became more equal, with each member contributing to key activities. This positive, equal, open group dynamic is also highlighted in the students' reflections. One prime example of this comes from contrasting reflections offered by three members of the same group early in the semester, versus later in the semester. For example, one group member early in the semester remarked that "*Some people [in my group] are very shy, another comes across like they don't want to share their ideas*" while another group member, in the same week noted, "*I found that other members weren't as vocal with their ideas and contributions as they could have been. I believe this task would have been a lot more successful and enjoyable if every member in our group fully contributed to the task at hand.*" This suggests that, for one reason or another, all members in the group were not participating to the same degree. From an outside perspective, based on instructor observations, it seemed that this was due to shyness on the part of two group members, as opposed to non-commitment to work. However, it became apparent as the module progressed, and as more support for peer-to-peer prompting and group facilitation was provided, that this group became more balanced in terms of equality of input from each

group member. This view is consistent with later reflections from the same group. One member, for example, reflected in week 4, *“I feel this week has improved my ability to brainstorm and to help me feel confident with giving my own ideas to a new task. Before I may have felt shy giving my opinion but as I get to work more with my group, I feel more confident working with them”*. It is noteworthy that week 4 is the week in which students were introduced to the concept of peer learning and engaged in peer-to-peer prompting during a collaborative task for the first time in the module. Thus, it may be that the provision of a graphic organiser of useful prompts, made the process of interaction and engagement somewhat easier for students who otherwise tended to be less vocal than their peers.

Notably, when Warfield designed IM, he sought to create conditions under which each group member was afforded equal opportunity to contribute. Warfield’s conceptualisation of consensus was grounded in his methodological focus on dialogue and the facilitation of turn-taking during idea-generation and structuring activities, and in principles of participatory democracy, where group members are empowered to offer ideas which will be listened to and acknowledged. Importantly, such open dialogue and sharing of contrasting ideas provides opportunities for constructive, cognitive conflict, which has been found to contribute to consensus building (Sambamurthy & Poole, 1992; Anderson & Martin, 1999). While creating such an environment generally falls under the role of the facilitator in an IM session, it is also important for self-directed groups to cultivate these conditions themselves. It is thus promising that, as in Study 3 where a strong sense of consensus and team orientation emerged in the peer-to-peer prompting condition, as well as a reduction in discomfort in group learning, observation and consideration of student reflections during the pilot module suggests that similar processes occurred in the “real-world” setting of the classroom, following the introduction of a focus on peer-to-peer prompting. Based on observation of these peer-driven discussions, students engaged in peer-to-peer prompting to probe for, or offer, alternative strategies, opinions and arguments, which appears to have helped them to progress towards consensus, through deliberation and cognitive conflict.

Relatedly, the manner in which students adopted and coordinated different actions and roles during the later, and increasingly complex group work activities of the module, again suggests that students were gaining important teamwork skills, including the ability to offer back-up support and adapt to different role requirements as needed. This was most evident during the systems model-building phase which involved students adopting, and transitioning between, several roles. At different stages throughout this process, each student would have taken on different roles, as facilitator, software operator (IM and Rationale), or participant

(i.e., developing and providing arguments during the systems model-building task). Each of these roles was different, and a great degree of flexibility was required to switch roles. For example, acting as facilitator involved adopting a reflective, open, and neutral stance while presenting each relational statement to the group, and initiating discussion. Operating computer software, in some instances, involved generating an argument map which represented the group's logic and argument for and against the relational statement. Finally, engaging in deliberation involved thinking about key relations and drawing upon the knowledge the group had accumulated over time in relation to specific issues. Again, to ensure each student gained experience in each role, students were encouraged to swap roles after every 3 or 4 relational statements. Observation of this process suggests that students became more adept at transitioning between roles over the course of the exercise, and the groups developed a productive rhythm and work dynamic.

It was also revealing to observe the groups' development of increasingly complex and nuanced understanding of the problem they were addressing. This emergent appreciation of complexity was evident as students generated more and more barriers relevant to the problem situation, and was increasingly consolidated as they categorised these barriers. Furthermore, the emergence of this shared and increasingly complex and nuanced understanding appeared to coincide with a growing appreciation of the applied systems science methodology. This became most apparent following the paired comparison stage of categorisation (week 9). For example, some groups arrived to class having already begun the process of categorisation outside of class, though without engaging in any particular method for doing so. As such, having already devoted some time and energy outside of class to categorisation, and likely feeling some affinity to the categories which they had developed, these students initially appeared to find the more methodical paired comparison method of categorisation (see Section 6.6.9.) somewhat tedious and overly time-consuming. However, when students were facilitated in this process, and began to engage with new lines of thinking and let go of their preconceived ideas as regards categories, it was evident that they saw the value in the prescribed methodology. As a result, one group in particular went on to develop more distinct and nuanced categories, revealing a more complex representation of their problem field. This more complex and nuanced representation of the problem field also suggests an emergence of systems thinking at the group level, as the group began to recognise, appreciate, and conceptualise the various components of the problem, and their interrelations.

Last, consideration of Dillenbourg's challenges of orchestration (2009), prompts a number of reflections on the design and delivery of this module. First, the challenge of

orchestrating at different social planes required both reflection and design thinking, during the week between each class. While the module activities were clearly defined in advance of the semester, the nature of design and delivery of a pilot module such as this, required intensive planning and simulation of activities at each stage. This planning and simulation was necessary to ensure that the purpose of, and instructional support provided for, each activity was consistent across the individual and group levels, and aligned with the instruction delivered by both facilitators and learning materials. For example, the collaborative exercise described in week 9 involved orchestration of many moving parts, including: the delivery of instruction in relation to the IM software, modelling of facilitator behaviours for students to emulate, instructional support for peer-to-peer prompting, and coordination of a number of alternating student roles within the group (e.g., facilitator, software operator, participant/argument provider). Furthermore, this orchestration and coordination involved continuous reflection upon the activities and experiences (e.g., reviewing student reflections) of the previous week, to inform refinements in the development and advancement of skill over the course of the module.

Similarly, the challenge of *teacher as orchestrator* was central to the design and delivery of learning activities. During collaborative exercises such as the week 9 exercise described above for example, the instructor very deliberately moved from centre-stage, after demonstrating and modelling the role of facilitator during IM structuring, to a more overseeing role, which involved monitoring the activities of the groups, and offering support when called upon, or when, based on observation, the need for support or instruction was apparent. Adopting this orchestrator role may present a challenge for both teachers or facilitators, who may be used to maintaining active involvement in learning processes, and students, who are used to having the majority of the classroom learning directed from the teacher or lecturer at the top of the room. As in Study 3, this evolving role must involve a gradual transition of empowerment and responsibility for learning, from the teacher to the students – a transition of empowerment which may have positive implications for group-based learning.

6.8.6. Considerations for future iterations

While this pilot module represents a positive step towards the development of an applied systems science education curriculum, a number of recommendations for future iterations of the module may be made.

First, consistent with Warfield's focus on methodological rigour, future iterations of this applied systems science module should ensure to continually impress upon students the importance of structure and method in collaborative problem-solving efforts, providing regular reminders of key methodological and procedural issues throughout the process. The basis for this recommendation stems from one occasion during the semester when a group proceeded to the next stage of the process, before being instructed to do so. In this case, the group began categorising their set of barriers outside of class, without following any prescribed method. While all students were provided with an overview of the various stages of the project before commencing, detailed descriptions of each stage were not provided until each new stage had been reached. Thus, it may have been that the group in question perceived categorisation to be a "common-sense" task, which simply involves reviewing a set of barriers and assigning categories based on common themes. However, in the context of a complex, diverse, and significantly large set of barriers, this process may quickly become unwieldy and cognitively demanding, if a strategic, structured approach is not adopted. Although the group, after recategorising and arriving at more nuanced categories of barriers, recognised and appreciated the benefits of the more methodical approach, efforts should be made in future to clearly and regularly describe and explain the stages of the collaborative process to students. More specifically, instructors should ensure to impress upon students the importance of devoting due consideration to each stage of the process, and not advancing to the next stage prematurely. In practise, this may involve, for example, presenting a more detailed description of the project stages and activities early in the semester, and presenting a timeline each week highlighting: (a) the core focus of the current task, (b) the implications of the current task for the subsequent task, and (c) the implications of the current task for the success of the project as a whole.

The need to reinforce the importance of structured methodology is perhaps not surprising. Working with stakeholders who had years of experience facilitating groups, Broome and Fulbright (1995) found that stakeholders identified *methodology deficiencies* as having the highest average negative influence on effective group work. At the same time, Broome and Fulbright also noted that many scholars (e.g., Comadena, 1984; Hiltz, Johnson, & Turoff, 1986) have traditionally downplayed the importance of methodology in group problem-solving, going so far as to suggest that "the manner in which a group arrives at a decision" is "a relatively unimportant variable" for group effectiveness (Hirokawa, 1985, p. 204). However, as noted by Warfield (1976, 2006), there are a host of human cognitive and behavioral limitations that can be ameliorated through methodology, and the development of

methodologies that support group problem-solving is one of the optimal means of ensuring the best scientific and contextual understanding relevant to a specific problem situation is given due consideration. The approach to applied systems science and collective intelligence advocated in this thesis includes a strong emphasis on both *structured methodologies* to help groups generate and structure ideas about complex problem situations, and *facilitation* of subtle and often unstructured dialogue and deliberation of groups, such that critical and reflective thinking skills are facilitated in the collective intelligence process. Facilitating collective intelligence implies the cultivation of skill in the use of structured methodologies and in working directly with the content of group deliberation and the broader psychological and social dynamics of group deliberation.

Another recommendation for a future iteration of this applied systems science module is based on a theme which emerged from students' reflections. Given the significant and complex workload involved in the group projects, a number of students recommended that more time be devoted to the project in future (i.e., beginning the group projects earlier in the semester), to allow for more time at each stage of the IM process (i.e., idea generation, categorisation, structuring, and scenario-based design). Relatedly, towards the end of the semester some students highlighted difficulties in arranging group meetings outside of class, given that group members had different timetables for their other modules, and thus may have had different deadlines for other assignments. These challenges may be alleviated by beginning the group projects earlier, allowing for more in-class time to work on group projects. However, another option would be to assist students in making arrangements for their outside of class meetings (e.g., by facilitating the booking of a productive workspace). In general, given the importance of the group project, and the key learning activities which it encompasses, it is critical to devote both sufficient support, and time, to this process.

More generally, in their study of barriers to effective group work, Broome and Fulbright (1995) highlighted *planning*, and *resource constraints* as two of the most negative factors influencing group progress. In particular, while *planning* and *resources* are important in setting the context within which group work takes place, Broome and Fulbright note that, traditionally, an emphasis on *planning* and *resources* were not a strong focus of analysis for researchers in the fields of communication and psychology. As highlighted by Broome and Fulbright, without proper *planning*, group sessions waste members' time and most attempts at dealing with complex problems will fail. Conversely, with proper planning prior to a group problem-solving meeting, or classroom session, many difficulties can be avoided or minimised. This planning must be done in advance of a session, and as part of the overall

curriculum design in the case of applied systems science education. In addition to specific planning behaviors (e.g., creating working groups, organising materials and methods, etc.), this often involves considerable mental simulation (i.e., simulating various methodological steps as options, adjusting in response to group size, work space, materials available, time available, etc.). As each new iteration of an applied systems science education programme will be unique in certain respects, in terms of group composition, problem focus, work space, materials, time, and so on, planning and simulation work needs to be done carefully in light of the specific teaching context, and plans need to be adapted as needed in light of constraints and unfolding group dynamics as the programme and curriculum is delivered.

More broadly, further development of this module may be achieved through a cycle of iterations of Design-Based Research (DBR). In explaining the need for a design-based approach to educational research, Brown (1992) stated that “effective intervention should be able to migrate from our experimental classroom to average classrooms operated by and for average students and teachers, supported by realistic technological and personal support” (p. 143). DBR generally typically begins with an initial pilot designed to test the potential of an educational innovation, and assess whether further development is warranted (Hall, Thompson Long, Flanagan, Flynn, & Lenaghan, 2017). This may then be followed by a scaling-up of the pilot to a mainstream intervention for further development and evaluation, followed by a capstone intervention which seeks to fine-tune the innovation, and verify and consolidate its efficacy (Thompson Long & Hall, 2015). As such, the pilot curriculum described in this chapter, which itself is informed by the experimental findings of Studies 1-3, may provide a useful starting point for future DBR innovation.

Furthermore, in advancing the design and delivery of this module, and empirically testing its efficacy, it would be beneficial for future iterations to measure key components of learning outcomes and processes before, during, and after the module, to assess learning gains, the development of collaborative competencies, and attitudes towards collaborative learning. Whereas the pilot module described here, as a first iteration of the curriculum, focused on evaluating the student experience through qualitative reflections, future iterations could incorporate objective measures of critical thinking, and systems thinking skills, as well as assessing changes in levels of team orientation, attitudes towards group learning, among other potential measures of teamwork. Collection and analysis of such data would prove valuable in the design of future iterations.

In line with Warfield’s original vision for a *Horizon College*, future iterations may also involve extending this module into an applied systems science programme of training

across a full year, or indeed across three years of undergraduate training. This would require a broader scoping of the full set of tools, talents, and teamwork dynamics that could be incorporated and integrated as a focus for learning. For instance, Hogan et al. (2015) considered ways in which mathematical systems modelling techniques could be integrated with IM systems modelling work, in an effort to develop a full complement of qualitative and quantitative skills that are useful in applied systems science projects. Also, in extending this programme of training, it would be useful to provide an opportunity for students to take a work placement in an organisational setting where applied systems science project work is central to the success of ongoing organisational projects (e.g., in health, education, or business settings). This would provide students with an understanding of real-world problems, and the stakeholders who are working to resolve these problems. Facilitating or co-facilitating these group efforts would help students to understand the challenges, and develop skills, associated with collaborative learning and collective action in real-world settings.

6.9. Conclusion

In conclusion, the pilot module presented in this chapter represents an important first step towards the development of an applied systems science curriculum. The module, which was built around Warfield's IM methodology, and informed by Studies 1-3, was positively received by students, who demonstrated their ability to conduct a collaborative applied systems science project in the context of structured facilitation and support. The pilot module described in this chapter may be used to inform future iteration and development of applied systems science curricula, which may seek to extend this initial pilot work by adopting an experimental approach to the evaluation of learning process and outcomes and by offering additional real-world organisational work experience to students.

Chapter 7: General discussion

7.1. Chapter overview

This chapter presents a general discussion of the research conducted in this thesis. It opens with an overview of the core thesis argument and research methods across Chapters 1 - 6. This is followed by a detailed summary of the main research findings of Studies 1, 2 and 3, with a specific focus on findings related to the effects of dialogue, process-level prompting, and peer-to-peer prompting on processes and outcomes in the context of IM-based CSCL systems model-building. Additional reflection on the pilot applied systems science education curriculum informed by Studies 1, 2 and 3 is then provided. Next, this chapter discusses the implications of the experimental research findings and pilot curriculum evaluation for teaching and learning, and for future research which may seek to advance systems science education. Last, this chapter addresses limitations of the current research, and closes with a general summary and conclusion.

7.2. Thesis overview

Chapter 1 introduced Warfield's approach to systems science, including a detailed description of the IM methodology, as well as his vision for the integration of systems science into university education. Consistent with Warfield's vision for systems science education, key perspectives on dialogue, as well as recent investigations of the role of dialogue in the classroom were presented. Stemming from this discussion of dialogue, Chapter 1 highlighted the need to move away from didactic approaches to classroom learning, to more student-centred pedagogical approaches which provide greater opportunities for students to engage in collaborative dialogue. From a methodological perspective, Chapter 1 also highlighted the value of process-oriented research, which allows light to be shed on processes occurring during collaboration. This process-oriented research focus was influential in the design of the research presented in this thesis. Chapter 1 closed with an overview of some of the core issues that need to be considered to support an integrated understanding of processes and outcomes in CSCL contexts, and the implications for research efforts focused on Warfield's vision for systems science education, which is fundamentally grounded in the use of CSCL methods.

Next, Chapter 2 provided an overview of research in the area of collaborative learning, with reference to meta-analyses highlighting the wide range of benefits which have been demonstrated in cooperative and collaborative learning settings. Following this

overview, Chapter 2 examined research on argumentation as a growing focus of enquiry in collaborative learning research, and as the primary mode of dialogic engagement for students in the current research, which focused primarily on collaborative argumentation in the context of systems model-building activity using Warfield's IM methodology. As such, Chapter 2 includes an overview of approaches to supporting and cultivating argumentation in the classroom, such as discourse instructions (Asterhan et al., 2010; Garcia-Mila et al., 2013), as well as prompts or question asking (Graesser, et al., 1993; King, 1990; Veerman et al., 2002; Webb et al., 2008; Webb, 2009). Following this, Chapter 2 introduced the concept of peer learning, with a specific focus on peer feedback and peer-to-peer prompting. This section highlighted that, while peer learning has been shown to be beneficial in a variety of learning contexts, in particular for written tasks (e.g., Cho & MacArthur, 2010; Gan & Hattie, 2014), the effects of peer-to-peer prompting in the context of collaborative argumentation have been the subject of little investigation. Research was reviewed showing that, with adequate instruction and support, students are capable of delivering effective prompts to their peers (Gan & Hattie, 2014), and it was suggested that, with similar structural support, these benefits may extend to collaborative argumentation tasks.

In the penultimate section of Chapter 2, an overview of research on key social-emotional processes in the context of collaborative learning was provided. This review highlighted the importance of: consensus, team orientation, attitudes towards group learning, perceived efficacy, and trust in the context of collaborative learning efforts. A focus on these social-emotional variables also aligns with the emphasis Warfield placed on teamwork and consensus-building in the context of applied systems science projects focused on complex, real-world problems. In the absence of a focus on these social-emotional dynamics, consistent with Warfield's view, it will be difficult to cultivate and sustain successful teamwork efforts at a societal level. Last, chapter 2 provided a rationale for each of the studies in this thesis.

Chapter 3 presented the first of three experimental studies conducted as part of this thesis. Building upon the literature on dialogue and collaboration discussed in Chapter 1, and the importance of social-emotional processes in collaborative learning described in Chapter 2, Study 1 examined the effects of the presence versus absence of dialogue, and high versus low trust, on perceived consensus, objective consensus, and perceived efficacy of the IM methodology in the context of a systems model-building task. Students were randomly assigned to one of two conditions, open dialogue or no dialogue. Students were also categorised based on pre-test measures, as high or low in trust. At the pre-test stage, each student also completed measures of perceived consensus and objective consensus in relation

to the topic of social media usage. Following completion of these measures, each student participated in an IM-based systems model-building task, within their assigned condition. Those in the open dialogue condition were permitted to engage in open deliberation and debate before voting on individual relations between elements in the systems model, whereas those in the no dialogue condition made their decisions after a period of private reflection, without any opportunity to engage in collaborative discussion with other group members. Following the completion of the systems model-building task, each student completed measures of perceived consensus and objective consensus, as well as a measure of perceived efficacy of the IM methodology. An overview of the results of this study is presented in Section 7.3.1., as well as a discussion of the implications of these results for teaching and learning.

Chapter 4 presented Study 2. Building upon the results of Study 1, Study 2 sought to further examine the process of dialogue and collaborative argumentation during systems model-building activity by manipulating the kinds of prompts delivered by the facilitator during an IM session. More specifically, students were assigned to one of four groups across two prompting conditions: process-level prompting, or task-level prompting. Prior to the systems model-building task, each student completed measures of: trust, perceived consensus, objective consensus, and team orientation. During the systems model-building task groups were provided with different kinds of facilitator prompts, depending on the condition to which they were assigned, i.e. process-level prompting condition, or task-level prompting condition. Once the systems model-building process had been completed, each student again completed measures of perceived consensus, objective consensus, and team orientation, and also a measure of perceived efficacy of the IM methodology. Furthermore, as each IM session was recorded with audio-visual equipment, a transcript of the dialogue during each session was compiled for analysis. An overview of the results of this study is presented in Section 7.3.2., along with a discussion of the implications of these results for teaching and learning.

Chapter 5 presented Study 3, which featured the integration of peer learning, in the form of peer-to-peer prompting, into the collaborative systems model-building task. As noted in Chapter 1, IM is traditionally a facilitator-driven process. However, given recent research interest in peer learning, and the additional benefits it may provide, Study 3 sought to examine whether or not peer-to-peer prompting is more effective than facilitator-driven prompting in cultivating and supporting collaborative argumentation in the systems model-building context. More specifically, students were assigned to one of eight groups, across two

conditions: peer-to-peer prompting or facilitator-driven prompting. Prior to the systems model-building task, each student completed measures of: trust, perceived consensus, objective consensus, team orientation, and discomfort in group learning. In the facilitator-driven condition, the systems model-building task was guided and supported by the facilitator, who delivered prompts to probe for the expression of viewpoints from the students. In the peer-to-peer prompting condition however, the facilitator gradually passed over the role of facilitation to the students themselves, through a graduated approach of (a) modelling the use of prompts, (b) coordinating peer-to-peer prompting interactions, and finally (c) passing over control of the prompting to students themselves. Once the systems model-building process had been completed, each student again completed measures of perceived consensus, objective consensus, team orientation, and discomfort in group learning, as well as the measure of perceived efficacy of the IM methodology at the post-test stage only. As each IM session was recorded with audio-visual equipment, a transcript of the dialogue during each session was compiled for analysis. An overview of the results of this study is presented in Section 7.3.3., as well as a discussion of the implications of these results for teaching and learning.

Last, Chapter 6 presented the design, implementation, and evaluation of a pilot 12-week applied systems science education curriculum, which was delivered to 23 undergraduate students. This chapter begins with reference to Warfield's vision for systems science education, as well as an overview of more recent perspectives from CSCL research and application, which informed the design of the pilot curriculum. An overview of perspectives and design considerations highlighted in the curriculum design literature is provided, followed by a section which situates the current pilot curriculum within these perspectives and design considerations. Following this, a discussion of the implications of Studies 1-3 for the design and implementation of this pilot curriculum is provided, including implications relating to harnessing consensus and team orientation during collaborative learning, and the use of prompting in supporting collaborative argumentation during systems science education tasks. Chapter 6 also provides a detailed week-by-week overview of learning activities, course content, tools, and materials. Last, an evaluation of this pilot module is provided, based on reflections from students and instructors, followed by recommendations and design considerations for future systems science education research and application. Further discussion of the implications of this pilot curriculum for teaching and learning is provided in Section 7.3.4.

7.3. Findings and implications

7.3.1. Study 1

The results of Study 1 indicated that, in comparison with students who completed the systems model-building task in the absence of dialogue, students in the open dialogue condition reported higher levels of perceived efficacy in relation to the IM methodology, as well as higher levels of perceived consensus. No significant difference in objective consensus was found, however. These results represent an important initial finding in the series of studies presented in this thesis, and in the context of systems science education. They highlight the critical role of dialogue in students' response to the system design methodology, in terms of the extent to which they perceive the process to be efficacious, as well as the extent to which they perceive the process to promote consensus. These results are consistent with previous research by Volery and Lord (2000) who highlighted the effects of instructors' support of interaction and collaboration on students' perceptions of educational technology in the context of e-learning. As was the case in Volery and Lord's (2000) research, the lack of support for interaction and collaboration in the no dialogue condition in Study 1 may have contributed to student's perceptions of the IM methodology as less efficacious.

Importantly, students' perceptions of the efficacy of a learning methodology or tool can have important implications for learning. For example, as highlighted in Chapter 2, students' levels of perceived usefulness of educational technology tools have been found to predict behavioural intention to use the tools (Liaw, 2008). As such, if students do not perceive the tools to be useful or effective, they may be less likely to engage with the tools in future. Thus, in the context of developing an applied systems science curriculum, or any curriculum that involves the use of CSCL tools, it is important for instructors to foster high quality interactions and exchanges between students while using the tools, as the quality of these interactions and exchanges may influence students' ongoing motivation and behavioural intentions to continue using the tools to support their collaborative learning.

Similarly, in the absence of dialogue, where there was no opportunity for exploration of different viewpoints, it may have been more difficult for students to develop a sense of consensus. This is consistent with research showing the positive impacts of cognitive conflict on consensus levels (Sambamurthy & Poole, 1992; Anderson & Martin, 1999), as well as research showing that groups who question each other, accept each other's suggestions and incorporate other's viewpoints into their own perspective, develop

higher levels of consensus (Mohammed & Ringseis, 2001). As such, consideration of the findings of Study 1, alongside previous findings in the literature, suggests that dialogue represents a key factor in students' perceptions of the collaborative systems model-building process.

These results, combined with results from studies showing increased learning gains in more open and interactive groups (e.g., Ada, 2009) suggest that open dialogue is a critical factor in the success of CSCL tool use. These results also have implications for the future design of CSCL tools and how they are used. Naturally, CSCL tools can be used in any number of different ways, for example, with approaches to facilitation being more or less directive, rule-based, democratic, open and adaptive, and so on. For example, Peterson (1997) highlighted the effect that a group leader's directiveness can have on the outcomes of collaborative working sessions. Peterson found that process-directive leaders, who aimed to foster the decision-making process by encouraging dialogue and by remaining open regarding their own position, facilitated more positive group processes and outcomes than outcome-directive leaders who did not encourage discussion in the group and who focused solely on reaching a decision. As such, in the context of CSCL use, it may be imperative that the facilitator of any group session provide both ample opportunities, and instructional support, for open dialogue in the group.

Furthermore, the results of Study 1 revealed that students who reported higher trust also reported higher levels of perceived efficacy in relation to the IM methodology, and higher levels of perceived consensus. Notably, that those with higher trust reported higher levels of perceived efficacy of the IM methodology is consistent with previous research by Ennen et al., (2015) who, for example, reported a positive association between levels of trust and levels of perceived satisfaction in the context of group learning. Furthermore, research by Huff et al., (2002) reported that trust is associated with increased levels of satisfaction, effort, and motivation in the context of collaborative learning, again implicating trust in student's positive perceptions of collaborative learning tools or environments.

That participants with higher trust also reported higher levels of perceived consensus following the collaborative systems model-building task is also consistent with previous research. For example, high levels of trust have been found to mediate the relationship between cognitive conflict and relationship conflict, such that high levels of trust act as a buffer against the development of relationship conflict and thus promoted cognitive conflict (Peterson & Behfar, 2003; Simons & Peterson, 2000).

Overall, the results of Study 1, in demonstrating the positive impact of open dialogue on students' perceptions of the efficacy of the IM methodology, as well as their perceptions of consensus among the group, suggests that further research which explores the role of the teacher or instructor in supporting dialogue at the group level is warranted, such that it may provide further insight into the processes at play during dialogue-based collaborative learning. As such, Study 2 sought to extend the findings of Study 1, by manipulating key aspects of the facilitation of dialogue, specifically the type of prompting provided by facilitators, and investigating the effects of these manipulations on student's social-emotional responses, as well as the complexity of the resultant dialogue, in the form of collaborative argumentation.

7.3.2. Study 2

The results of Study 2 indicated that, compared to those in the task-level prompt condition, those in the process-level prompt condition reported higher levels of perceived consensus and higher levels of perceived efficacy of the IM methodology. Furthermore, the process-level prompting condition resulted in more varied and complex forms of argumentation during their deliberations, as revealed by the CACS and the complexity of their IM-generated systems models. No significant differences in objective consensus or team orientation were found.

Again, the finding that higher levels of perceived consensus were reported by students in the process-level prompting condition is consistent with research on cognitive conflict and argumentativeness in the context of consensus-building. For example, confrontiveness in collaborative exchanges - the extent to which groups addressed their differing perspectives during a decision-making process - has been found to be positively associated with levels of perceived consensus (Sambamurthy & Poole, 1992). Similarly, argumentativeness - a person's willingness to argue issues with another - was found by Anderson and Martin (1999) to be positively associated with perceived consensus. As such, the process-level prompts used in Study 2 may have facilitated greater cognitive conflict and argumentativeness, and thus upheld an environment which was more conducive to consensus-building. This is suggested by the CACS results, which revealed more frequent use of *challenges* in the process-level condition than in the task-level condition. When considered alongside the findings of Study 1, the results of Study 2 suggest that teachers or instructors may support consensus-building in relation to complex problems by using process-level prompts or probing questions to foster open discussion and exploration of key issues.

Furthermore, process-level prompts resulted in higher levels of perceived efficacy of the IM methodology in Study 2. Again, this is consistent with research by Liaw et al., (2007) and Volery and Lord (2000) which has highlighted the influential role of the instructor in students' perceived satisfaction in group learning scenarios. By prompting for deeper engagement and reflection during the systems model-building task, the process-level prompts provided by the facilitator may have contributed to more positive perceptions of the IM methodology than the task-level prompting. This suggests that, in addition to providing an environment that is generally conducive to open dialogue (Study 1), teachers or instructors may positively impact on students' perceptions of the efficacy of educational tools or methodologies by paying careful attention to the manner in which they facilitate the collaboration, i.e. by delivering effective, process-level prompts.

Focusing specifically on the nature of the collaborative argumentation, Study 2 revealed significant differences between the process-level and task-level prompting conditions. In comparison with task-level prompting, the process-level prompting produced greater variety and complexity in the collaborative argumentation. For example, based on the CACS, groups in the process-level prompt condition demonstrated significantly more frequent usage of *propositions*, *amplifications* and *challenges*. Importantly, that the argumentation in the process-level condition contained higher levels of these more complex argument codes suggests a higher-level of engagement with the content during collaborative argumentation. More specifically, these patterns of argumentation suggest students made more effective moves towards reaching a level of understanding and consensus within the group, including developing more complex generative mechanisms (*propositions*), reasoning activities (*amplifications*) and disagreement-relevant intrusions (*challenges*) than were seen in the task-level condition. Overall, of the 16 different types of argument codes under the CACS, 12 different codes were observed in the process-level prompt condition, whereas only eight different codes were observed in the task-level prompt condition. This again suggests a greater level of variety and complexity of argument in the process-level prompt condition.

Last, complexity score analysis of the IM-generated systems models revealed differences in complexity of argument structures across conditions. The average complexity score for the problematques generated by the process-level prompt groups was 43. The average complexity score for the problematques generated by the task-level prompt groups was 35.5. That the average complexity score for systems-models developed by groups in the process-level prompting condition was higher, alongside the finding that these groups produced more varied forms of argumentation, again suggests that overall they were

engaging with a higher degree of differentiation and complexity in their deliberations in the systems model-building task.

These results have a number of implications for teaching and learning in the context of collaborative argumentation. The need to design learning environments which support collaboration, meaning-making, and problem-solving is well established (Pea, 2004; Strijbos, Kirschner, & Martens, 2004). Furthermore, it is recognised that creating such environments may require the provision of skilled facilitation and instructional support for learning, if quality classroom interactions are to be achieved and sustained (Gabelica et al., 2012). In line with these identified needs, the findings presented in Study 2 demonstrate that collaborative argumentation, in terms of the variety of argument moves present, and the overall complexity of the collaborative argumentation observed, can be supported through facilitation and the provision of instructional support. Consistent with a review conducted by Asterhan and Schwarz (2016) which highlighted process support (including teacher scaffolding), as a key enabler of argumentative dialogue, Study 2 demonstrates the benefits of providing process-level prompts to groups of students engaged in collaborative argumentation.

These findings suggest that, in the context of collaborative argumentation, teachers or instructors can potentially make good use of prompting as a means to support and guide students' collaborative efforts. This is in line with numerous studies which have reported the benefits of providing prompts as a means of supporting argumentation (e.g., King, 1990; Veerman et al., 2002; Webb, 2008; Webb, 2009; Yiong-Hwee & Churchill, 2007). However, the results of Study 2 also permit a second, more specific observation, one which advances upon the previous literature on prompting, by demonstrating the relative success of two different types of prompting strategies in facilitating collaborative argumentation. While research in other learning contexts has highlighted the benefits of process-level prompts, for example, in the context of writing-to-learn tasks (Hübner, Nückles, & Renkl, 2010), teacher education (Harford & MacRuairc, 2008) and e-learning (Krause, Stark, & Mandl, 2009), studies in the area of collaborative argumentation have not, to date, investigated the relative effects of different kinds of prompts. As such, the results of Study 2 suggest that teachers or instructors should carefully design the specific prompts which they use in efforts to support collaborative argumentation and collaborative learning. Importantly, while Study 2 focused on a specific set of process-level prompts that were appropriate for a 2-hour systems model-building activity, the growth of knowledge and skills over the duration of a semester or year-long course may require additional design thinking as regards an orderly, cumulative, and directional sequence of prompts that best promote learning gains. More generally, future

research studies need to consider carefully the design of different types of prompting strategies for different types of collaborative learning experiences.

Similarly, these findings also build on the review of *enablers and inhibitors* of argumentation presented by Asterhan and Schwarz (2016). More specifically, process-level prompts represent a form of *teacher scaffolding* and a key type of *process support* for argumentation identified by these researchers. Notably, *teacher scaffolding* has been found to be most effective when it involves low-content intervention, which focuses more on providing prompts to elicit student thinking, as opposed to content-specific information. The results of Study 2 complement and add to this literature, by demonstrating the benefits of a specific type of prompt (i.e., process-level prompts), in the context of teacher scaffolding for collaborative argumentation in the classroom.

Furthermore, the findings from Study 2 which provide evidence of the positive effects of process-level prompts on perceived consensus and perceived efficacy of the IM methodology represent a significant addition to the prompting literature. While prompting research has predominantly focused on investigating the benefits of prompts for cognitive learning outcomes such as encouraging and eliciting more elaborate explanations (Webb, 1995), and promoting information exchange (Veerman et al., 2002), the findings that process-level prompts are also influential in student's development of a sense of consensus and perceived efficacy extend this literature to include social-emotional benefits, which in themselves are important factors in the success of collaborative learning approaches.

Overall, the results of Study 2, by demonstrating the positive impact of process-level prompting on levels of perceived consensus, perceived efficacy of the IM methodology, and the complexity of collaborative argumentation, thus suggested that further exploration of the potential benefits of prompting was warranted. Following this line of enquiry, and given the growth in the research and application of peer learning methods, Study 3 sought to investigate the effects of facilitator-driven versus peer-to-peer prompting on key processes and outcomes in a systems model-building context.

7.3.3. Study 3

The results of Study 3 indicated that, compared to those in the facilitator-driven prompting condition, those in the peer-to-peer prompting condition reported higher levels of perceived efficacy of the IM methodology, higher levels of perceived consensus, higher levels of team orientation, and lower levels of discomfort in group learning. Furthermore, analysis of the dialogue during the systems model-building task revealed that those in the peer-to-peer

prompting condition exhibited higher levels of variety and complexity in their arguments, as revealed by their CACS scores. No significant difference in objective consensus was found, however.

The finding that peer-to-peer prompting resulted in higher levels of perceived efficacy of the IM methodology is, again, consistent with the findings of Volery and Lord (2000). One of the key instructor behaviour factors which positively impacts on perceived satisfaction in a learning context, according to Volery and Lord's (2000) research, involves the role of the instructor in encouraging student interaction. As such, it seems likely that by facilitating peer-to-peer interaction, the peer-to-peer prompting condition resulted in higher levels of perceived efficacy of the IM methodology. This finding is also consistent with research conducted by Cho and MacArthur (2007), who reported that the improvements on written tasks displayed by students who received feedback from peers, were greater than those who received feedback from a single teacher. It may be, according to Cho and MacArthur, that even in the absence of the same level of expertise as teachers, peers may provide comments which are more accessible to other students. Furthermore, they suggest that peers may be better able to recognise difficulties faced by peers due to their own similar perspective or experience. It may follow then, that in the same way that peer engagement contributed to greater improvements in written tasks, receiving accessible, relevant prompts from a peer can contribute to a greater sense of both perceived efficacy, and perceived consensus, of the collaborative process. Therefore, by providing opportunities for, and adequately supporting, peer-to-peer prompting and peer interaction, teachers or instructors may enhance students' perceptions of the learning methodology or tool being employed.

That peer-to-peer prompting produced in higher levels of perceived consensus is consistent with Boud et al.'s (2001) review of peer learning. In this review, Boud et al. highlights a number of benefits associated with peer learning, each of which are conducive to consensus, including: ability to work with others, communication and articulation of knowledge, and critical enquiry and reflection. As such, it is likely that the reported positive effects of cognitive conflict on consensus are influential here again, given that the peer-to-peer prompt condition also displayed more varied and complex forms of argumentation (Anderson & Martin, 1999; Sambamurthy & Poole, 1992) and, crucially, significantly higher levels of *challenges* and acknowledgements. As such, providing opportunities, as well as instructional support, for peer-to-peer prompting may be an effective approach for instructors to adopt in efforts to support consensus-building in the context of collaborative learning.

The finding that peer-to-peer prompting resulted in higher levels of team orientation when compared with facilitator-driven prompting is also consistent with the findings of Boud et al. (2001). Given the participatory culture of peer learning experiences (Kollar & Fischer, 2010), the reported benefits of peer learning on the ability of students to work together, and on their overall communication and articulation of knowledge (Boud et al., 2001), may be associated with the development of team orientation in the peer-to-peer prompting condition. The effect of peer-to-peer prompting on levels of team orientation observed in Study 3 has important implications, as team orientation has been associated with a number of related benefits including: enhanced cooperation, team member exchange, empowerment, team performance, and team productivity (Bell, 2007; Eby & Dobbins, 1997; Wang et al., 2014). As such, that peer-to-peer prompting, as compared to facilitator-driven prompting, positively influenced levels of team orientation, represents an important finding for the harnessing of effective collaboration in the classroom. This finding again leads to the suggestion that teachers may wish to integrate peer-to-peer prompting into collaborative learning exercises, rather than seek to always lead the prompting process in the orchestration of collaborative learning experiences.

Further support for the above suggestion is provided by the finding that peer-to-peer prompting resulted in lower levels of discomfort in group learning. As noted in Chapter 2, it is not uncommon for students to report aversive feelings towards group work (Wolfe, 2008), and feelings of discomfort in group learning contexts (Cantwell & Andrews, 2002), which may have negative implications for learning (Volet & Mansfield, 2006). As such, given that Study 3 demonstrated that peer-to-peer prompting resulted in both higher levels of team orientation, and lower levels of discomfort in group learning, provides additional support for the claim that teachers or instructors can potentially enhance the collaborative experience of students by gradually handing over control of the prompting process to students.

As regards the CACS analysis of the collaborative argumentation, results revealed that peer-to-peer prompting groups produced more varied and complex argumentation during the systems model-building task. More specifically, when compared with the facilitator-driven prompting condition, participants in the peer-to-peer prompting condition demonstrated significantly higher levels of *amplifications*, *justifications*, *acknowledgements*, and *challenges*. As described in Chapter 5, the higher prevalence of these argument codes in the peer-to-peer prompting condition suggests that students in these groups were engaged in deeper critical and reflective thinking in relation to the claims presented during the IM-based systems model-building task. More specifically, the peer-to-peer prompting groups

demonstrated more frequent complex reasoning activities (*amplifications* and *justifications*), convergence-seeking activities (*acknowledgements*), and disagreement-relevant intrusions (*challenges*) than were seen in the facilitator-driven prompting condition. Also, it is worth noting that of the 16 different types of argument codes under the CACS, 15 different codes were observed in the peer-to-peer prompting condition, whereas 12 different codes were observed in the facilitator-driven prompting condition. This again suggests a greater level of variety and complexity of argument in the peer-to-peer prompting condition.

These findings have further implications for the use of prompting in the context of collaborative argumentation. First, while peer-to-peer prompting has been found to be effective for a variety of learning activities (e.g., Cho & MacArthur, 2011; Gan & Hattie, 2014; Hartberg et al., 2008; Patchan et al., 2016; Novacovich, 2016), Study 3 extends these findings into the area of collaborative argumentation. Importantly, by comparing the effects of facilitator-driven versus peer-to-peer prompting, and by highlighting unique effects of peer-to-peer prompting on collaborative argumentation, Study 3 suggests that teachers or instructors should seek to incorporate peer-to-peer prompting into collaborative argumentation tasks. In addition, Study 3 suggests that teachers or instructors should provide structured instructional support, and model key prompting behaviours for students, to guide them in the process of delivering prompts to one another. This is consistent with research demonstrating the benefits of providing students with graphic organisers (Gan, 2011) or feedback template and structures (Gielen & De Wever, 2015) in peer-to-peer learning situations.

As such, both structure and guidance may be critical for the success of peer-to-peer prompting. In Study 3, the facilitator first modelled the use of peer-to-peer prompting, then coordinated peer-to-peer prompt interactions between peers, before passing over control to the students themselves. This, as outlined in Chapter 5, is consistent with research by van Steendam et al. (2010), who demonstrated the benefits of modelling peer feedback behaviour to students on their subsequent ability to effectively engage in peer feedback. As such, the findings of Study 3 suggest that, in the context of promoting collaborative argumentation, the use of peer-to-peer prompting supported by a graphic organiser, and facilitated by graduated modelling and demonstration, represents a promising approach for teachers or instructors to engage in with their students.

The findings presented in Study 3 also make important contributions to the research literature on peer learning, prompting, and argumentation. While the majority of studies on prompting and argumentation have focused on teacher delivery of prompts or other forms of

process support (Asterhan & Schwarz, 2016) some studies (e.g., King, 1990), have included peer questioning as part of investigations. However, prior to Study 3 in the current thesis, no study had empirically tested the effects of facilitator-driven versus peer-to-peer prompts in the context of collaborative argumentation. As such, by comparing these two types of prompting conditions, Study 3 makes a significant contribution to the literature, by adding to the growing literature reporting upon the benefits of peer learning in a variety of learning contexts. Furthermore, by highlighting the benefits of peer-to-peer prompts on social-emotional outcomes including perceived consensus, perceived efficacy of the IM methodology, team orientation, and discomfort in group learning, Study 3 sheds further light on the process of peer learning, by demonstrating benefits beyond the core cognitive task focus of the learning experience, and thus extending the literature on peer-to-peer prompting to include benefits for both cognitive and social-emotional outcomes in the context of collaborative argumentation.

Additionally, Study 3 builds upon literature on the use of graphic organisers as a form of instructional support for peer-to-peer prompting, including the study by Gan and Hattie (2014) who reported on the use of graphic organisers to support peer feedback delivery in written tasks. By demonstrating the use of graphic organisers to support students' delivery of peer-to-peer prompts in the context of collaborative argumentation, Study 3 provides a template for future research to extend the investigation, and use, of graphic organisers in various collaborative learning contexts.

7.3.4. Pilot applied systems science curriculum

Evaluation of the pilot applied systems science curriculum described in Chapter 6 also prompts additional considerations in relation to teaching and learning, particularly in the context of future iteration and development of an applied systems science curriculum. Importantly, this module may serve as a template for future design efforts in the context of systems science education, providing insight into the process of curriculum design, the integration and application of a variety of computer-supported collaborative enquiry methods and tools, a week-by-week description of learning activities, as well as a description of specific methods of assessment. Furthermore, as illustrated across sections 6.6.3 – 6.6.10 and 6.8.1 – 6.8.5 this pilot module involved the collection of a considerable quantity of student reflection and testimony, specifically, on key module content, processes, and implementation strategies, which provides insights into the students' experiences of various aspects of the module. These student reflections provide an important catalyst for future design thinking in

relation to Warfield's general vision for applied systems science education. Importantly, students' reflections in relation to the value of Warfield's methodology, and the module generally, were predominantly positive. Students felt that the skills they had gained during the module were "*highly practical*" and "*can be applied to all of my future endeavours*". Consistent with Warfield's objectives for systems science education, the students perceived themselves to have gained broadly applicable communication, teamwork, and problem-solving skills, which can be applied in a wide variety of scenarios, outside of the domain-specific knowledge and skill which they have gained from the subject of their primary degree.

While positive student responses were anticipated during the design of the module, particularly given the promising results of Studies 1-3, it was important to gather students' reflections during the learning and application of IM (a) over a longer timespan i.e. 12-weeks, and (b) in a non-laboratory, university education context in which students were engaged in their project work linked to real-world societal problem and design challenges. That students endorsed the IM methodology both during and after group project work lends support to the conclusions from the experimental studies that students perceived the process to be useful and effective.

It is also noteworthy, and consistent with the findings from Studies 2 and 3, that students taking the pilot applied systems science module highlighted benefits associated with the facilitation provided during collaborative discourse and argumentation, noting for example, "*The quality of facilitation within the class was very high. During each discussion the instructor would join the group and add content, probe a specific question or ask for an evaluation of points being made. This encouraged a higher level of thinking within the group*". They also highlighted as important the development of their own ability to "*assume the role of the facilitator and mediate discussions*". Based on student reflections, it appears that the process-level prompts provided by the module instructors, and the support for peer-to-peer prompting, were generating similar benefits to those demonstrated in Studies 2 and 3. As such, these reflections and observations lend weight to the recommendations made above that teachers should seek to provide process-level feedback to groups engaged in collaborative argumentation tasks, and also provide opportunities, and instructional support, for peer-to-peer feedback in during such activities.

7.4. Further reflections

In addition to the discussion points outlined above, it is noteworthy that while significant increases in perceived consensus were reported in each study, in the open dialogue condition (Study 1), in the process-level prompting condition (Study 2), and in the peer-to-peer prompting condition (Study 3), no increase in objective consensus was observed as a result of key experimental manipulations (across Studies 1-3). This suggests that while dialogue, process-level facilitation, and peer-to-peer facilitation were each instrumental in moving groups of students towards greater levels of shared understanding and agreement, their actual levels of agreement, in terms of Likert scale agreement/disagreement with IM relational statements, did not increase to the same degree. There are a number of potential reasons for this lack of effect of collaborative learning on objective consensus across Studies 1-3. First, it may be the case that a longer duration of dialogue and interaction is needed to produce an increase in objective consensus, especially in the context of evaluating multiple relational statements in a systems model-building task. Across studies, groups worked together to discuss relational statements which formed the basis for the objective consensus measure, over approximately 110 to 120 minutes (with the exception of the no dialogue condition in Study 1 which lasted approximately 45 minutes). This relatively short timeframe for discussing multiple relational statements, each of which were open to a variety of opinions and perspectives, may not have been sufficient for groups to move towards high levels of objective consensus.

It is also possible, however, that the measure used to assess objective consensus was not optimal. While it was necessary to record participants' levels of agreement with a random set of ten relational statements in advance of the session as a baseline measure of consensus, using these same relational statements to measure changes in consensus after the session was, in retrospect, not ideal. This is due to the fact that all of these pairs of statements may not have been presented by the ISM software for discussion during the session, depending on the pattern of voting during structuring. As such, participants may have been reporting their levels of agreement at post-test on some relational statements which were not discussed by the group, and thus which may not have been impacted upon by collaborative learning conditions. Furthermore, there may have been variability across groups and conditions as regards the number of relational statements which appeared both in the random set in the objective consensus measure, and during the systems-model building task.

Despite the potential methodological issues in measuring objective consensus, the practical implications of differences in levels of perceived and objective consensus warrant consideration. In practical terms, the implications of any discrepancy between perceived and objective consensus may depend on the context in which these differences are observed. For example, consistent with previous research (e.g., Mohammed & Ringseis, 2001), if levels of perceived consensus in a group are higher than levels of objective consensus, this may not necessarily have a negative impact on group work in the context of complex, open-ended, multi-faced problem situations. In the context of high perceived consensus, it may be reasonably expected that the group would continue to be satisfied with their ongoing collaborative learning process and the varied levels of objective agreement across sub-issues, particularly if the overall system design process supports differential patterns of objective agreement across sub-issues and the emergence of a higher-level synthesis and consensus across multiple decisions, as is the case in the IM method. In other words, the process of arriving at a higher-level synthesis and consensus in the IM process, in the form of a consensus-based systems model, is a slow process that involves many independent relational decisions, each of which produce a distinct pattern of deliberation and voting across the collaborative working group.

However, if the level of objective consensus is high, but levels of perceived consensus in the group are low, this might suggest that the group may not be aware of their agreement levels or that the relatively higher level of objective consensus voiced by group members does not reflect their deeper thinking in relation to issues. For example, shallow levels of agreement may arise in groupthink situations (Janis, 1972), where a group is dominated by a charismatic leader and where the group collectively emphasises agreement over dissent in their general pattern of interaction and exchange with one another. This, in turn, may suggest that the group is not functioning optimally, even if objective consensus appears high, or that other factors may be having a negative impact on the emergence of deeper, transparent, genuine consensus-based interactions. As such, for the purpose of creating a positive and effective learning environment, a growing sense of perceived consensus may be more important during the unfolding of deliberations and in efforts to facilitate positive group interactions, and in the long term, these qualities of interaction may aid the group in moving towards higher levels of objective consensus (e.g., at a higher level of systems thinking). Future research may seek to investigate these issues further, for example, under different testing conditions and by measuring levels of consensus over a longer time period, using

alternative measures of perceived and objective consensus, and by assessing the factors which influence the development of both perceived and objective consensus over time.

It is also important to note, in relation to consensus, that Warfield's goal was not to harness consensus *for the sake of consensus*, nor should this be the goal of collaborative learning activities in an educational, organisational, or societal context. Rather, consensus for Warfield was predicated on the participatory design of the methodology. This design sought to ensure that each participant was afforded equal opportunity to contribute, and that the ideas of each participant were acknowledged by others, such that each individual felt that their views have been listened to and understood (Janes, Ellis, & Hammer, 2003). Warfield sought to cultivate consensus through dialogue and democratic voting, such that participants do not feel compelled to agree (Alexander, 2002). By applying simple rules as regards levels of objective consensus needed to enter a path of influence in a systems model, Warfield overcame the reliance on any simple rule of thumb as regards the nature of consensus that should emerge in the overall system design across multiple relational decisions. Indeed, as many as 60 – 100 discrete relational queries are not uncommon in systems model building projects that involve the structuring of 12 to 15 elements in a matrix. As such, it is a higher-order form of both objective and perceived consensus which emerges over the course of an IM session.

As such, a shallow or narrow view in relation to the meaning of consensus should be avoided in collaborative learning situations. This is important in the context of collaborative learning generally, as dissent and critique have been found to be conducive to learning and reflection, both at a societal level (Sunstein, 2005) and in the classroom (Johnson, Johnson, & Smith, 2007). Importantly then, the patterns of argumentation reflected in the CACS analysis in Studies 2 and 3 suggest that students were not moving towards consensus for the sake of consensus, but rather they were engaging in a process of deeper analysis and evaluation of their peer's arguments, before reaching a collective decision as regards discrete paths of influence in a systems model. Again, this is reflected in the additional variety and complexity of argumentation in the process-level prompt condition (Study 2), and the peer-to-peer prompting condition (Study 3). That each of these conditions across Study 2 and 3 were, for example, characterised by higher levels of *challenges* (i.e., *statements that offer problems or questions that must be solved if agreement is to be secured on an arguable*), suggests that critique and dissent were common features of the systems model-building efforts of these groups. As such, while the IM methodology is designed to facilitate consensus, the manner of the consensus-building appears to be more conducive to exploration and learning, rather than

groupthink or shallow consensus, particularly when an IM session is adequately facilitated with process-level prompting (Study 2) or provides opportunities, as well as instructional support, for peer-to-peer prompting.

It is also noteworthy that, while an increase in team orientation was hypothesised in Study 2 (in the process-level prompt condition) and in Study 3 (in the peer-to-peer prompting condition), a significant increase was found only in Study 3. This may suggest that, while students were involved in collaborative learning in each case, the more direct, peer-to-peer interaction inherent in the peer-to-peer prompting condition in Study 3 was more effective in harnessing a sense of affiliation with team members. Alternatively, it is possible that this increase in team orientation in Study 3 was due to an interaction between duration of collaboration and style of prompting used. In contrast to Study 2, in which students worked together for approximately three hours in just one session, students in Study 3 worked together for approximately four hours, across two separate 2-hour sessions. Thus, students in Study 3 had both more time to interact with the students in their group and also more time overall to reflect on this experience, as there was one week between the first and second session. While this time variable was the same for both conditions in Study 3, it may have been some combination of the duration of interaction, and the nature of the peer-to-peer prompting condition, which contributed to the difference in team orientation outcomes between conditions in Study 3, but not Study 2.

More generally, as noted in Chapter 1, while IM has been applied successfully in a wide variety of scenarios, in the context of many complex issues such as conflict resolution (Broome, 2004), mobilising stakeholders in efforts to promote marine sustainability (Domegan et al., 2016), and informing the design of open data platforms (Ruijter et al., 2017), its potential value as an educational tool has not previously been the subject of experimental research. Looking across all three experimental studies presented in this thesis, it is clear that the role of the instructor or teacher is critical to the success of IM as a learning tool for supporting collaborative argumentation and systems thinking in a classroom setting. Notably, providing opportunities for open dialogue, and providing process-level prompting, are within the control of the teacher. Even in the case of Study 3, which employed peer-to-peer prompting, the role of the instructor remains critical, as peer-to-peer prompting is not something that will necessarily be readily practiced in the absence of quality instructional support and modelling of specific behaviours.

As noted by Dillenbourg et al. (2009) in the context of CSCL, the evolution of the teacher “from the sage on the stage to the guide on the side” (p. 14) is recognised as a

valuable transition of instructional style in a classroom setting, as the role of the teacher changes from one of the primary knowledge provider to that of a conductor who orchestrates a range of collaborative learning activities. In the case of Study 3, in which the learning activity involves coordination of both computer-support and peer-to-peer interaction, this role of the teacher as orchestrator is both challenging and of vital importance. A considerable amount of training, piloting, and feedback to classroom facilitators was needed in advance of Study 3, and much was learnt from conducting a pilot study in this regard. While the teacher's role may appear to involve less direct engagement in the latter phase of a peer-to-peer learning activity, the task of effectively providing support and guidance for peer-to-peer prompting should not be understated. Consistent with van Steendam et al. (2010), who reported that modelling and emulation of peer interactions can improve the quality of peer feedback delivered by students, Study 3 highlights these benefits, but the task of modelling and guiding students, and offering teachers instructional guidance in how best to do this, requires further investigation in the Learning Sciences literature.

Finally, findings in relation to perceived consensus across Studies 1-3 have implications for collaborative learning practices. Importantly, an increase in perceived consensus reflects changes in attitudes and opinions in relation to the topic under discussion, and the generation of a shared level of understanding. In a teaching context, efforts to measure and report back to students on their unfolding perception of consensus may give students the opportunity to reflect on their learning throughout a CSCL process. This reflection is important given that, according to Michaelsen and Sweet (2008), students often fail to realise how much they have learned in team-based settings. By taking time to think about their perceptions of shared consensus after the group discussion, students may become increasingly aware of the resulting changes in their attitudes and opinions. Tjosvold (2008) argues that open-minded discussion of diverse views is a social process which results in increased awareness of the complexity of a problem. By engaging in dialogue and reflecting on emergent perceptions of consensus at the group level, groups may work not only toward shared mental models of a problem situation (van den Bossche, Gijsselaers, Segers, Woltjer, & Kirschner, 2011), their shared mental models may collectively advance toward increasingly higher levels of complexity, and thus support increasingly adaptive and flexible responses to the problem they are addressing together.

7.5. Advancing upon the vision of Warfield

As highlighted in the preface to this thesis, Dewey believed that an educated population is a fundamental requirement in efforts to sustain a democratic society. As elaborated by Stein (2017), Dewey argued that “true democracy is intrinsically educational because it is a process that seeks a continued opening into new experience and learning. Our current democracies are at their best when they spark reasonable and reflective discourse, beyond the spectatorship and sports-fan-like jeering, where people come together with a feeling that their words matter and they have the power to decide what is best for their lives and communities” (p. 169). Such a goal, of having an informed society that includes an increasingly well-educated population who are motivated to engage in discourse pertaining to complex societal problems, implies a need for the design of educational systems that promote dialogue and collaboration around societal issues, providing students with the skills to engage in the democratic process. While the work presented in this thesis, including the pilot applied systems education curriculum, represents an important advance in this regard, change is also needed at the level of educational culture, policy, and infrastructure, and also more broadly at the social and political levels of social system design. As noted by Stein (2017), the culture that permeates our education system and the culture in our society are inextricably linked. Importantly, Stein argues that educational system designs that promote and cultivate dialogue and collaboration are closely aligned with the broader political philosophy of deliberative democracy which can be a model of governance that shapes collaborative learning activities across a host of societal institutions and organisations. At the political level, this model moves beyond a representative democracy by empowering citizens to influence policy decision more directly through ongoing deliberation between public administrators and citizens in an open process of dialogue. At the institutional and organisational levels, this model can similarly be used to empower groups and teams to co-create their own policies, programmes and projects as part of an ongoing collaborative learning process.

Importantly, as argued by Dewey, Stein, and others, a focus on promoting dialogue and democratic decision-making in both student groups in formal education and in citizens in the socio-political realm is a critical step towards the full realisation of human potential, specifically, where increasingly well-educated members of society are empowered to shape the design of their own futures and respond collaboratively to the challenges they face together. As such, while Warfield envisioned an approach to education which cultivates systems thinking and systems design skills in teams, with an emphasis on dialogue,

consensus-building and teamwork in efforts to prepare students to work together as adults to address complex societal problems, the realisation of Warfield's vision may prove difficult to achieve in the absence of a cultural shift towards greater emphasis on student-centred dialogue, collaboration, and empowerment of students to become more active agents in their education.

Notably, McKenney (2018) in an editorial piece in the *Journal of the Learning Sciences*, addressed the need for the field of the Learning Sciences to enhance its impact on policy and practice, so that research findings can be contextualised and implemented in the support of “real-world improvement in educational systems” (p. 1). McKenney emphasised the need to understand and influence broader factors which shape the settings in which learning takes place, including key social, historical, and economic factors. Furthermore, McKenney raises questions around how research in the Learning Sciences can inform educational policy. Indeed, from Warfield's perspective, addressing these design challenges would entail collaborative systems thinking and systems design efforts. For example, as described by Hogan et al. (2017), mobilising the transformation of educational systems requires the engagement of key stakeholders (e.g., students, teachers, policymakers, researchers, educational technologists) in a process of educational design-based research where new systems and practices are designed collaboratively, and then implemented and evaluated as part of an iterative social learning process. Advancing Warfield's vision for applied systems science education will require a specific line of collaborative design thinking and iterative development at both the curriculum and systemic levels. More broadly, at the systemic level, advancement of systems science education and the development of the associated skills of systems design and collaborative systems change implies the cultivation of expertise in systems methods, at both the interdisciplinary and transdisciplinary levels. This systemic approach to the iterative redesign of education systems is necessary, given that many of the more complex social and scientific problems faced by society today require an interdisciplinary perspective and the development of transdisciplinary methods that support systems thinking and systems design work in an increasingly well-educated population. However, as noted by Warfield in his deliberations in relation to the *Horizon College*, a clear demand for collaborative systems design skill needs to be recognised by societal stakeholders, and this demand may be slow to arise given the habitual approaches to problem-solving that are prominent within society. Furthermore, increasing the demand for collaborative systems design skill requires further demonstration of the power and potential of collaborative systems design methods. Clear demonstration of this power and potential

requires carefully designed research and case study work, and dissemination of key findings to the community. This process is ongoing and the research presented in this thesis contributes to this ongoing change process by demonstrating some of the key benefits of collaborative systems design work.

7.6. Limitations and future research

Limitations associated with each study were discussed in Chapters 3, 4 and 5. However, several key issues common to more than one study are discussed below.

First, a potential limitation of Studies 1-3 relates to the use of self-report measures to assess trust, perceived consensus, objective consensus, perceived efficacy, team orientation, and discomfort in group learning. Self-report measures are susceptible to issues of response bias and it is possible for participants to answer in ways which do not reflect their true beliefs or perceptions. Further, self-report measures may be affected by respondent attitudes, cognitive processes, mood, and personality (e.g., Spector, 1994). Although the reliability and validity of the measures used in the current research was deemed to be acceptable, future research should adopt alternative approaches to measure key constructs of interest. For example, future research may adopt behavioural measures of trust such as an adapted version of the *Rely-or-Verify Game* (Levine & Schweitzer, 2015), which involves a trust-based reward system between two players, with the amount of money (reward) a player can earn depending on whether they opt to rely upon (trust) or verify (distrust) the information provided to them by another player. It is also worth noting, in relation to the pilot module described in Chapter 6, that the reflections collected from students represent another type of self-report measure, and it is possible that students responded to the reflective journal exercise in a socially desirable manner. That the reflections provided by students in the anonymous end-of-semester module evaluation were also predominantly positive, however, suggests that earlier reflections provided were indicative of students' true experience.

Second, convenience sampling was used in each study. All participants were self-selected from one university, and all were psychology students. Furthermore, the vast majority of these students completed these studies as part of research credit requirements set by the university. While the results and implications of these studies are primarily concerned with university students, there remains nonetheless a potential issue of generalisability owing to the fact that participants were, for the most part, ethnically, socio-economically, and educationally homogenous. Future research should attempt to replicate the findings presented

in this thesis with a more heterogeneous sample, to assess the generalisability of these findings.

Third, there was a gender imbalance in the samples of each study, with an overall ratio of approximately 3:2 females to males across each study. This is a common sampling issue in university samples, particularly for research in psychology due to the typical gender imbalance of the psychology student population (Skinner & Louw, 2009). While there is some suggestion in the literature regarding differences in male and female patterns of discussion in CSCL research, with some studies suggesting, for example, that females are more likely to qualify and justify their assertions in collaborative exchanges (Fahy, 2003; Smith, McLaughlin & Osbourne, 1997) whereas males are more likely to assert their opinions as facts (Fahy, 2002). However, these findings are not consistently reported in the literature, with other studies reporting that any gender differences are diminished when hints (e.g., prompts) are provided (e.g., Ding & Harskamp, 2009), or when students interactions are facilitated (Gillies and Ashman, 1995). As such, while possible, it is not thought that the distribution of males and females across working groups influenced results in Studies 1-3. However, it may be beneficial for future research to attempt to replicate these findings with more gender-balanced samples, or examine effects for groups of males and group of females, separately.

Fourth, in relation to Studies 2 and 3 in which there were multiple groups in each condition, it is possible that specific patterns of interactions occurring between students within, but not across, groups, may have had an impact on the findings observed across studies. While considerable efforts were made to standardise the learning conditions in each group and minimise any potential variability, including careful training of facilitators to provide facilitation within strict protocols at all times during each of the experimental studies, the nature of collaborative learning research is such that differences in interactions between group members is possible. As such, the interactions between students within the two groups in each condition in Study 2, and within the four groups in each condition in Study 3 may have varied in ways beyond the control of the researcher.

Fifth, another potential limitation relates to the fact that no method for gauging students' interest in the topics of discussion in any of the three studies was used. It is possible that differences within or across groups in levels of interest in the topics being discussed may have impacted on levels of engagement, and thus, for example, influenced the degree to which students engaged in in-depth argumentation, or perceived the IM methodology to be effective. While such differences in interest may of course be a feature of any real-world

classroom, it may be of interest in future research to incorporate a measure of interest in, or familiarity with, the topic of discussion during such investigations.

Sixth, this thesis did not provide an experimental examination of the pilot systems science education module. While providing a useful template for future design of curricula, the pilot curriculum designed in Chapter 6 did not include pre- and post-measures of performance on relevant outcomes such as consensus-building, critical thinking, systems thinking, argumentation skills, or team orientation. As such, future research should seek to replicate, or extend this curriculum design, with the inclusion of measures of key learning processes and outcomes. Similarly, future research may seek to compare learning outcomes associated with a systems science education module against a variety of different control conditions, to assess its efficacy in fostering key skills in students when compared with other learning experiences.

Seventh, while a primarily experimental approach was deemed appropriate for the research goals of the current thesis, it should be acknowledged that other approaches may have provided certain advantages or affordances. DBR, for example, provides opportunities for iterative subtle changes and adaptations to ongoing interventions, while maintaining the validity and authenticity of the classroom context in the absence of experimental controls. Thus, a DBR approach to the current research may have shed light on additional aspects of classroom complexity, and how this complexity interacts with the application of the facilitation styles (e.g. peer prompting) in the context of the systems model-building task. However, it may be argued that the application of DBR in this context, rather than representing an alternative approach to the current research, may in fact represent a next step. Given that DBR generally begins with the piloting of an intervention, followed by cycles of further iterations, scaling-up, and evaluation, the pilot curriculum presented in Chapter 6 may provide the platform for subsequent DBR investigation of the application of the experimental findings (e.g. implementing peer prompting) within the context of a systems science education curriculum. Such a DBR investigation, building upon the experimental findings now integrated into the pilot curriculum, may serve as a solid basis for iterative design, development, implementation, and evaluation of a systems science education curriculum.

Eighth, and finally, the IM process itself, including the ISM systems model-building tool, was not modified during this research. The IM process has been employed extensively in a wide variety of group problem-solving contexts, with numerous successful applications and outcomes described in the literature (as noted in section 1.2.1.). However, it is acknowledged that further investigation of the IM process as an educational tool, such as

experimental research or DBR, is necessary. While the current research focused on facilitation and social processes in collaborative learning, and thus employed IM primarily as the context in which dialogue and collaborative argumentation took place (i.e. during the systems model-building task), future research may seek to manipulate and investigate aspects of the IM process itself, including the ISM tool as a means of working with students to generate systems models of complex issues.

7.7. Overall conclusion

The current research marks the first steps towards the integration of John Warfield's vision for systems science into university education. The experimental findings presented in this thesis offer insight into key design considerations that are central to the realisation of Warfield's vision for systems science education. These include the fostering of dialogue in systems model-building activities, facilitation and prompting of argumentation during systems model-building activities, as well as consideration of key social-emotional processes and outcomes which may influence students' response to, and engagement with, applied systems science education initiatives. Crucially, this thesis provides evidence for the benefits of process-level prompting, as well as peer-to-peer prompting in the context of collaborative learning, both on the variety and complexity of argumentation, and aforementioned social-emotional processes. The reported beneficial effects of peer-to-peer prompting are particularly promising for future research and practice in collaborative learning, with peer learning increasingly being recognised as a means of providing opportunities for engaging students in dialogue with their peers, and directing their own learning. As such, the current findings provide a strong basis for future research on peer-to-peer prompting, and peer learning more broadly. Overall, this thesis, which culminates in the design and implementation of a pilot systems science education curriculum, has significant implications for teaching and learning in collaborative learning contexts, and provides, in particular, a springboard for further research, development and design efforts that aim to bring Warfield's vision to fruition.

References

- Abrami, P.C., Bernard, R.M., Borokhovski, E., Wade, A., Surkes, M.A., Tamim, R., & Zhang, D. (2008). Instructional interventions affecting critical thinking skills and dispositions: A stage 1 meta-analysis. *Review of Educational Research, 78, 4*, 1102-1134.
- Ackoff, R. L. (1981). *Creating the corporate future: Plan or be planned for*. New York: John Wiley and Sons.
- Ada, M. A. (2009). Computer supported collaborative learning and higher order thinking skills: A case study of textile studies. *Interdisciplinary Journal of E-Learning and Learning Objects, 5(1)*, 145-167.
- Adams, S. (2014). The 10 skills employers most want in 2015 graduates. *Forbes Leadership*. Retrieved from: <https://www.forbes.com/sites/susanadams/2014/11/12/the-10-skills-employers-most-want-in-2015-graduates/#4c2f96302511>.
- Aikins, J. W., Bierman, K. L., & Parker, J. G. (2005). Navigating the transition to junior high school: The influence of pre-transition friendship and self-system characteristics. *Social Development, 14(1)*, 42-60.
- Alavi, M. (1994). Computer-mediated collaborative learning: An empirical evaluation. *MIS quarterly, 18(2)*, 159-174.
- Alberts, H. (1992). *Acquisition: past, present and future*. Paper presented at the meeting of the Institute of Management Sciences and Operations Research Society, Orlando, FL.
- Alexander, R. (2004). *Towards dialogic teaching*. York: Dialogos.
- Alvero, A., Bucklin, B., & Austin, J. (2001). An Objective Review of the Effectiveness and Essential Characteristics of Performance Feedback in Organizational Settings (1985–1998). *Journal of Organizational Behavior Management, 21(1)*, 3-30. doi: 10.1300/J075v21n01_02.
- Alberts, H. (1992, March). *Acquisition: Past, present and future*. Paper presented at the meeting of the Institute of Management Sciences and Operations Research Society, Orlando, FL.
- Alvarez-Ortiz, C. (2007). Does Philosophy Improve Critical Thinking Skills? Unpublished Masters Thesis. The University of Melbourne.
- American Chamber of Commerce. (2016). *Submission to the Department of Education and Skills consultation on Statement of Strategy 2016-2018*.

- Anderson, R. C., Chinn, C., Wagoner, M., & Nguyen, K. (1998). Intellectually stimulating story discussions. In J. Osborn & F. Lehr (Eds.). *Literacy for all* (pp. 170-186). New York, NY: Guilford.
- Anderson, R. C., Chinn, C., Chang, J., Waggoner, M., & Yi, H. (1997). On the logical integrity of children's arguments. *Cognition and Instruction, 15*(2), 135-167.
- Anderson, C. M., & Martin, M. M. (1999). The relationship of argumentativeness and verbal aggressiveness to cohesion, consensus, and satisfaction in small groups. *Communication Reports, 12*(1), 21-31.
- Andriessen, J. & Baker, M. (2014). Arguing to learn. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 439-460). New York: Cambridge University Press.
- Andriessen, J., & Schwarz, B. (2009). Argumentative Design. In N, Muller. & A, Perret-Clermont. (Eds.). *Argumentation and education* (pp. 145-176). New York: Springer.
- Andrews, R. (1995). *Teaching and learning argument*. London: Cassell Publishers.
- Arbaugh, J. B. (2000). Virtual classroom characteristics and student satisfaction with internet-based MBA courses. *Journal of Management Education, 24*(1), 32-54.
- Arbaugh, J. B. (2002). Managing the on-line classroom: a study of technological and behavioral characteristics of web-based MBA courses. *Journal of High Technology Management Research, 13*, 203-223.
- Arbaugh, J. B., & Duray, R. (2002). Technological and structural characteristics, student learning and satisfaction with web-based courses – An exploratory study of two on-line MBA programs. *Management Learning, 33*(3), 331-347.
- Argyris, C. (1982). *Reasoning, learning, and action: Individual and organizational*. San Francisco: Jossey-Bass.
- Ashby, W. R. (1958). *An Introduction to Cybernetics*. New York: Wiley.
- Asterhan, C. S. C., Butler, R., & Schwarz, B. B. (2010). Goals for learning and interaction in argumentation and conceptual change. In K. Gomez, L. Lyons, & J. Radinsky (Eds.). *Learning in the Disciplines: Proceedings of the 9th International Conference of the Learning Sciences (ICLS 2010) - Volume 1*. Chicago IL: International Society of the Learning Sciences.
- Asterhan, C. S., & Schwarz, B. B. (2007). The effects of monological and dialogical argumentation on concept learning in evolutionary theory. *Journal of Educational Psychology, 99*(3), 626-639.

- Asterhan, C. S., & Schwarz, B. B. (2009). Argumentation and explanation in conceptual change: Indications from protocol analyses of peer-to-peer dialog. *Cognitive science*, 33(3), 374-400.
- Asterhan, C. S., & Schwarz, B. B. (2010). Online moderation of synchronous e-argumentation. *International Journal of Computer-Supported Collaborative Learning*, 5(3), 259-282. doi: 10.1007/s11412-010-9088-2.
- Asterhan, C. S., & Schwarz, B. B. (2016). Argumentation for learning: Well-trodden paths and unexplored territories. *Educational Psychologist*, 51(2), 164-187.
- Baker, M. J. (2003). Computer-Mediated Argumentative Interactions for the Co-Elaboration of Scientific Notions. In J. Andriessen, M. J. Baker, & D. D. Suthers (Eds.). *Arguing to learn: Confronting Cognitions in Computer-Supported Collaborative Learning Environments* (pp. 47–78). Dordrecht: Kluwer Academic.
- Baker, M. J., Quignard, M., Lund, K., & Séjourné, A. (2003, June). *Computer-supported collaborative learning in the space of debate*. Paper presented at the International Conference on Computer Support for Collaborative Learning: Designing for Change in Networked Learning Environments, Dordrecht, The Netherlands: doi:10.1007/978-94-017-0195-2_4.
- Bakhtin, M. M. (1981). *The dialogic imagination: Four essays* (M. M. Bakhtin & M. Holquist, Eds., C. Emerson & M. Holquist, Trans.). University of Texas, USA: University of Texas Press.
- Balcazar, F. E., Shupert, M. K., Daniels, A. C., Mawhinney, T. C., & Hopkins, B. O. (1989). An Objective Review and Analysis of Ten Years of Publication in the Journal of Organizational Behavior Management. *Journal of Organizational Behavior Management*, 10(1), 7–38. doi:10.1300/J075v10n01_02.
- Barr, S. H., & Conlon, E.J. (1994). Effects of distribution of feedback in work groups. *Academy of Management Journal*, 37(3), 641-655. doi:10.2307/256703.
- Barron, B. (2000). Achieving Coordination in Collaborative Problem-Solving Groups. *The Journal of the Learning Sciences*, 9(4), 403–43. doi:10.1207/S15327809JLS0904_2.
- Barron, B. (2003). When smart groups fail. *The Journal of the Learning Sciences*, 12(3), 307-359.
- Beauchamp, G., & Kennewell, S. (2010). Interactivity in the classroom and its impact on learning. *Computers & Education*, 54(3), 759-766.

- Beck, S. J., Gronewold, K., & Western, K. (2012). Intergroup argumentation in city government decision making: The Wal-Mart dilemma. *Small Group Research, 43*(5), 87-612. doi: 10.1177/1046496412455435.
- Beckman, M. (1990). Collaborative learning: Preparation for the workplace and democracy? *College Teaching, 38*(4), 128-133.
- Beers, P. J., Boshuizen, H. P. A., Kirschner, P. A., & Gijsselaers, W. H. (2007). The analysis of negotiation of common ground in CSCL. *Learning and Instruction, 17*(4), 427-435.
- Bell, P. (2004). Promoting students' argument construction and collaborative debate in the science classroom. In M.C. Linn, E.A. Davis, & P. Bell (Eds.). *Internet environment for science education* (pp.115-143). Mahwah, NJ: Lawrence Erlbaum Associates.
- Bell, P., & Linn, M. C. (2000). Scientific arguments as learning artifacts: Designing for learning from the web with KIE. *International Journal of Science Education, 22*(8), 797–817.
- Bell, S. T. (2007). Deep-level composition variables as predictors of team performance: a meta-analysis. *Journal of Applied Psychology, 92*(3), 595-615.
- Berland, L. K. (2011). Explaining variation in how classroom communities adapt the practice of scientific argumentation. *Journal of the Learning Sciences, 20*(4), 625-664.
- Berthold, K., Nückles, M., & Renkl, A. (2007). Do learning protocols support learning strategies and outcomes? The role of cognitive and metacognitive prompts. *Learning and Instruction, 17*, 564–577. doi: 10.1016/j.learninstruc.2007.09.007.
- Bettenhausen, K. L. (1991). Five years of groups research: What we have learned and what needs to be addressed. *Journal of Management, 17*, 345-381.
- Bianchi, E. C., & Brockner, J. (2012). In the eyes of the beholder? The role of dispositional trust in judgments of procedural and interactional fairness. *Organizational Behavior and Human Decision Processes, 118*(1), 46-59.
- Bleicher, R.E., Tobin, K.G., & McRobbie, C.J. (2003). Opportunities to talk science in a high school chemistry classroom. *Research in Science Education, 33*, 319-339.
- Bloxham, S., & West, A. (2004). Understanding the rules of the game: marking peer assessment as a medium for developing students' conceptions of assessment. *Assessment & Evaluation in Higher Education, 29*(6), 721-733. doi: 10.1080/0260293042000227254.
- Blumenfeld, P., Soloway, E., Marx, R., Krajcik, J., Guzdial, M. and Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26*, 369-398. doi:10.1080/00461520.1991.9653139.
- Bohm, D. (1996). *On dialogue*. London: Routledge.

- Boud, D. (1990). Assessment and the promotion of academic values. *Studies in Higher Education, 15*, 101– 111. doi:10.1080/03075079012331377621
- Boud, D., Cohen, R., & Sampson, J. (2001). *Peer Learning in Higher Education: Learning from & with Each Other*. Psychology Press.
- Boulding, K. E. (1966). *The impact of the social sciences*. New Brunswick, NJ: Rutgers University Press.
- Broome, B. J. (1995). Collective design of the future: Structural analysis of tribal vision statements. *American Indian Quarterly, 19*(2), 205-228.
- Broome, B. J. (2004). Reaching across the dividing line: Building a collective vision for peace in Cyprus. *Journal of Peace Research, 41*(2), 191-209.
- Broome, B. J. (2006). *Applications of Interactive Design Methodologies in Protracted Conflict Situations. Facilitating group communication in context: Innovations and applications with natural groups*: Hampton Press.
- Broome, B. J. (2009). Dialogue Theories. In S. Littlejohn & K. Foss (Eds.). *Encyclopedia of Communication Theory* (pp. 302-307). Thousand Oaks, CA: SAGE Publications.
- Broome, B. J., & Chen, M. (1992). Guidelines for computer-assisted group problem-solving: Meeting the challenges of complex issues. *Small Group Research, 23*(2), 216-236. doi:10.1177/1046496492232005.
- Broome, B. J., & Christakis, A. N. (1998). A culturally-sensitive approach to tribal governance issue management. *International Journal of Intercultural Relations, 12*(2), 107-123. doi:10.1016/0147-1767(88)90043-0.
- Broome, B. J., & Cromer, I. L. (1991). Strategic planning for tribal economic development: A culturally appropriate model for consensus building. *International Journal of Conflict Management, 2*(3), 217-234. doi:http://dx.doi.org/10.1108/eb022700.
- Broome, B. J., & Fulbright, L. (1995). A multi-stage influence model of barriers to group problem solving. *Small Group Research, 26*(1), 25-55. doi:10.1177/1046496495261002.
- Broome, B. J., & Kever, D. B. (1989). Next generation group facilitation: Proposed principles. *Management Communication Quarterly, 3*(1), 107-127.
- Brossmann, B. G., & Canary, D. J. (1990). An observational analysis of argument structures: The case of Nightline. *Argumentation, 4*, 199-212.
- Brown, A. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences, 2*(2), 141-178.

- Brown, A. L., & Campione, J. C. (1990). Communities of learning and thinking, or a context by any other name. In *Developmental perspectives on teaching and learning thinking skills* (pp. 108-126). Karger Publishers.
- Brown, A. L., & Palincsar, A. S. (1989). Guided, cooperative learning and individual knowledge acquisition. In L. B. Resnick (Ed.). *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 393-451). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
- Buber, M. (1958). *I and Thou* (2nd ed.; R. G. Smith, Trans.). New York: Scribner.
- Burnett, A., & Badzinski, D. M. (2000). An exploratory study of argument in the jury decision-making process. *Communication Quarterly*, 48(4), 380-396.
- Butchart, S., Bigelow, J., Oppy, G., Korb, K., & Gold, I. (2009). Improving critical thinking using web-based argument mapping exercises with automated feedback. *Australasian Journal of Educational Technology*, 25(2), 268-291.
- Cáceres, M., Nussbaum, M., Marroquín, M., Gleisner, S., & Marquínez, J. T. (2017). Building arguments: key to collaborative scaffolding. *Interactive Learning Environments*, 25, 1-17.
- Campion, M. A., Medsker, G., & Higgs, C. (1993). Relations between work group characteristics and effectiveness: Implications for designing effective work groups. *Personnel Psychology*, 46, 823-847.
- Canary, D. J., Brossmann, B. G., & Siebold, D., R. (1987) Argument structures in decision-making groups. *Southern Speech Communication Journal*, 53(1), 18-37. doi: 10.1080/10417948709372710.
- Canary, D. J., Brossmann, J., Brossmann, B. G., & Weger, H., Jr. (1995). Toward a theory of minimally rational argument: Analyses of episode-specific effects of argument structures. *Communication Monographs*, 62, 183-212.
- Cantwell, R. H., & Andrews, B. (2002). Cognitive and psychological factors underlying secondary school students' feelings towards group work. *Educational Psychology*, 22(1), 75-91.
- Castells, M. (2001). *The Internet Galaxy. Reflections on the Internet, Business and Society*. Oxford: Oxford University Press.
- Cazden, C. (2001). *Classroom discourse: The language of teaching and learning*. Portsmouth, NH: Heinemann.
- Chang, H. M. (2009). *Students' trust building in a collaborative learning team*. Retrieved from ProQuest Dissertations and Theses database.

- Cheng, W. Y., Lam, S. F., & Chan, C. Y. (2008). When high achievers and low achievers work in the same group: The roles of group heterogeneity and processes in project-based learning. *British Journal of Educational Psychology*, 78(2), 205-221.
- Chi, M. T. H. (2000). Self-explaining expository texts: The dual processes of generating inferences and repairing mental models. In Glaser, R. (Ed). *Advances in Instructional Psychology* (pp. 161-238). Mahwah, NJ: Lawrence Erlbaum Associates.
- Chi, M. T. H., de Leeuw, N., Chiu, M., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science*, 18, 439-477. doi: 10.1207/s15516709cog1803_3.
- Chin, C. (2006). Classroom Interaction in Science: Teacher questioning and feedback to students' responses. *International Journal of Science Education*, 28(11), 1315-1346.
- Chiu, C. M., Hsu, M. H., & Wang, E. T. (2006). Understanding knowledge sharing in virtual communities: An integration of social capital and social cognitive theories. *Decision Support Systems*, 42(3), 1872-1888.
- Chiriac, E. H. (2014). Group work as an incentive for learning—students' experiences of group work. *Frontiers in Psychology*, 5, 1-10.
- Cho, K., Chung, T. R., King, W. R., & Schunn, C. D. (2008). Peer-based computer supported knowledge refinement: an empirical investigation. *Communications of the ACM*, 51(3), 83-88.
- Cho, K., & MacArthur, C. (2010). Student revision with peer and expert reviewing. *Learning and Instruction*, 20(4), 328-338.
- Cho, K., & MacArthur, C. (2011). Learning by reviewing. *Journal of Educational Psychology*, 103(1), 73-84.
- Cho, K., & Schunn, C. D. (2007). Scaffolded writing and rewriting in the discipline: A web-based reciprocal peer review system. *Computers & Education*, 48(3), 409-426.
- Chinn, C. A., Anderson, R. C., & Waggoner, M. A. (2001). Patterns of discourse in two kinds of literature discussion. *Reading Research Quarterly*, 36, 378-411.
- Christakis, A. N. (1987). Systems profile: The Club of Rome revisited. *Systems Research*, 4(1), 53-58. doi:10.1002/sres.3850040107.
- Clark, D. B., & Sampson, V. (2008). Assessing dialogic argumentation in online environments to relate structure, grounds, and conceptual quality. *Journal of Research in Science Teaching*, 45, 293-321. <http://dx.doi.org/10.1002/tea.20216>
- Cleveland, H. (1973). The decision makers. *Center Magazine*, 6(5), 9-18.

- Coke, J. G., & Moore, C. M. (1981). Coping with a budgetary crisis: Helping a city council decide where expenditure cuts should be made. In S. W. Burks & J. F. Wolf (Eds.). *Building city council leadership skills: A casebook of models and methods* (pp. 72-85). Washington, DC: National League of Cities.
- Coleman, E. B. (1998). Using explanatory knowledge during collaborative problem solving in science. *Journal of the Learning Sciences*, 7(3-4), 387-427.
- Collazos, C. A., Guerrero, L. A., Pino, J. A., Renzi, S., Klobas, J., Ortega, M., Redondo, M. A., & Bravo, C. (2007). Evaluating Collaborative Learning Processes using System-based Measurement. *Educational Technology & Society*, 10(3), 257-274.
- Collis, B. (1991). Anticipating the impact of multimedia in education: Lessons from literature. *International Journal of Computers in Adult Education and Training*, 2(2), 136-149.
- Comadena, M. E. (1984). Brainstorming groups: Ambiguity tolerance, communication apprehension, task attraction, and individual productivity. *Small Group Behavior*, 15(2), 251-264.
- Cress, U., & Kimmerle, J. (2008). A systemic and cognitive view on collaborative knowledge building with wikis. *International Journal of Computer-Supported Collaborative Learning*, 3(2), 105-122.
- Crook, C. (2000). Motivation and the ecology of collaborative learning. In R. Joiner, K. Littleton, D. Faulkner, & D. Miell (Eds.), *Rethinking collaborative learning* (pp. 161-178). London: Free Association Books.
- Currall, S.C. & Judge, T.A. (1995). Measuring trust between organizational boundary role persons. *Organizational Behavior and Human Decision Processes*, 64(2), 151-170. doi: 10.1006/obhd.1995.1097
- Davies, M., & Meissel, K. (2016). The use of Quality Talk to increase critical analytical speaking and writing of students in three secondary schools. *British Educational Research Journal*, 42(2), 342-365.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. *MIS Quarterly*, 13(3), 319-340.
- Davis, E.A. (2003). Prompting Middle School Science Students for Productive Reflection: Generic and Directed Prompts. *The Journal of the Learning Sciences*, 12(1), 91-142. doi: 10.1207/S15327809JLS1201_4.
- Deal, T. E. & Kennedy, A. A. (1982). *Corporate cultures: The rites and rituals of corporate life*. Reading, MA: Addison-Wesley.

- Delbeq, A. L., Van De Ven, A. H., & Gustafson, D. H. (1975). *Group techniques for program planning: A guide to nominal group and Delphi processes*. Glenview, IL: Scott, Foresman.
- Department of Business, Enterprise and Innovation. (2016). *Strategy for Research and Development Science, Technology, and Innovation*.
- Denson, R. W. (1981). *Team Training: Literature Review and Annotated Bibliography*. Brooks Air Force Base, TX: Air Force Human Resources Laboratory.
- Deutsch, M. (1973). *The resolution of conflict: Constructive and destructive processes*. New Haven, CT: Yale University Press.
- Dewett, T. (2003). Towards an Interactionist Theory of Group-Level Feedback. *Management Research News*, 26(10-11), 1-21. doi:10.1108/01409170310784041.
- De Hoyos Guevara, M. (2004). *Assessment of teamwork in higher education collaborative learning teams: A validation study*. Retrieved from ProQuest Dissertations and Theses database.
- de Vries, E., Lund, K., & Baker, M. (2002). Computer-mediated epistemic dialogue: Explanation and argumentation as vehicles for understanding scientific notions. *Journal of the Learning Sciences*, 11(1), 63-103.
- Dickinson, T. L., & McIntyre, R. M. (1997). A conceptual framework for teamwork measurement. In M. T. Brannick, E. Salas, & C. Prince (Eds.). *Team Performance and Measurement: Theory, Methods, and Applications* (pp. 19-43). Mahwah, NJ: Lawrence Erlbaum Associates.
- Diehl, M., & Stroebe, W. (1987). Productivity loss in brainstorming groups: Toward the solution of a riddle. *Journal of Personality and Social Psychology*, 53(3), 497-509.
- Dierick, S., & Dochy, F. (2001). New lines in edumetrics: New forms of assessment lead to new assessment criteria. *Studies in Educational Evaluation*, 27, 307-329. doi:10.1016/S0191-491X(01)00032-3.
- Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1996). The evolution of research on collaborative learning In E. Spada & P. Reiman (Eds.). *Learning in Humans and Machine: Towards an interdisciplinary learning science* (pp. 189-211). England: Elsevier.
- Dillenbourg, P. (1999). What do you mean by collaborative learning? In P. Dillenbourg (Ed.). *Collaborative learning: Cognitive and Computational Approaches* (pp. 1-19). Oxford: Elsevier.

- Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In P. A. Kirschner (Ed.). *Three worlds of CSCL. Can we support CSCL* (pp. 61-91). Heerlen: Open Universiteit Nederland.
- Dillenbourg P., Järvelä S., & Fischer F. (2009). The evolution of research on computer-supported collaborative learning: From design to orchestration. In Balacheff, N., Ludvigsen, S., de Jong, T., Lazonder, T. A., & Barnes, S. (Eds.). *Technology enhanced learning: Principles and products* (pp. 3-19). Netherlands: Springer.
- Dillon, J. T. (1985). Using questions to foil discussion. *Teaching and Teacher Education, 1*(2), 109-121.
- Ding, N. & Harskamp, E. G. (2009). Gender Difference in Students' Cognitive Representations during Collaborative Problem-Solving in Physics. *International Journal of Science Education*. Retrieved May 2nd, 2015 from: <https://www.rug.nl/research/portal/files/14562479/Chapter%205>.
- Domegan, C., McHugh, P., Devaney, M., Duane, S., Hogan, M., Broome, B. J., ... & Piwowarczyk, J. (2016). Systems-thinking social marketing: conceptual extensions and empirical investigations. *Journal of Marketing Management, 32*(11-12), 1123-1144.
- Driskell, J. E., & Salas, E. (1992). Collective behavior and team performance. *Human Factors, 34*(3), 277-288.
- Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education, 38*, 39-72.
- Dwyer, C. P. (2011). The evaluation of argument mapping as a learning tool. Doctoral Dissertation. National University of Ireland, Galway.
- Dwyer, C. P., Hogan, M. J., Harney, O. M., & Kavanagh, C. (2017). Facilitating a student-educator conceptual model of dispositions towards critical thinking through Interactive Management. *Educational Technology Research and Development, 65*(1), 47-73.
- Dwyer, C. P., Hogan, M. J., Harney, O. M., & O'Reilly, J. (2014). Using interactive management to facilitate a student-centred conceptualisation of critical thinking: a case study. *Educational Technology Research and Development, 62*(6), 687-709.
- Dwyer, C. P., Hogan, M. J., & Stewart, I. (2015). The effects of argument mapping-infused critical thinking instruction on reflective judgement performance. *Thinking Skills and Creativity, 16*, 11-26.
- Dwyer, C. P., Hogan, M. J., & Stewart, I. (2012). An evaluation of argument mapping as a method of enhancing critical thinking performance in e-learning environments. *Metacognition and Learning, 7*(3), 219-244.

- Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction, 20*(4), 399-483.
- Eby, L. & Dobbins, G. 1997. Collectivistic orientation in teams: An individual and group-level analysis. *Journal of Organizational Behavior, 18*, 275-295. doi:10.2307/3100145.
- Eden, C., Jones, S., Sims, D., & Smithin, T. (1981). The intersubjectivity of issues and issues of intersubjectivity. *Journal of Management Studies, 18*, 37-47.
- Edwards, D. & Mercer, N. (2013). *Common knowledge: The growth of understanding in the classroom*. London: Routledge.
- Ellis, D. G., & Maoz, I. (2007). Online argument between Israeli Jews and Palestinians. *Human Communication Research, 33*(3), 291–309.
- Ennen, N. L., Stark, E., & Lassiter, A. (2015). The importance of trust for satisfaction, motivation, and academic performance in student learning groups. *Social Psychology of Education, 18*(3), 615-633.
- Ennis, R. H. (1989). Critical thinking and subject specificity: Clarification and needed research. *Educational Researcher, 18*(3), 4-10.
- Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science education, 88*(6), 915-933.
- Erkens, G. (2005). Multiple Episode Protocol Analysis. (Version 4.10). [Software] Available from <http://edugate.fss.uu.nl/mepa/>.
- Fahy, P. (2002). Use of linguistic qualifiers and intensifiers in computer conference. *The American Journal of Distance Education, 16*(1), 5-22. doi: 10.1207/S15389286AJDE1601_2.
- Fahy, P. (2003). Indicators of support in online interaction. *International Review of Research in Open and Distance Learning, 4*(1). Retrieved May 2nd, 2015 from: <http://www.irrodl.org/index.php/irrodl/article/view/129/600>.
- Falchikov, N. (1995). Peer feedback marking: developing peer assessment. *Innovations in Education and Training International, 32*(2), 175-187.
- Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175-191.
- Feeg, R. (1988). Forum of the future of pediatric nursing: Looking toward the 21st century. *Pediatric Nursing, 14*, 393-396.

- Felton, M., Crowell, A., & Liu, T. (2015). Arguing to agree mitigating myside bias through consensus-seeking dialogue. *Written Communication, 32*, 1-15.
- Fiol, C. M. (1994). Consensus, diversity and learning in organizations. *Organization Science, 5*, 403-420.
- Fischer, F., Kollar, I., Stegmann, K., & Wecker, C. (2013). Toward a script theory of guidance in computer-supported collaborative learning. *Educational Psychologist, 48*(1), 56-66.
- Fisher, B. A. (1970). Decision emergence: Phases in group decision making. *Speech Monographs, 37*, 53-66.
- Fisher, B. A. (1980). *Small Group Decision Making*. New York, McGraw-Hill.
- Forrester, J. W. Growth cycles. *De Economist, 125*(4), 525-543.
- Fransen, J., Weinberger, A., & Kirschner, P. A. (2013). Team effectiveness and team development in CSCL. *Educational psychologist, 48*(1), 9-24. doi: 10.1080/00461520.2012.747947
- Gabelica, C., Bossche, P. V. D., Segers, M., & Gijsselaers, W. (2012). Feedback, a powerful lever in teams: A review. *Educational Research Review, 7*(2), 123-144. doi:10.1016/j.edurev.2011.11.003.
- Gadamer, H. G. (1960). *Truth and Method*. New York: Continuum.
- Gamlem, S. M., & Munthe, E. (2014). Mapping the quality of feedback to support students' learning in lower secondary classrooms. *Cambridge Journal of Education, 44*(1), 75-92. doi: 10.1080/0305764X.2013.855171.
- Gan, M. J. (2011). *The effects of prompts and explicit coaching on peer feedback quality*. Doctoral dissertation. Retrieved from ResearchSpace@Auckland (2292/13035)
- Gan, M. J., & Hattie, J. (2014). Prompting secondary students' use of criteria, feedback specificity and feedback levels during an investigative task. *Instructional Science, 42*(6), 861-878. doi: 10.1007/s11251-014-9319-4.
- Garcia-Mila, M., Gilabert, S., Erduran, S., & Felton, M. (2013). The effect of argumentative task goal on the quality of argumentative discourse. *Science Education, 97*, 497-523.
- Ge, X., & Land, S. M. (2003). Scaffolding students' problem-solving processes in an ill-structured task using question prompts and peer interactions. *Educational Technology Research and Development, 51*(1), 21-38. doi: 10.1007/BF02504515.
- Gelmini-Hornsby, G., Ainsworth, S., & O'Malley, C. (2011). Guided reciprocal questioning to support children's collaborative storytelling. *International Journal of Computer-Supported Collaborative Learning, 6*(4), 577-600. doi: 10.1007/s11412-011-9129-5.

- Ghodrati, N. (2015). Conceptualising and measuring collaborative critical thinking on asynchronous discussion forums; Challenges and possible solutions. *Digital Culture & Education*, 7(1), 86-103.
- Gibbs, G., & Simpson, C. (2004). Conditions under which assessment supports students' learning. *Learning & Teaching in Higher Education*, 1, 3-31.
- Giddens, A. (1979). *Central problems in social theory: Action, structure, and contradiction in social analysis*. Berkeley: University of California Press.
- Gielen, M., & De Wever, B. (2015). Scripting the role of assessor and assessee in peer assessment in a wiki environment: Impact on peer feedback quality and product improvement. *Computers & Education*, 88, 370-386. doi: 10.1016/j.compedu.2015.07.012
- Gielen, S., Peeters, E., Dochy, F., Onghena, P., & Struyven, K. (2010a). Improving the effectiveness of peer feedback for learning. *Learning and instruction*, 20(4), 304-315.
- Gielen, S., Tops, L., Dochy, F., Onghena, P., & Smeets, S. (2010b). A comparative study of peer and teacher feedback and of various peer feedback forms in a secondary school writing curriculum. *British educational research journal*, 36(1), 143-162.
- Gillies, R. M. (2004). The effects of cooperative learning on junior high school students during small group learning. *Learning and instruction*, 14(2), 197-213
- Gillies, R. M. and Ashman, A.F. (1995) 'The effects of gender and ability on students' behaviours and interactions in classroom-based work groups'. *British Journal of Educational Psychology*, 65, 211-225.
- Gillies, R. & Boyle, M. (2010). Teachers' reflections on cooperative learning: Issues of implementation. *Teaching and Teacher Education*, 26, 933-940.
- Gillies, R. M., & Boyle, M. (2011). Teachers' reflections on cooperative learning (CL): a two-year follow-up. *Teaching Education*, 1, 63-78. doi: 10.1080/10476210.2010.538045.
- Golanics, J. D., & Nussbaum, E. M. (2008). Enhancing collaborative online argumentation through question elaboration and goal instructions. *Journal of Computer Assisted Learning*, 24, 167-180. [http://dx.doi.org/ 10.1111/j.1365-2729.2007.00251.x](http://dx.doi.org/10.1111/j.1365-2729.2007.00251.x)
- Graesser, A.C., Person, N.K. & Huber, J. (1993). Question asking during tutoring and in the design of educational software. In M. Rabinowitz (Ed.). *Cognitive Foundations of Instruction* (pp. 149-172). Hillsdale, NJ: Lawrence Erlbaum.
- Groarke, J. M., & Hogan, M. J. (2016). Enhancing wellbeing: An emerging model of the adaptive functions of music listening. *Psychology of Music*, 44(4), 769-791.
- Guiller, J., Ross, A., & Durndell, A. (2008). Peer interaction and critical thinking: face-to-face or online discussion? *Learning and Instruction*, 18, 187-200.

- Guzdial, M. & Turns, J. 2000. Effective discussion through a computer-mediated anchored forum. *The Journal of the Learning Sciences*, 9(4): 437-469.
- Guzzo, R. A., Jette, R. D., & Katzell, R. A. (1985). The effects of psychologically based intervention programs on worker productivity: A meta-analysis. *Personnel Psychology*, 38(2), 275-291. doi:10.1111/j.1744-6570.1985.tb00547.x.
- Haberyan, A. (2007). Team-Based learning in an Industrial/Organizational Psychology Course. *North American Journal of Psychology*, 9(1), 143-152.
- Hackman, J. R. (1987). The design of work teams. In J. W. Lorsch (Ed.). *Handbook of organizational behavior* (pp. 315-342). Englewood Cliffs, NJ: Prentice Hall.
- Hall, T., Thompson Long, B., Flanagan, E., Flynn, P., & Lenaghan, J. (2017). 'Design-Based Research as Intelligent Experimentation: Towards Systematising the Conceptualisation, Development and Evaluation of Digital Learning in Schools'. In Marcus-Quinn, A., & Hourigan, T. (Eds.) *Handbook on Digital Learning for K-12 Schools*. Switzerland: Springer, pp. 59-73.
- Halpern, D.F. (2010). *The Halpern Critical Thinking Assessment: Manual*. Schuhfried: Vienna.
- Hansen, R. S. (2006). Benefits and problems with student teams: suggestions for improving team projects. *Journal of Education for Business*, 82, 11–19. doi:10.3200/JOEB.82.1.11-19.
- Hardman, F., & Abd-Kadir, J. (2010). Classroom discourse: towards a dialogic pedagogy. *The international handbook of English, language and literacy*, 254-264.
- Harford, J., & MacRuairc, G. (2008). Engaging student teachers in meaningful reflective practice. *Teaching and teacher education*, 24(7), 1884-1892. doi: 10.1016/j.tate.2008.02.010.
- Harney, O. M., Hogan, M. J., & Broome, B. (2012). Collaborative learning: The effects of trust and open and closed dynamics on consensus and efficacy. *Social Psychology of Education*, 15(4), 517–532. doi:10.1007/s11218-012-9202-6.
- Harney, O. M., Hogan, M. J., Broome, B., Hall, T., & Ryan, C. (2015). Investigating the effects of prompts on argumentation style, consensus and perceived efficacy in collaborative learning. *International Journal of Computer-Supported Collaborative Learning*, 10(4), 367-394.
- Harney, O. M., Hogan, M. J., & Quinn, S. (2017). Investigating the effects of peer to peer prompts on collaborative argumentation, consensus and perceived efficacy in collaborative

- learning. *International Journal of Computer-Supported Collaborative Learning*, 12(3), 307-336.
- Hartberg, Y., Gunersel, A. B., Simpson, N., & Balester, V. (2012). Development of student writing in biochemistry using Calibrated Peer Review. *Journal of the Scholarship of Teaching and Learning*, 8(1), 29-44.
- Hattie, J.A.C., & Gan. M. (2011). Instruction based on feedback. In R. Mayer & P. Alexander (Eds.), *Handbook of Research on Learning and Instruction*. (pp. 249-271). New York: Routledge.
- Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, 77(1), 81–112. doi: 10.3102/003465430298487.
- Havnes, A. (2008). Peer-mediated learning beyond the curriculum. *Studies in Higher Education*, 33(2), 193-204.
- Hay, D., Kinchin, I., & Lygo-Baker, S. (2008). Making learning visible: the role of concept mapping in higher education. *Studies in higher education*, 33(3), 295-311.
- Hefter, M. H., Berthold, K., Renkl, A., Riess, W., Schmid, S., & Fries, S. (2014). Effects of a training intervention to foster argumentation skills while processing conflicting scientific positions. *Instructional Science*, 42(6), 929-947.
- Henri, F. (1992). "Computer conferencing and content analysis". In *Collaborative learning through computer conferencing: The Najaden papers*, Edited by: Kaye, A. R. 117–136. Berlin: Springer-Verlag.
- Hesse, F., Care E., Buder J., Sassenberg K., Griffin P. (2015) A Framework for Teachable Collaborative Problem Solving Skills. In: Griffin P., Care, E. (Eds.) *Assessment and Teaching ;of 21st Century Skills. Educational Assessment in an Information Age*. Dordrecht: Springer.
- Higgins, R., Hartley, P., & Skelton, A. (2002). The conscientious consumer: Reconsidering the role of assessment feedback in student learning. *Studies in higher education*, 27(1), 53-64.
- Hiltz, S. R., Coppola, N., Rotter, N., Turoff, M., & Benbunan-Fich, R. (2000). Measuring the importance of collaborative learning for the effectiveness of ALN: A multi-measure, multi-method approach. *Journal of Asynchronous Learning Networks*, 4(2), 103-125.
- Hiltz, S. R., Johnson, K., & Turoff, M. (1986). Experiments in group decision making communication process and outcome in face-to-face versus computerized conferences. *Human communication research*, 13(2), 225-252.

- Hirokawa, R. Y. (1985). Discussion procedures and decision-making performance. *Human Communication Research*, 12(2), 203-224.
- Hitchcock, D. (2003). *The effectiveness of computer-assisted instruction in critical thinking*. (Doctoral Dissertation). Philosophy department. McMaster University.
- Hmelo-Silver, C. E. (2002, January). Collaborative ways of knowing: Issues in facilitation. *Computer Support for Collaborative Learning: Foundations for a CSCL Community*. Paper presented at the International Conference on Computer Supported Collaborative Learning, Boulder, Colorado. doi:10.1.1.16.9070.
- Hogan, K. (1999). Thinking aloud together: A test of an intervention to foster students' collaborative scientific reasoning. *Journal of Research in Science Teaching*, 36, 1085-1109. doi: 10.1002/(SICI)1098-2736(199912)36:10<1085::AID-TEA3>3.0.CO;2-D.
- Hogan, M. J. (2006). Against Didacticism: A psychologist's view. *Educational Research and Reviews*, 1(6), 206-212.
- Hogan, M. J., Dwyer, C. P., Harney, O. M., Noone, C., & Conway, R. J. (2015). Metacognitive skill development and applied systems science: A framework of metacognitive skills, self-regulatory functions and real-world applications. In *Metacognition: Fundamentals, applications, and trends* (pp. 75-106). London: Springer.
- Hogan, M. J., Hall, T., & Harney, O. M. (2017). Collective Intelligence Design and a New Politics of System Change. *Civitas educationis. Education, Politics, and Culture*, 6(1), 51-78.
- Hogan, M. J., Harney, O. M., & Broome, B. J. (2014). Integrating Argument Mapping with Systems Thinking Tools - Advancing Applied Systems Science. In A. Okada, S. Buckingham Shum, & T. Sherborne (Eds.), *Knowledge Cartography: Software Tools and Mapping Techniques* (pp. 401-421). London: Springer.
- Hogan, M. J., Harney, O. M., & Broome, B. J. (2015). Catalyzing Collaborative Learning and Collective Action for Positive Social Change through Systems Science Education. In R. Wegerif, J. Kaufman, & L. Li (Eds). *The Routledge Handbook of Research on Teaching Thinking* (pp. 441-456). Oxford: Routledge.
- Hong, K. S. (2002). Relationships between students' and instructional variables with satisfaction and learning from a Web-based course. *Internet and Higher Education*, 5, 267-281.
- Howe, C., Tolmie, A., Thurston, A., Topping, K., Christie, D., Livingston, K., Jessiman, E., & Donaldson, C. (2007). Group work in elementary science: Towards organisational principles for supporting pupil learning. *Learning and Instruction*, 17(5), 549-563.

- Hübner, S., Nückles, M., & Renkl, A. (2010). Writing learning journals: Instructional support to overcome learning-strategy deficits. *Learning and Instruction, 20*, 18-29. doi: 10.1016/j.learninstruc.2008.12.001
- Huff, L. C., Cooper, J., & Jones, W. (2002). The development and consequences of trust in student project groups. *Journal of Marketing Education, 24*(1), 24-34.
- Ilgén, D. R., Fisher, C. D., & Taylor, M. S. (1979). Consequences of individual feedback on behavior in organizations. *Journal of Applied Psychology, 64*(4), 349–371. doi:10.1037/0021-9010.64.4.349.
- Infante, D. A., & Rancer, A. S. (1996). Argumentativeness and verbal aggressiveness: A review of recent theory and research. *Communication Yearbook, 19*, 319-351.
- Jackson, S., & Jacobs, S. (1980). Structure of conversational argument: Pragmatic cases for the enthymeme. *Quarterly Journal of Speech, 66*, 251–265.
- Janis, I. L. (1972). *Victims of Groupthink*. New York: Houghton Mifflin.
- Janssen, J., Erkens, G., Kirschner, P. A., & Kanselaar, G. (2010a). Effects of representational guidance during computer-supported collaborative learning. *Instructional Science, 38*(1), 59-88.
- Janssen, J., Kirschner, F., Erkens, G., Kirschner, P. A., & Paas, F. (2010b). Making the black box of collaborative learning transparent: Combining process-oriented and cognitive load approaches. *Educational psychology review, 22*(2), 139-154.
- Janssen, O., Van de Vliert, E., & Veenstra, C. (1999). How task and person conflict shape the role of positive interdependence in management teams. *Journal of Management, 25*, 117-142.
- Jarvenpaa, S. L., Knoll, K., & Leidner, D. (1998). Is Anybody Out There? The Antecedents of Trust in Global Virtual Teams. *Journal of Management Information Systems, 14*(4), 29–64.
- Jeong, A., & Joung, S. (2007). Scaffolding collaborative argumentation in asynchronous discussions with message constraints and message labels. *Computers & Education, 48*, 427–445.
- Jiménez-Aleixandre, M. P. (2007). Designing Argumentation Learning Environments. In S. Erduran., & M. P. Jiménez-Aleixandre. (Eds.). *Argumentation in science education: Perspectives from classroom-based research* (pp. 91-115). New York: Springer.
- Johnson, D. W., & Johnson, R. T. (1975). *Learning together and alone; cooperation, competition, and individualization*. New Jersey, USA: Prentice-Hall.

- Johnson, D. W., & Johnson, R. T. (1989). *Cooperation and competition: Theory and research*. Edina, MN: Interaction Book Company.
- Johnson, D. W., & Johnson, R. T. (1990). Cooperative learning and achievement. In S. Sharan (Ed.), *Cooperative learning: Theory and research* (pp. 151–171). New York: Praeger.
- Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational researcher*, 38(5), 365-379.
- Johnson, D. W., Johnson, R. T., & Smith, K. A. (2014). Cooperative learning: Improving university instruction by basing practice on validated theory. *Journal on Excellence in University Teaching*, 25(4), 85-118.
- Johnson, D. W., Johnson, R. T., & Smith, K. (2007). The state of cooperative learning in postsecondary and professional settings. *Educational Psychology Review*, 19(1), 15-29. doi: 10.1007/s10648-006-9038-8.
- Jonassen, D. H., & Kim, B. (2010). Arguing to learn and learning to argue: Design justifications and guidelines. *Educational Technology Research and Development*, 58(4), 439-457.
- Kanuka, H., & Nocente, N. (2003). Exploring the effects of personality type on perceived satisfaction with web-based learning in continuing professional development. *Decision Education*, 24(2), 227–245.
- Keever, D. B. (1989, April). *Cultural complexities in the participative design of a computer-based organization information system*. Paper presented at the International Conference on Support, Society and Culture: Mutual Uses of Cybernetics and Science, Amsterdam, The Netherlands.
- Kemeny, J. (1980). Saving American democracy: The lesson of Three Mile Island. *Technology Review*, 83, 7, 64-75.
- Kenny, D. A., Albright, L., Malloy, T. E., & Kashy, D. A. (1994). Consensus in interpersonal perception: Acquaintance and the big five. *Psychological Bulletin*, 116(2), 245–358. doi:10.1037/0033-2909.116.2.245.
- Kenworthy, J. B., & Miller, N. (2001). Perceptual asymmetry in consensus estimates of majority and minority members. *Journal of Personality and Social Psychology*, 80(4), 597–612. doi:10.1037/0022-3514.80.4.597.
- Ketelaar, E., Den Brok, P., Beijaard, D., & Boshuizen, H. P. (2012). Teachers' perceptions of the coaching role in secondary vocational education. *Journal of Vocational Education & Training*, 64(3), 295-315. doi: 10.1080/13636820.2012.691534.

- Kim, I.-H., Anderson, R.C., Nguyen-Jahiel, K., & Archodidou, A. (2007). Discourse patterns during children's collaborative online discussions. *Journal of the Learning Sciences, 16*(3), 333–370.
- Kinchin, I. M., & Hay, D. B. (2007). The myth of the research-led teacher. *Teachers and Teaching: theory and practice, 13*(1), 43-61.
- King, A. (1990). Enhancing peer interaction and learning through guided student-generated questioning. *Educational Psychologist 27*(4): 111–126. doi:10.3102/00028312027004664.
- King, A., & Rosenshine, B. (1993). Effects of guided cooperative questioning on children's knowledge construction. *The Journal of Experimental Education, 61*(2), 127-148.
- King, A., Staffieri, A. & Aldelgais, A. (1998). Mutual peer tutoring: Effects of structuring tutorial interaction to scaffold peer learning. *Journal of Educational Psychology, 90*, 134–152.
- Kingery, J. N., Erdley, C. A., & Marshall, K. C. (2011). Peer acceptance and friendship as predictors of early adolescence' adjustment across the middle school transition. *Merrill-Palmer Quarterly, 57*, 215–243.
- Kirkman, B. L., & Rosen, B. (1999). Beyond self-management: Antecedents and consequences of team empowerment. *Academy of Management journal, 42*(1), 58-74.
- Kirkman, B. L., & Shapiro, D. L. (2001). The impact of cultural values on job satisfaction and organizational commitment in self-managing work teams: The mediating role of employee resistance. *Academy of Management journal, 44*(3), 557-569.
- Kirschner, P. A. (2009). Epistemology or pedagogy, that is the question. In S. Tobias, & T.M. Duffy (Eds.), *Constructivist theory applied to instruction: Success or failure?* (pp. 144-157) New York: Routledge.
- Kirschner, F., Paas, F. & Kirschner, P. (2009a). A cognitive load approach to collaborative learning: United brains for complex tasks. *Educational Psychology Review, 21*: 31–42. doi:10.1007/s10648-008-9095-2
- Kirschner, F., Paas, F. & Kirschner, P. (2009b). Individual and group-based learning from complex cognitive tasks: Effects on retention and transfer efficiency. *Computers in Human Behavior, 25*: 306–314. doi:10.1016/j.chb.2008.12.008
- Kirschner, F., Paas, F. & Kirschner, P. (2011). Task complexity as a driver for collaborative learning efficiency: The collective working-memory effect. *Applied Cognitive Psychology, 25*: 615–624. doi:10.1002/acp.1730.

- Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational psychologist, 41*(2), 75-86.
- Klein, J. D., & Pridemore, D. R. (1992). Effects of cooperative learning and need for affiliation on performance, time on task, and satisfaction. *Educational Technology Research and Development, 40*(4), 39–47.
- Kluger, A. N., & DeNisi, A. (1996). The effects of feedback interventions on performance. A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological Bulletin, 119*(2), 254–284. doi: 10.1037/0033-2909.119.2.254.
- Koc, E.W, Koncz, A. J., Tsang, K.C., & Longenberger, A. (2015). *Jobs Outlook 2015*. Retrieved from <http://www.umuc.edu/documents/upload/nace-job-outlook-2015.pdf>
- Kollar, I., & Fischer, F. (2010). Peer assessment as collaborative learning: A cognitive perspective. *Learning and Instruction, 20*(4), 344-348.
- Kozlowski, S. W. J., & Ilgen, D. R. (2006). Enhancing the effectiveness of work groups and teams. *Psychological Science in the Public Interest, 7*(3), 77–124. doi:10.1111/j.1529-1006.2006.00030.x.
- Kramer, T. J., Fleming, G. P., & Mannis, S. M. (2001). Improving faceto-face brainstorming through modeling and facilitation. *Small Group Research, 32*(5), 533-557.
- Krause, U. M., Stark, R., & Mandl, H. (2009). The effects of cooperative learning and feedback on e-learning in statistics. *Learning and Instruction, 19*(2), 158-170. doi:10.1016/j.learninstruc.2008.03.003.
- Kreijns, K. (2004). *Sociable CSCL Environments: Social affordances, sociability, and social presence* (Doctoral Dissertation). Retrieved from DSpace.ou.nl.
- Kreijns, K., Kirschner, P. A., & Jochems, W. (2002). The sociability of Computer-Supported Collaborative Learning environments. *Educational Technology and Society, 5*(1), 8–22. doi:10.1.1.95.4422.
- Kreijns, K., Kirschner, P. A., & Jochems, W. (2003). Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: a review of the research. *Computers in human behavior, 19*(3), 335-353.
- Kuhn, D. (1991). *The skills of argument*. Cambridge: Cambridge University Press.
- Kuhn, D. (2005). *Education for thinking*. Cambridge, Mass.: Harvard University Press.
- Kuhn, D., Shaw, V., & Felton, M. (1997). Effects of dyadic interaction on argumentive reasoning. *Cognition and instruction, 15*(3), 287-315.

- Kuhn, D., & Udell, W. (2003). The development of argument skills. *Child development, 74*(5), 1245-1260.
- Kraut, R. E., Fussell, S. R., Brennan, S. E., & Siegel, J. (2002). Understanding effects of proximity on collaboration: Implications for technologies to support remote collaborative work. In P. Hinds & S. Kiesler (Eds.), *Distributed work* (pp. 137–162). Cambridge, MA: MIT Press.
- Lave, J. & Wenger, E. (1991) *Situated Learning: legitimate peripheral participation*. Cambridge: Cambridge University Press.
- LeBaron, C. (2002). Technology does not exist independent of its use. In T. Koschmann, R. Hall, & N. 734 Miyake (Eds.), *CSCL2: Carrying forward the conversation* (pp. 433–440). Mahwah: Lawrence Erlbaum.
- Lemke, J. (1990). *Talking Science: language, learning and values*. Norwood, NJ: Ablex Publishing.
- Levine, E. E., & Schweitzer, M. E. (2015). Prosocial lies: When deception breeds trust. *Organizational Behavior and Human Decision Processes, 126*, 88-106.
- Liaw, S. S. (2008). Investigating students' perceived satisfaction, behavioral intention, and effectiveness of e-learning: A case study of the Blackboard system. *Computers & Education, 51*(2), 864-873.
- Liaw, S. S., Huang, H. M., & Chen, G. D. (2007). An activity-theoretical approach to investigate learners' factors toward e-learning systems. *Computers in Human Behavior, 23*, 1906–1920.
- Linell, P. 2009. *Rethinking Language, Mind, and World Dialogically*. NY: Information Age Pub Inc.
- Lockhart, C., & Ng, P. (1995). Analyzing talk in ESL peer response groups: stances, functions and content. *Language Learning, 45*, 605–655.
- Löfstrand, P. (2015, January). Conversational arguments in small group decision making: Reasoning activity and perceived influence over the decision are keys for success. In *Independent in the heard: Inclusion and exclusion as social processes. Proceedings from the 9th GRASP conference, Linköping University, May 2014* (No. 121, pp. 64-81). Linköping University Electronic Press.
- Lou, Y., Abrami, P., & D'Apollonia, S. (2001). Small group and individual learning with technology: a meta-analysis. *Review of Educational Research, 71*(3), 449-521.
- Ludvigsen, S., and Mørch, A. (2010). Computer-supported collaborative learning: Basic concepts, multiple perspectives, and emerging trends. In B. McGaw, P. Peterson & E.

- Baker (Eds.), *The International Encyclopedia of Education* (pp. 290-296). Oxford, UK: Elsevier.
- Lundstrom, K., & Baker, W. (2009). To give is better than to receive: The benefits of peer review to the reviewer's own writing. *Journal of Second Language Writing, 18*(1), 30–43.
- Marsh, S., & Dibben, M. R. (2005). Trust, Untrust, Distrust and Mistrust-An Exploration of the Dark(er) Side. In Herrmann, P., Issarny, V., & Shiu, S (Eds.), *iTrust* (pp. 17-33). Paris: Springer.
- Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An integrative model of organizational trust. *The Academy of Management Review, 20*(3), 709-734. doi: 10.5465/AMR.1995.9508080335.
- Mayer, R. E., & Alexander, P. A. (Eds.). (2011). *Handbook of research on learning and instruction*. London: Routledge.
- McCorkle, D. E., Reardon, J., Alexander, J. F., Kling, N. D., Harris, R. C., & Iyer, R. V. (1999). Undergraduate marketing students, group projects, and teamwork: The good, the bad, and the ugly?. *Journal of Marketing Education, 21*(2), 106-117.
- McIntyre, E., Kyle, D.W., & Moore, G.H. (2006). A primary-grade teacher's guidance toward small-group dialogue. *Reading Research Quarterly, 41*(1), 36–66.
- McKenney, S. (2018). How Can the Learning Sciences (Better) Impact Policy and Practice?, *Journal of the Learning Sciences, 27*(1), 1-7, doi: 10.1080/10508406.2017.1404404
- McKenney, S., Nieveen, N., & van den Akker, J. (2006). Design research from a curriculum perspective. In J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 67-90). London: Routledge.
- McKnight, D.H., Cummings, L.L., & Chervany, N.L. (1998) Initial trust formation in new organizational relationships. *Academy of Management Review, 23*(3), 513-530. doi:10.5465/AMR.1998.926622.
- Mehan, H. (1979). *Learning lessons*. Cambridge, MA: Harvard University Press.
- Mento, A., Steel, R. P., & Karren, R. J. (1987). A meta-analytic study of the effects of goal setting on task performance: 1966–1984. *Organizational Behavior and Human Decision Processes, 39*(1), 52–83. doi:10.1016/0749-5978(87)90045-8.
- Mevarech, Z. R., & Kramarski, B. (2003). The effects of metacognitive training versus worked-out examples on students' mathematical reasoning. *The British Journal of Educational Psychology, 73*(4), 449–471.
- Mercer, N. (2000). *Words and minds: How we use language to think together*. Psychology Press.

- Mercer, N., Dawes, L., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: ways of helping children to use language to learn science. *British educational research journal*, 30(3), 359-377.
- Mercer, N., & Littleton, K. (2007). *Dialogue and the development of children's thinking: A sociocultural approach*. London: Routledge.
- Mercer, N., Wegerif, R., & Dawes, L. (1999). Children's talk and the development of reasoning in the classroom. *British educational research journal*, 25(1), 95-111.
- Meyers, R. A., & Brashers, D. E. (1998). Argument in group decision making: Explicating a process model and investigating the argument-outcome link. *Communication Monographs*, 65(4), 261-281. doi:10.1080/03637759809376454.
- Michaelsen, L., K., & Sweet, M. (2008). The essential elements of team-based learning. *New Directions for Teaching and Learning*, 116I, 7-27. doi: 10.1002/tl.330
- Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychology Review*, 63(2), 81-97. doi:10.1037/h0043158.
- Min, H. T. (2005). Training students to become successful peer reviewers. *System*, 33, 293–308.
- Mitchell, B. (2016). Curriculum Construction and Implementation. *International Journal of Liberal Arts and Social Science*, 4(4), 45-56.
- Mohammed, S., & Angell, L. C. (2004). Surface-and deep-level diversity in workgroups: Examining the moderating effects of team orientation and team process on relationship conflict. *Journal of Organizational Behavior*, 25(8), 1015-1039.
- Mohammed, S., & Ringseis, E. (2001). Cognitive diversity and consensus in group decision making: The role of inputs, processes, and outcomes. *Organizational Behavior and Human Decision Processes*, 85(2), 310–335. doi:10.1006/obhd.2000.2943.
- Monaghan, F. (2005). 'Don't think in your head, think aloud': ICT and exploratory talk in the primary school mathematics classroom. *Research in Mathematics Education*, 7(1), 83-100.
- Mooradian, T., Renzl, B., & Matzler, K. (2006). Who trusts? Personality, trust and knowledge sharing. *Management learning*, 37(4), 523-540.
- Mortimer, E., & Scott, P. (2003). *Meaning making in secondary science classrooms*. Maidenhead: Open University Press.
- Muller Mirza, N., Tartas, V., Perret-Clermont, A.-N., & de Pietro, J.-F. (2007). Using graphical tools in a phased activity for enhancing dialogical skills: An example with

- digalo. *International Journal of Computer-Supported Collaborative Learning*, 2(2–3), 247–272. doi: 10.1007/s11412-007-9021-5.
- Murphy, P.K., Soter, A.O., Wilkinson, I.A., Hennessey, M.N., & Alexander, J.F. (2009). Examining the effects of classroom discussion on students' comprehension of text: A meta-analysis. *Journal of Educational Psychology*, 101(3), 740–764. doi:10.1037/a0015576.
- Nadler, D. A., (1979). The effects of feedback on task group behavior: a review of the experimental research. *Organisation Behaviour and Human Performance*, 23(3), 309-338. doi:10.1016/0030-5073(79)90001-1.
- Nemeth, C. J. (1986). Differential contributions of majority and minority influence. *Psychological Review*, 93, 23-32.
- Neubert, M. J. (1998). The value of feedback and goal setting over goal setting alone and potential moderators of this effect: A meta-analysis. *Human Performance*, 11(4), 321–335. doi:10.1207/s15327043hup1104_2.
- Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education*, 21(5), 553-576.
- Nichols, J. D. (1996). The effects of cooperative learning on student achievement and motivation in a high school geometry class. *Contemporary Educational Psychology*, 21(4), 467–476.
- Noroozi, O., Weinberger, A., Biemans, H. J., Mulder, M., & Chizari, M. (2013). Facilitating argumentative knowledge construction through a transactive discussion script in CSCL. *Computers & Education*, 61, 59-76.
- Novakovich, J. (2016). Fostering critical thinking and reflection through blog-mediated peer feedback. *Journal of Computer Assisted Learning*, 32(1), 16-30.
- Nussbaum, E. M. (2008). Collaborative discourse, argumentation, and learning: Preface and literature review. *Contemporary Educational Psychology*, 33(3), 345-359.
- Nussbaum, E. M., & Kardash, C. M. (2005). The effects of goal instructions and text on the generation of counterarguments during writing. *Journal of Educational Psychology*, 97, 157–169.
- Nystrand, M., Wu, L., Gamorgan, A., Zeiser, S., & Long, D. (2003). Questions in time: investigating the structure and dynamics of unfolding classroom discourse. *Discourse Processes*, 35, 135–198.
- O'Donnell, A. M. (2006). The role of peers and group learning. In P. H. Winne & P. A.

- Alexander (Eds.), *Handbook of educational psychology* (pp. 781–802). Mahwah, NJ: Lawrence Erlbaum Associates.
- O'Donnell, A. M., Dansereau, D. F., Hall, R. H., & Rocklin, T. R. (1987). Cognitive, social/affective, and metacognitive outcomes of scripted cooperative learning. *Journal of Educational Psychology, 79*(4), 431.
- O'Donnell, A. M., & King, A. (Eds.). (1998). *Cognitive perspectives on peer learning*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Offner, A. K., Kramer, T. J., & Winter, J. P. (1996). The effects of facilitation, recording, and pauses on group brainstorming. *Small Group Research, 27*(2), 183-298.
- Olitsky, S. (2007). Promoting student engagement in science: Interaction rituals and the pursuit of a community of practice. *Journal of Research in Science Teaching, 44*(1), 33–56.
- Ornstein, A. C., & Hunkins, F. P. (2009). *Curriculum foundations, principles and issues* (6th ed.). Boston, MA: Pearson Education.
- Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science, 328*(5977), 463-466.
- Oxley, N. L., Dzindolet, M. T., & Paulus, P. B. (1996). The effects of facilitators on the performance of brainstorming groups. *Journal of Social Behavior & Personality, 11*(4), 633-646.
- Palinscar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. *Cognition and instruction, 1*(2), 117-175.
- Paul, R. (1993). *Critical thinking: What every person needs to survive in a rapidly changing world*, Santa Rosa, CA: Foundation for Critical Thinking.
- Patchan, M. M., Schunn, C. D., & Correnti, R. J. (2016). The nature of feedback: How peer feedback features affect students' implementation rate and quality of revisions. *Journal of Educational Psychology, 108*(8), 1098.
- Paolucci, M., Suthers, D. D., & Weiner, A. (1995, May). *Belvédère: stimulating students' critical discussion*. Paper presented at The Conference on Human Factors in Computing Systems, Denver, Colorado. doi:10.1145/223355.223461.
- Pea, R.D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *The Journal of the Learning Sciences, 13*(3), 423-451. doi:10.1207/s15327809jls1303_6.

- Perelman, C. H., & Olbrechts-Tyteca, L. (1969). *The new rhetoric: A treatise on argumentation* (J. Wilkinson & P. Weaver, Trans.). Notre Dame, IN: University of Notre Dame Press.
- Peterson, R., & Behfar, K. (2003). The dynamic relationship between performance feedback, trust, and conflict in groups: A longitudinal study. *Organizational Behavior and Human Decision Processes*, 92, 102–112. doi:10.1016/S0749-5978(03)00090-6.
- Pineda, R. C., Barger, B., & Lerner, L. D. (2009). Exploring differences in student perceptions of teamwork: the case of US and Lithuanian students. *Journal of International Business and Cultural Studies*, 1, 1-9.
- Pollock, E., Chandler, P., & Sweller, J. (2002) Assimilating complex information. *Learning & Instruction*, 12, 61-86.
- Poole, M. S., & Roth, J. (1989). Decision development in small groups IV a typology of group decision paths. *Human Communication Research*, 15(3), 323-356.
- Priem, R. L. (1990). Top management team group factors, consensus, and firm performance. *Strategic Management Journal*, 11(6), 469-478.
- Prins, F. J., Sluijsmans, D. M., Kirschner, P. A., & Strijbos, J. W. (2005). Formative peer assessment in a CSCL environment: A case study. *Assessment & Evaluation in Higher Education*, 30(4), 417-444.
- Prins, F., Sluijsmans, D., & Kirschner, P. (2006). Feedback for general practitioners in training: Quality, styles and preferences. *Advances in Health Sciences Education*, 11, 289–303.
- Qin, Z., Johnson, D., & Johnson, R. (1995). Cooperative versus competitive efforts and problem solving. *Review of Educational Research*, 65(2), 129-143.
- Reed, J.H. & Kromrey, J.D., (2001). Teaching critical thinking in a community college history course: Empirical evidence from infusing Paul’s model. *College Student Journal*, 35(2), 201-215.
- Reninger, K. B., & Rehack, L. (2009). Discussions in a fourth-grade classroom: Using exploratory talk to promote children's dialogic identities. *Language Arts*, 86(4), 268-279.
- Resnick, L. B., Asterhan, C. S. C., & Clarke, S. (Eds.) (2015). *Socializing intelligence through academic talk and dialogue*. Washington, DC: AERA.
- Resnick, L. B., Michaels, S., & O’Connor, M. C. (2010). How (well structured) talk builds the mind. In R. J. Sternberg & D. D. Preiss (Eds.), *Innovations in educational psychology: Perspectives on learning, teaching and human development* (pp. 163–194). New York, NY: Springer.

- Resnick, L. B., Salmon, M., Zeitz, C. M., Wathen, S. H., & Holowchak, M. (1993). Reasoning in conversation. *Cognition and instruction*, 11(3-4), 347-364.
- Rezaei-Zadeh, M., Hogan, M., O'Reilly, J., Cleary, B., & Murphy, E. (2014). Using interactive management to identify, rank and model entrepreneurial competencies as universities' entrepreneurship curricula. *The Journal of Entrepreneurship*, 23(1), 57-94.
- Rittel, H., & Webber, M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, 4(2), 155-169. doi:10.1007/BF01405730.
- Roberts, K., & O'Reilly, C. (1974). Measuring organizational communication. *Journal of Applied Psychology*, 59(3), 321-326. doi:10.1037/h0036660.
- Rojas-Drummond, S., Mazón, N., Fernández, M., & Wegerif, R. (2006). Explicit reasoning, creativity and co-construction in primary school children's collaborative activities. *Thinking Skills and Creativity*, 1(2), 84-94.
- Rollinson, P. (2005). Using peer feedback in the ESL writing class. *ELT Journal: English Language Teachers Journal*, 59(1), 23-30.
- Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. E. O'Malley (Ed.), *Computer-Supported Collaborative Learning* (pp.69-197). Berlin: Springer-Verlag. doi:10.1007/978-3-642-85098-1_5
- Roseth, C., Johnson, D., & Johnson, R. (2008). Promoting early adolescents' achievement and peer relationships: the effects of cooperative, competitive and individualistic goal structures. *Psychological Bulletin*, 134(2), 223-246.
- Rosson, M. B., & Carroll, J. M (2000) Scenario-Based Design. In J. Jacko & A. Sears (Eds.), *The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications*. (pp. 1032-1050). Florida: CRC Press.
- Rotter, J. B. (1967). A new scale for the measurement of interpersonal trust. *Journal of personality*, 35(4), 651-665.
- Rowe, M. B. (1974a). Relation of wait time and rewards to the development of language, logic and fate control: Part one—wait time. *Journal of Research in Science Education*, 11, 81-84.
- Rowe, M. B. (1974b). Relations of wait time and rewards to the development of language, logic and fate control: Part two—rewards. *Journal of Research in Science Education*, 11, 291-308.
- Ruijter, E., Grimmelikhuijsen, S., Hogan, M., Enzerink, S., Ojo, A., & Meijer, A. (2017). Connecting societal issues, users and data. Scenario-based design of open data platforms. *Government Information Quarterly*, 34(3), 470-480.

- Rummel, N., & Spada, H. (2005). Learning to Collaborate: An instructional approach to promoting collaborative problem solving in computer-mediated settings. *The Journal of the Learning Sciences, 14*(2), 201–241. doi: 10.1207/s15327809jls1402_2.
- Russell, T. L. (1983). Analyzing arguments in science classroom discourse: Can teachers' questions distort scientific authority? *Journal of Research in Science Teaching, 20*, 27–45.
- Sacks, H., & Schegloff, E. A. (1995). *Lectures on conversation: Volumes I & II*. Oxford: Blackwell.
- Sadler, T. D., Barab, S. A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry?. *Research in Science Education, 37*(4), 371-391.
- Salas, E., Sims, D. E., & Burke, C. S. (2005). Is there a “big five” in teamwork?. *Small group research, 36*(5), 555-599.
- Saleh, M., Lazonder, A. W., & De Jong, T. (2005). Effects of Within-Class Ability Grouping on Social Interaction, Achievement, and Motivation. *Instructional Science, 33*(2), 105-119.
- Samaha, N. V., & DeLisi, R. (2000). Peer collaboration on a nonverbal reasoning task by urban minority students. *Journal of Experimental Education, 69*, 5–22.
- Sambamurthy, V., & Poole, M. S. (1992). The effects of variations in capabilities of GDSS designs on management of cognitive conflict in groups. *Information Systems Research, 3*(3), 224-251.
- Sato, T. (1979). Determination of hierarchical networks of instructional units using the ISM method. *Educational Technology Research, 3*, 67-75.
- Sawyer, R. K. (Ed.). (2005). *The Cambridge handbook of the learning sciences*. Cambridge University Press
- Scardamalia, M., & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: A challenge for the design of new knowledge media. *The Journal of the learning sciences, 1*(1), 37-68.
- Schaffert, S., Gruber, A. & Westenthaler, R. (2006). A semantic wiki for collaborative knowledge formation. In S. Reich, G. Güntner, T. Pellegrini, A. & Wahler (Eds.): *Semantic Content Engineering*, Austria: Trauner Verlag.
- Schegloff, E. A. (2007). *Sequence organization in interaction: Volume 1: A primer in conversation analysis*. Cambridge: Cambridge University Press.

- Scheuer, O., Loll, F., Pinkwart, N., & McLaren, B. M. (2010). Computer-supported argumentation: A review of the state of the art. *International Journal of Computer-Supported Collaborative Learning*, 5(1), 43-102. doi:10.1007/s11412-009-9080-x.
- Schoenfeld, A. H. (1985). *Mathematical problem solving*. New York: Academic Press.
- Schwartz, D. L. (1995). The emergence of abstract representations in dyad problem solving. *Journal of the Learning Sciences*, 4(3), 321–354.
- Schwarz, B. B., & de Groot, R. (2007). Argumentation in a changing world. *The International Journal of Computer-Supported Collaborative Learning*, 2, 297–313.
- Schwarz, B. B., & Glassner, A. (2003). The blind and the paralytic: Fostering argumentation in social and scientific issues. In J. Andriessen, M. J. Baker, & D. D. Suthers (Eds.), *Arguing to learn: Confronting cognitions in computer-supported collaborative learning environments* (pp. 227–260). Dordrecht: Kluwer Academic.
- Schwarz, B. B., Neuman, Y., & Biezuner, S. (2000). Two wrongs may make a right... if they argue together!. *Cognition and instruction*, 18(4), 461-494.
- Seibold, D. R., & Meyers, R. A. (2007). Group argument: A structuration perspective and research program. *Small Group Research*, 38(3), 312-336. doi:10.1177/1046496407301966.
- Selim, H. M. (2003). An empirical investigation of student acceptance of course websites. *Computers & Education*, 40(4), 343-360.
- Shirouzu, H., Miyake, N., & Masukawa, H. (2002). Cognitively active externalization for situated reflection. *Cognitive science*, 26(4), 469-501.
- Simmons, M., & Cope, D. (1993). Angle and rotation: Effects of different types of feedbacks on the quality of response. *Educational Studies in Mathematics*, 24(2), 163-176. doi:10.1007/BF01273690.
- Simon, H. A. (1960). *The new science of management decisions*. New York: Harper & Row.
- Simons, T. L., & Peterson, R. S. (2000). Task conflict and relationship conflict in top management teams: the pivotal role of intragroup trust. *Journal of applied psychology*, 85(1), 102-111.
- Sinclair, J., & Coulthard, R. M. (1975). *Towards an analysis of discourse: The English used by teachers and pupils*. Oxford: Oxford University Press.
- Skinner, K., & Louw, J. (2009). The feminization of psychology: Data from South Africa. *International Journal of Psychology*, 44(2), 81-92. doi: 10.1080/00207590701436736.
- Slavin, R. E. (1989). Research on cooperative learning: An international perspective. *Scandinavian Journal of Educational Research*, 33(4), 231-243.

- Slavin, R. E. (1996). Research on cooperative learning and achievement: What we know, what we need to know. *Contemporary educational psychology*, 21(1), 43-69.
- Sluijsmans, D. M., Brand-Gruwel, S., & van Merriënboer, J. J. (2002). Peer assessment training in teacher education: Effects on performance and perceptions. *Assessment & Evaluation in Higher Education*, 27(5), 443-454.
- Sluijsmans, D. M. A., & van Merriënboer, J. J. G. (2000). *A peer assessment model* (Heerlen, Open University of the Netherlands, Center for Educational Technology and Expertise).
- Smith, C., McLaughlin, M., & Osborne, K. (1997). Conduct controls on Usenet. *Journal of Computer-Mediated Communication*, 2(4). doi: 10.1111/j.1083-6101.1997.tb00197.x
- Soter, A. O., Wilkinson, I. A., Murphy, P. K., Rudge, L., Reninger, K., & Edwards, M. (2008). What the discourse tells us: Talk and indicators of high-level comprehension. *International Journal of Educational Research*, 47(6), 372-391.
- Spector, P. E. (1994). Using self-report questionnaires in OB research: A comment on the use of a controversial method. *Journal of Organizational Behavior*, 15(5), 385-392.
- Stahl, G. (2010). Guiding group cognition in CSCL. *International Journal of Computer-Supported Collaborative Learning*, 5(3), 255-258. doi:10.1007/s11412-010-9091-7.
- Stahl, G. (2013). Theories of cognition in collaborative learning. In C. Hmelo-Silver, A. O'Donnell, C. Chan, & C. Chinn (Eds.), *International handbook of collaborative learning* (pp. 74-90). London, UK: Routledge.
- Stahl, G. (2015). The group as paradigmatic unit of analysis: The contested relationship of CSCL to the learning sciences. In M. Evans, M. Packer & K. Sawyer (Eds.) *Reflections on the learning sciences: Past, present, and future*. Cambridge, UK: Cambridge University Press.
- Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. In R.K. Sawyer (Ed.) *Cambridge handbook of the learning sciences* (pp.409-426). Cambridge, UK: Cambridge University Press.
- Staley, S. M., & Broome, B. J. (1993, November). *Managing cultural issues associated with technological change: Applications of interactive design methodology in the automotive industry*. Paper presented at the annual convention of the Speech Communication Association, Miami.
- Stark, R., Puhl, T., & Krause, U.-M. (2009). Improving scientific argumentation skills by a problem-based learning environment: Effects of an elaboration tool and relevance of

- student characteristics. *Evaluation and Research in Education*, 22(1), 51-68.
doi:10.1080/09500790903082362.
- Stegmann, K., Weinberger, A., & Fischer, F. (2007). Facilitating argumentative knowledge construction with computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning*, 2(4), 421–447. doi:10.1007/s11412-007-9028-y.
- Stevens, M. J., & Campion, M. A. (1994). The knowledge, skills and ability requirements for teamwork: Implications for human resources management. *Journal of Management*, 20, 502-528
- Stevenson, C. E., Hickendorff, M., Resing, W. C., Heiser, W. J., & de Boeck, P. A. (2013). Explanatory item response modeling of children's change on a dynamic test of analogical reasoning. *Intelligence*, 41(3), 157-168. doi:10.1016/j.intell.2013.01.003.
- Straus, S. G., Parker, A. M., Bruce, J. B., & Dembosky, J. W. (2009). *The group matters: A review of the effect of group interaction on processes and outcomes in analytic teams*. Santa Monica, CA: RAND Corporation.
- Strayer, J. F. (2012). How learning in an inverted classroom influences cooperation, innovation and task orientation. *Learning Environments Research*, 15(2), 171-193.
- Strijbos, J.W., Kirschner, P. A. & Martens, R. L. (Eds.). (2004). *What we know about CSCL: And implementing it in higher education*. Boston, MA: Springer.
- Strijbos, J. W., Narciss, S., & Dünnebier, K. (2010). Peer feedback content and sender's competence level in academic writing revision tasks: Are they critical for feedback perceptions and efficiency? *Learning and Instruction*, 20(4), 291–303.
- Sun, P. C., Tsai, R. J., Finger, G., Chen, Y. Y., & Yeh, D. (2008). What drives a successful e-Learning? An empirical investigation of the critical factors influencing learner satisfaction. *Computers & education*, 50(4), 1183-1202.
- Sung, H. Y., & Hwang, G. J. (2013). A collaborative game-based learning approach to improving students' learning performance in science courses. *Computers & Education*, 63, 43-51.
- Sunstein, C. R. (2005). *Why societies need dissent* (Vol. 9). Cambridge, MA: Harvard University Press.
- Suthers, D., & Hundhausen, C. (2003). An empirical study of the effects of representational guidance on collaborative learning. *Journal of the Learning Sciences*, 12(2), 183-219. doi:10.1207/S15327809JLS1202_2.
- Taba, H. (1962). *Curriculum Development: Theory and Practice*. New York: Harcourt Brace.

- Tabak, I. (2004). Synergy: A complement to emerging patterns of distributed scaffolding. *The Journal of the Learning Sciences*, 13(3), 305-335.
- Tannen, D. (1998). *The argument culture: Moving from debate to dialogue*. New York: Random House Trade.
- Thompson Long, B., & Hall, T. (2015). R-NEST: Design-based research for technology-enhanced reflective practice in initial teacher education. *Australasian Journal of Educational Technology*, 31(5), 572–596
- Thompson Long, B., Hall, T., Hogan, M. J., Harney, O. M., Doukoulos, T., & Murray, C. (2017). Using Collective Intelligence methodology to design and develop innovative technologies to support children’s literacy. *Journal of Literacy and Technology*, 18(2), 2-46.
- Tjosvold, D. (2008). The conflict-positive organization: It depends upon us. *Journal of Organizational Behavior*, 29, 19–28.
- Topping, K. (1998). Peer assessment between students in colleges and universities. *Review of Educational Research*, 68, 249–276.
- Topping, K. J. (2003). Self and peer assessment in school and university: Reliability, validity and utility. In M. Segers, F. Dochy, & E. Cascallar (Eds.), *Optimising new modes of assessment: In search of qualities and standards* (pp. 55–89). Dordrecht, The Netherlands: Kluwer Academic Publishers.
- Toulmin, S. E. (1958). *The uses of argument*. Cambridge, UK: The University Press.
- Toulmin, S. E., Reike, R., & Janik, A. (1979). *An introduction to reasoning*. New York: Macmillan.
- van Aalst, J. (2009). Distinguishing knowledge-sharing, knowledge-construction, and knowledge-creation discourses. *International Journal of Computer-Supported Collaborative Learning*, 4(3), 259-287.
- van Boxtel, C., van der Linden, J., & Kanselaar, G. (2000). Collaborative learning tasks and the elaboration of conceptual knowledge. *Learning and instruction*, 10(4), 311-330.
- van Bruggen, J.M., Boshuizen, H. P., & Kirschner, P. A. (2003). A cognitive framework for cooperative problem solving with argument visualization. In P. A. Kirschner, S. J. Buckingham Shum, & C. S. Carr (Eds.), *Visualizing argumentation: Software tools for collaborative and educational sense-making*. (pp. 25-47). London: Springer.
- van den Akker, J. (2003). Curriculum perspectives: An introduction. In van den Akker, J., Kuiper, W. and Hameyer, U. (Eds.). *Curriculum Landscapes and Trends*, (pp. 1–10). Dordrecht: Kluwer Academic Publishers.

- Van Den Bossche, P., Gijsselaers, W. H., Segers, M., & Kirschner, P. A. (2006). Social and cognitive factors driving teamwork in collaborative learning environments: Team learning beliefs and behaviors. *Small group research*, 37(5), 490-521.
- Van Den Bossche, P., Gijsselaers, W. H., Segers, M., Woltjer, G., & Kirschner, P. A. (2011). Team learning: building shared mental models. *Instructional Science*, 39(3), 283-301.
- van Eemeren, F. H., Grootendorst, R. (1999). Developments in argumentation theory. In J. Andriessen & P. Coirier (Eds.), *Foundations of argumentative text processing* (pp. 43-57). Amsterdam: Amsterdam University Press.
- van Gelder, T. J. (2001). How to improve critical thinking using educational technology. In G. Kennedy, M. Keppell, C. McNaught, & T. Petrovic (Eds.), *Meeting at the Crossroads: Proceedings of the 18th Annual Conference of the Australian Society for Computers In Learning In Tertiary Education*, (pp. 539– 548). Melbourne: Biomedical Multimedia Unit, University of Melbourne.
- van Gelder, T. (2007). The rationale for Rationale™. *Law, Probability & Risk*, 6(1-4), 23-42.
- van Gelder, T.J., Bissett, M., & Cumming, G. (2004). Enhancing expertise in informal reasoning. *Canadian Journal of Experimental Psychology* 58, 142-52.
- van Gennip, N. A., Segers, M. S., & Tillema, H. H. (2010). Peer assessment as a collaborative learning activity: The role of interpersonal variables and conceptions. *Learning and Instruction*, 20(4), 280-290.
- van Steendam, E., Rijlaarsdam, G., Sercu, L., & Van den Bergh, H. (2010). The effect of instruction type and dyadic or individual emulation on the quality of higher order peer feedback in EFL. *Learning and Instruction*, 20(4), 316–327.
- Veerman, A.L., Andriessen, J.E.B. & Kanselaar, G. (2000). Learning through synchronous electronic discussion. *Computers & Education*, 34(2–3): 1–22. doi:10.1016/S0360-1315(99)00050-0.
- Veerman, A., Andriessen, J.E.B., & Kanselaar, G. (2002). Collaborative argumentation in academic education. *Instructional Science*, 30(3), 155-186.
- Vidovic, J. (2010). Teaching with spirit: Freire, Dialogue, and Spirituality in the Composition Classroom (Unpublished doctoral dissertation). Wayne State University. MI: USA.
- Volet, S., & Mansfield, C. (2006). Group work at university: Significance of personal goals in the regulation strategies of students with positive and negative appraisals. *Higher Education Research & Development*, 25(4), 341-356.
- Volery, T., & Lord, D. (2000). Critical success factors in online education. *International journal of educational management*, 14(5), 216-223.

- Vygotsky, L. (1978) Interaction between Learning and Development. In M. Cole, V. John-Steiner, S. Scribner and E. Souberman (Eds. and Trans.) *Mind in Society: The Development of Higher Psychological Processes*, (pp. 79–91). Cambridge, MA: Harvard University Press.
- Wang, Z., Li, C., Wu, J., & Liu, L. (2014). The mediating effect of cooperative goals on the relationship between team orientation and team member exchange. *Social Behavior and Personality: an international journal*, 42(4), 685-693.
- Warfield, J. N. (1976). *Societal systems: Planning, policy, and complexity*. New Jersey: John Wiley & Sons.
- Warfield, J. N. (2006). *An introduction to systems science*. Singapore: World Scientific.
- Warfield, J. N. (2007). Obstacles to systems science programs in higher education: overview. *International Journal of General Systems*, 36(1), 79-89.
- Warfield, J. N. (2010). The Cognition Partition: Toward the Horizons College. *Transdisciplinary Journal of Engineering and Science*, 1, 5-16.
- Warfield, J., & Cardenas, R. (1994). *A handbook of interactive management*. Ames: Iowa State University Press.
- Webb, N. M. (1984). Sex differences in interaction and achievement in cooperative small groups. *Journal of educational psychology*, 76(1), 33-44.
- Webb, N. M. (1989). Peer interaction and learning in small groups. *International Journal of Educational Research*, 13(1), 21–39.
- Webb, N. M. (1991). Task-related verbal interaction and mathematics learning in small groups. *Journal for Research in Mathematics Education*, 22(5), 366–389.
- Webb, N.M. (1995). Group collaboration in assessment: multiple objectives, processes and outcomes. *Educational Evaluation and Policy Analysis*, 17(2): 239–261.
doi:10.3102/01623737017002239.
- Webb, N. M. (2009). The teacher's role in promoting collaborative dialogue in the classroom. *British Journal of Educational Psychology*, 79(1), 1-28.
- Webb, N. M., Franke, M. L., Ing, M., Chan, A., De, T., Freund, D., & Battey, D. (2008). The role of teacher instructional practices in student collaboration. *Contemporary Educational Psychology*, 33(3), 360-381.
- Webb, N. M., & Farivar, S. (1999). Developing productive group interaction in middle school mathematics. In A. O'Donnell & A. King (Eds.), *Cognitive perspectives on peer learning* (pp. 117–149). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers

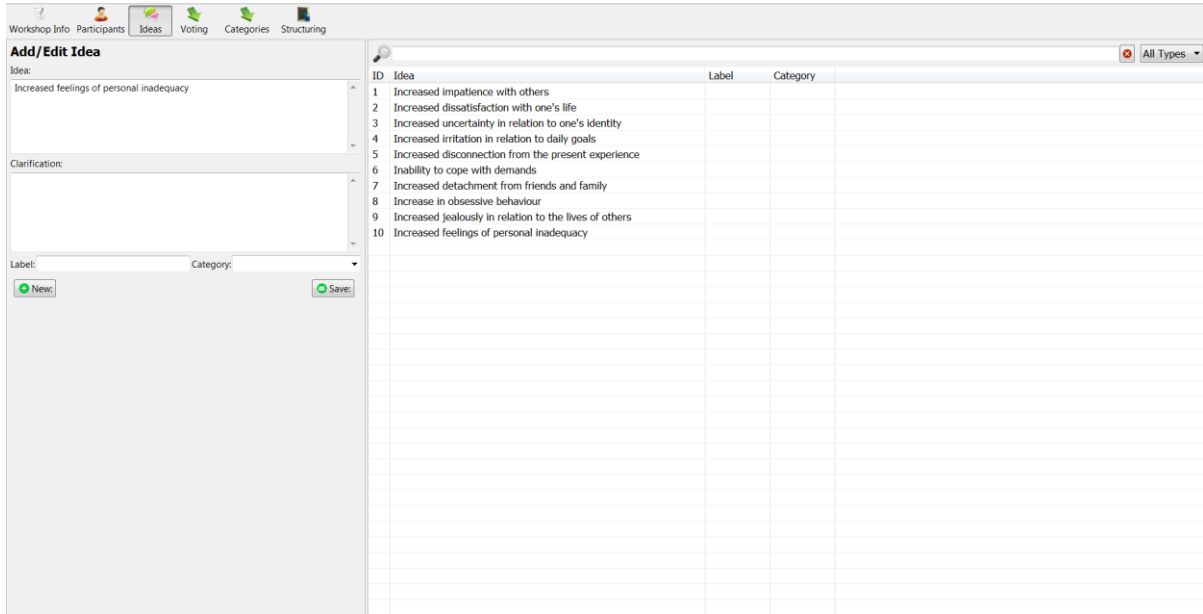
- Webb, N. M., & Mastergeorge, A. (2003). Promoting effective helping behavior in peer-directed groups. *International Journal of Educational Research*, 39(1), 73-97.
- Webb, N. M., Nemer, K. M., Chizhik, A. W., & Sugrue, B. (1998). Equity issues in collaborative group assessment: Group composition and performance. *American Educational Research Journal*, 35(4), 607–651
- Webb, N. M., Nemer, K. M., & Zuniga, S. (2002). Short circuits or superconductors? Effects of group composition on high-achieving students' science assessment performance. *American Educational Research Journal*, 39(4), 943-989.
- Webb, N. M., & Palincsar, A. S. (1996). Group processes in the classroom. In Berliner, D., and Calfee, R. (eds.), *Handbook of Educational Psychology*, MacMillan, New York, pp. 841–876.
- Webb, N. M., Troper, J. D., & Fall, R. (1995). Constructive activity and learning in collaborative small groups. *Journal of educational psychology*, 87(3), 406.
- Wegerif, R. (1996). Using computers to help coach exploratory talk across the curriculum. *Computers & Education*, 26(1-3), 51-60.
- Wegerif, R. (1998). The social dimension of asynchronous learning networks. *Journal of Asynchronous Learning Networks*, 2(1), 34–49.
- Wegerif, R. (2006). Dialogic Education: what is it and why do we need it? *Education Review* 19(2), 58-67.
- Wegerif, R. (2007). *Dialogic, Education and Technology: Expanding the Space of Learning*. New York: Springer.
- Wegerif, R. (2008). Dialogic or dialectic? The significance of ontological assumptions in research on educational dialogue. *British Educational Research Journal*, 34(3), 347-361.
- Wegerif, R. (2010a). Dialogue and teaching thinking with technology: Opening, expanding and deepening the 'inter-face'. In K. Littleton & C. Howe (Eds.), *Educational Dialogues: Understanding and Promoting Productive Interaction* (pp. 338–357). Oxford: Routledge.
- Wegerif, R. (2010b). *Mind Expanding: Teaching for Thinking and Creativity in Primary Education*. Buckingham: Open University Press/McGraw Hill.
- Wegerif, R. (2015). Toward Dialogic Literacy Education for the Internet Age. *Literacy Research: Theory, Method, and Practice*, 64(1), 56-72.
- Wegerif, R., Fujita, T., Doney, J., Linares, J. P., Richards, A., & Van Rhyn, C. (2017). Developing and trialing a measure of group thinking. *Learning and Instruction*, 48, 40-50.
- Wells, G. (1999) *Dialogic Inquiry: Toward a Sociocultural Practice and Theory of Education*. Cambridge, UK: Cambridge University Press.

- Wen, Y., Looi, C. K., & Chen, W. (2015). Appropriation of a representational tool in a second-language classroom. *International Journal of Computer-Supported Collaborative Learning*, *10*(1), 77-108. doi: 10.1007/s11412-015-9208-0.
- Wentzel, K. R., Barry, C. M., & Caldwell, K. A. (2004). Friendship in middle school: Influences on motivation and school adjustment. *Journal of Educational Psychology*, *96*, 195-203.
- Whyte, G. (1989). Groupthink reconsidered. *Academy of Management Review*, *14*(1), 40-56.
- Wilson, D. S., Ostrom, E., & Cox, M. E. (2013). Generalizing the core design principles for the efficacy of groups. *Journal of Economic Behavior & Organization*, *90*, 21-32.
- Wolfe, A. M. (2008). Student attitudes toward team projects. *Marketing Management Association 2008 Proceedings*, 119-126.
- Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry*, *17*, 89-100.
- Woolley, A. W. (2009). Means vs. ends: Implications of process and outcome focus for team adaptation and performance. *Organization Science*, *20*(3), 500-515.
- Xing, W., Wadholm, R., Petakovic, E., & Goggins, S. (2015). Group Learning Assessment: Developing a Theory-Informed Analytics. *Educational Technology & Society*, *18*(2), 110–128.
- Yang, M., Badger, R., & Yu, Z. (2006). A comparative study of peer and teacher feedback in a Chinese EFL writing class. *Journal of Second Language Writing*, *15*, 179–200.
- Yiong-Hwee, T., & Churchill, D. (2007). Using sentence openers to support students' argumentation in an online learning environment. *Educational Media International*, *44*(3), 207-218.
- Zhang, J., Scardamalia, M., Reeve, R., & Messina, R. (2009). Designs for collective cognitive responsibility in knowledge-building communities. *The Journal of the Learning Sciences*, *18*(1), 7-44.
- Zheng, B., & Warschauer, M. (2015). Participation, interaction, and academic achievement in an online discussion environment. *Computers & Education*, *84*, 78-89.
- Zhu, W. (1995). Effects of training for peer response on students' comments and interaction. *Written Communication*, *12*, 492–528.

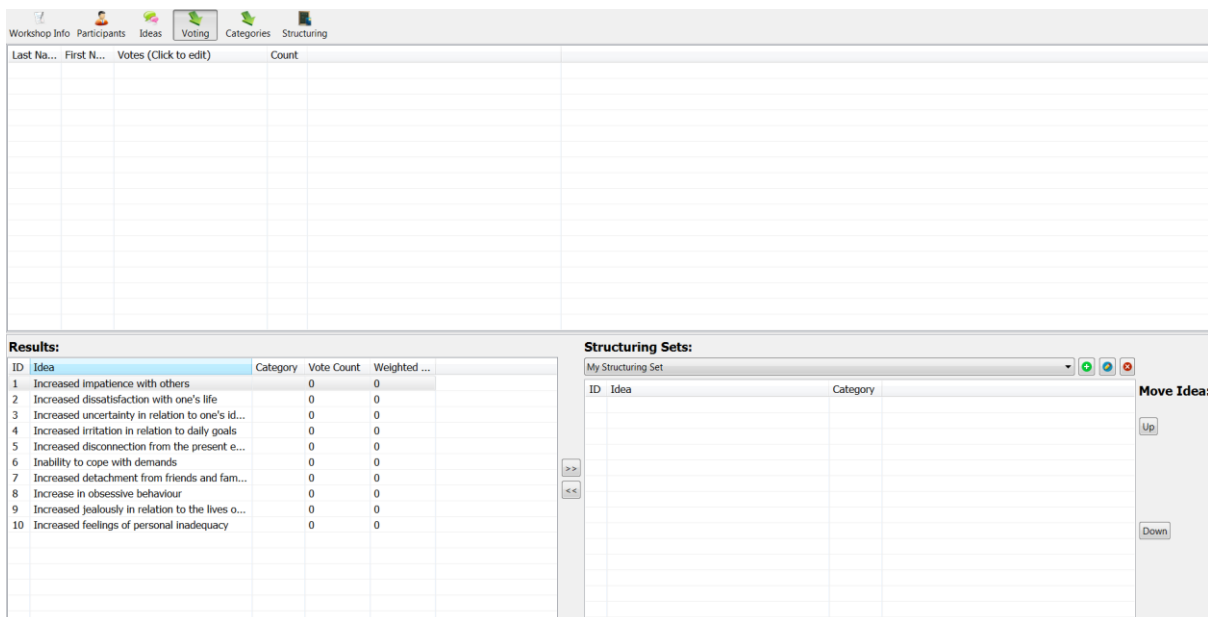
Appendices

Appendix A: Screenshots of the Interpretive Structural Modelling process & Examples of Applications

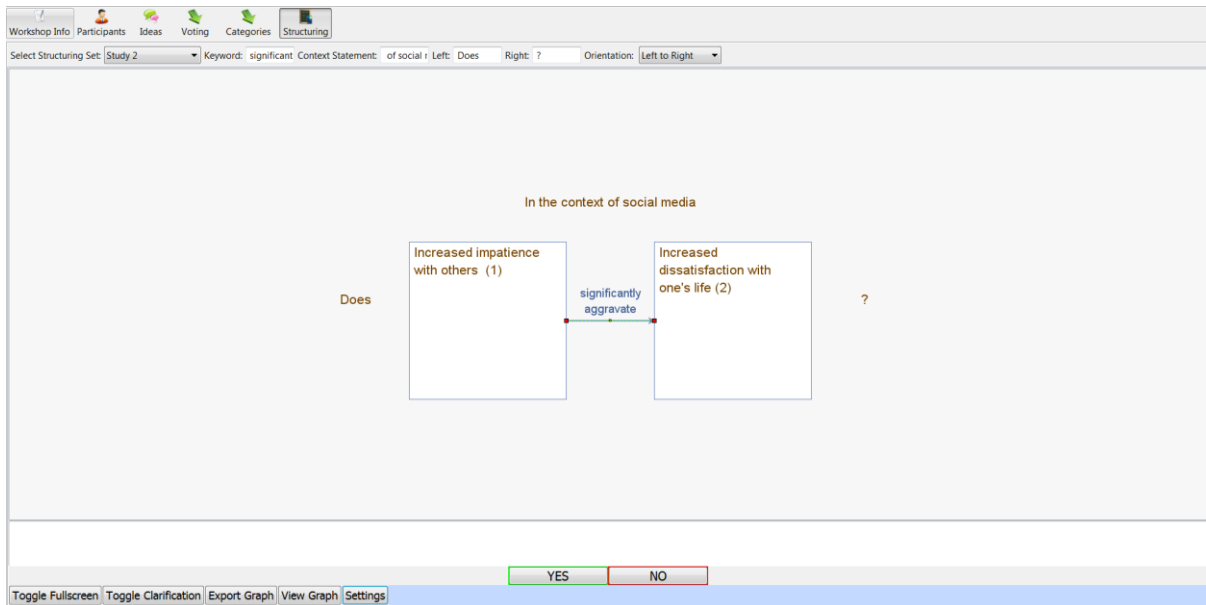
- 1) The *ideas* tab in the ISM software allows the facilitator to record all the ideas generated by the group in response to the trigger question.



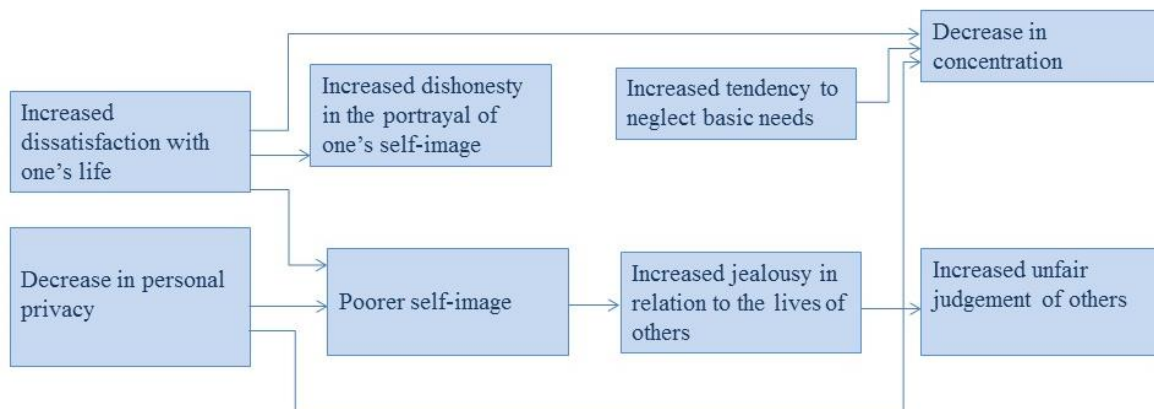
- 2) The *voting* tab allows the facilitator to record the votes made by individual group members as regards the most important ideas. These votes are aggregated across the group to produce a consensus set which are carried forward for structuring.



- 3) In the *structuring* tab, pairs of ideas prioritised by the group in the *voting* tab are entered into a relational question “Does A significantly aggravate B?”



- 4) The group’s answers to these questions (“yes” or “no”) are entered into a matrix by the software, which is transformed upon completion into a problematique representing the group’s decisions as regards the relationships between ideas in the system. A sample problematique is provided below.



Sample application: Applying IM in the motor industry (Staley & Broome, 1993)

The problematique presented below (Figure A) is one of a series of outputs from Interactive Management (IM) sessions carried out by Staley and Broome (1993), in consultation with a manufacturer in the automotive industry. The overall goal of the project was to assist the manufacturer in planning for the development and introduction of new technology in the automotive design process (AP), by identifying issues which must be addressed if the process is to be successful. Initial IM sessions highlighted *organisational culture* as a core component of many of the barriers to the success of the AP program. In order to address such issues, a further series of IM sessions were conducted to inform the development of a cultural change program, with a view to supporting the introduction of new technologies. This process involved phases of cultural problem identification; structuring of cultural problems; generation of options for overcoming the identified problems; structuring of a set of selected options, and sequencing of options to inform the development of a cultural change programme.

Crucially, the use of the problematique, which displayed a graphical representation of the relationships between issues, provided the participants with a guide and a platform on which to build a systematic plan. In response to the problematique, participants generated over two hundred potential options, which could be used to address problems associated with the organisational culture. This led, in the short-term, to the implementation of a set of options which were determined as *high-priority*, and which resulted in significant cultural change within the organisation.

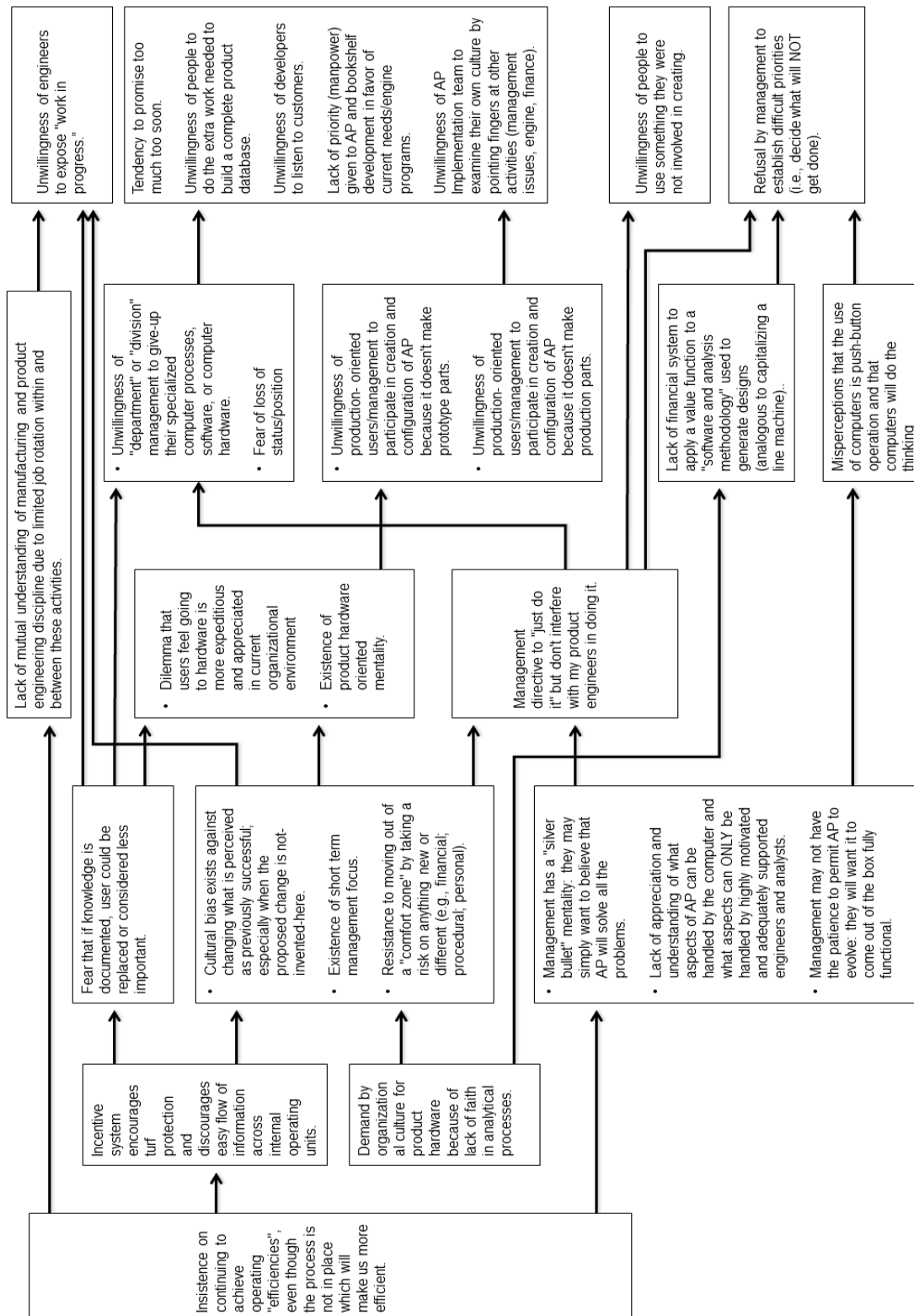


Figure A. IM problematic of cultural issues in the automotive design process

Sample application: Applying IM in peace-building in Cyprus (Broome, 2004).

A second example of the application of IM comes from Broome (2004). This problematique (Figure B) was developed in the context of peace-building efforts between Greek and Turkish Cypriots, and depicts a collective vision statement for peace. In this politically and socially complex context, according to Broome, the IM methodology provided an opportunity “for dialogue that gave voice to individual contributions and promoted a consensus that reflected the variety of needs and opinions within the group” (p. 191).

In contrast to Figure A, which presented the negative influence relationships between barriers of organisational culture (i.e., barrier A aggravates barrier B), the problematique below (Figure B) represents goals for peace which positively influence each other (i.e., goal A supports goal B). This graphical representation of shared goals, which was the result of months of engagement with two politically, socially, and physically divided groups, became the catalyst for a number of ground-breaking peace-building efforts.

Following IM sessions with Greek-Cypriots and Turkish-Cypriots separately, to develop a vision statement from each of their perspectives, a series of overlapping goals for peace were identified. This paved the way for IM sessions at which both groups were present, with a focus on both key similarities in their goals for peace-building, as well as recognition and acknowledgement of remaining differences or contrasting priorities. The engagement which ensued during subsequent IM sessions, resulted in the development of the collective vision statement presented in Figure B. This vision statement was then used to inform the development of a collaborative action agenda for implementing shared goals. This process resulted in the generation of 245 options which aimed to support the achievement of goals, and the subsequent prioritisation of 15 options as projects to be implemented during the following year. This action agenda, developed through the IM process, resulted in the implementation of numerous peace-building activities in Cyprus.

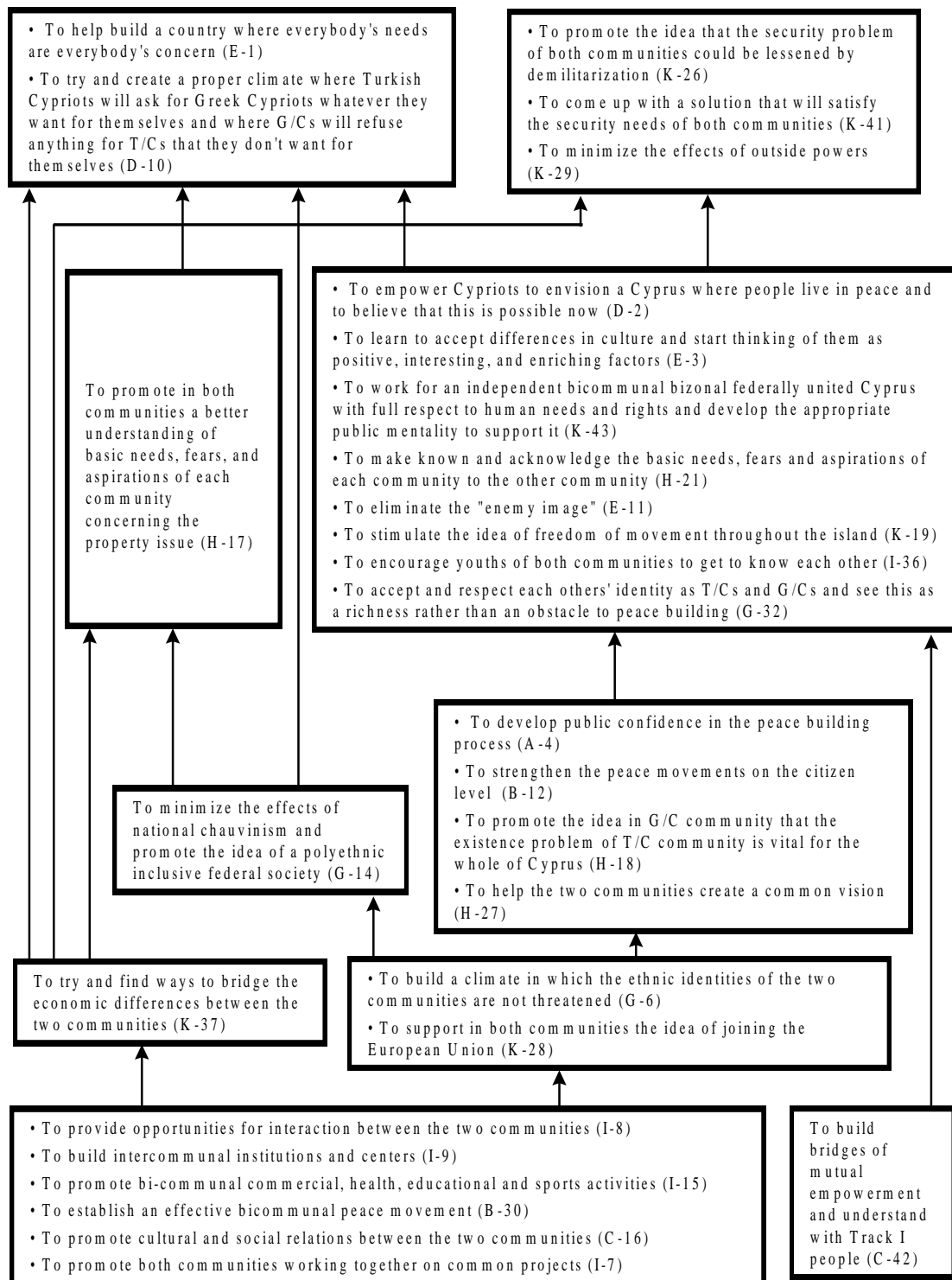
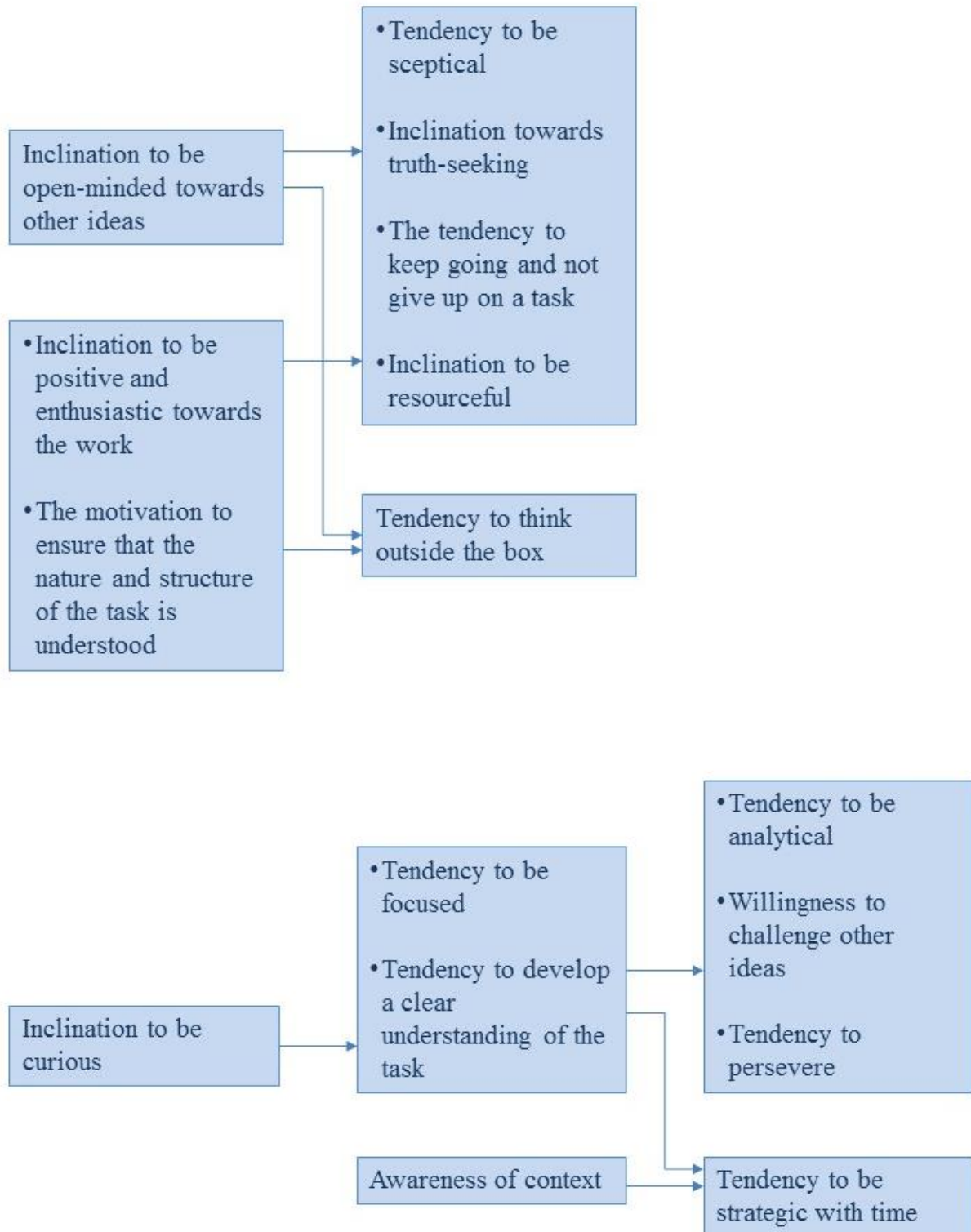


Figure B. Collective vision for statement for peace IM problematique

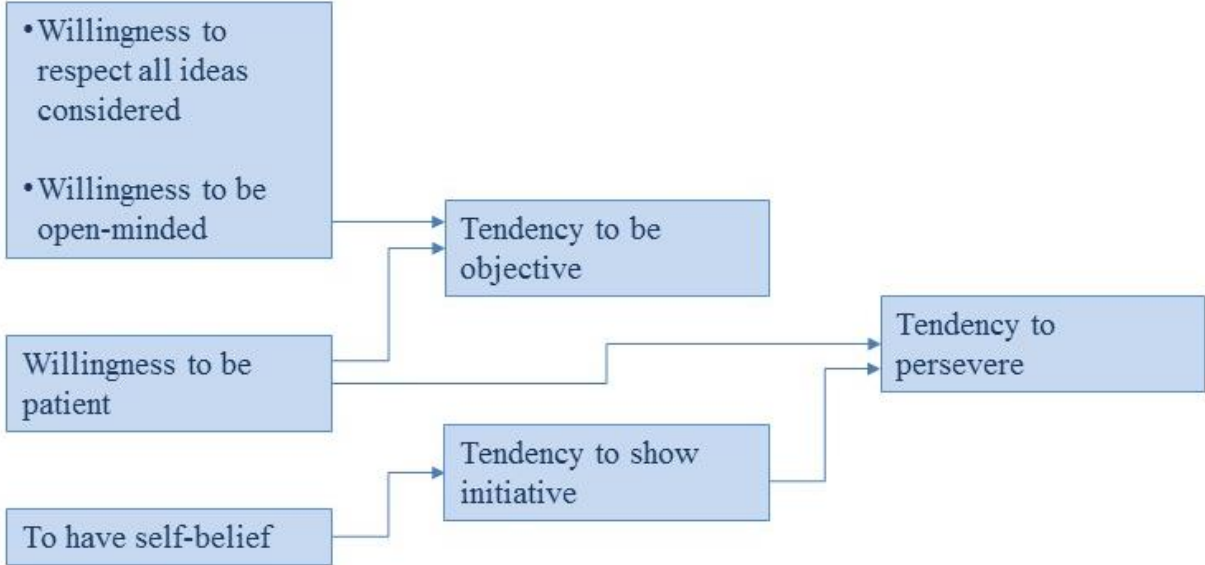
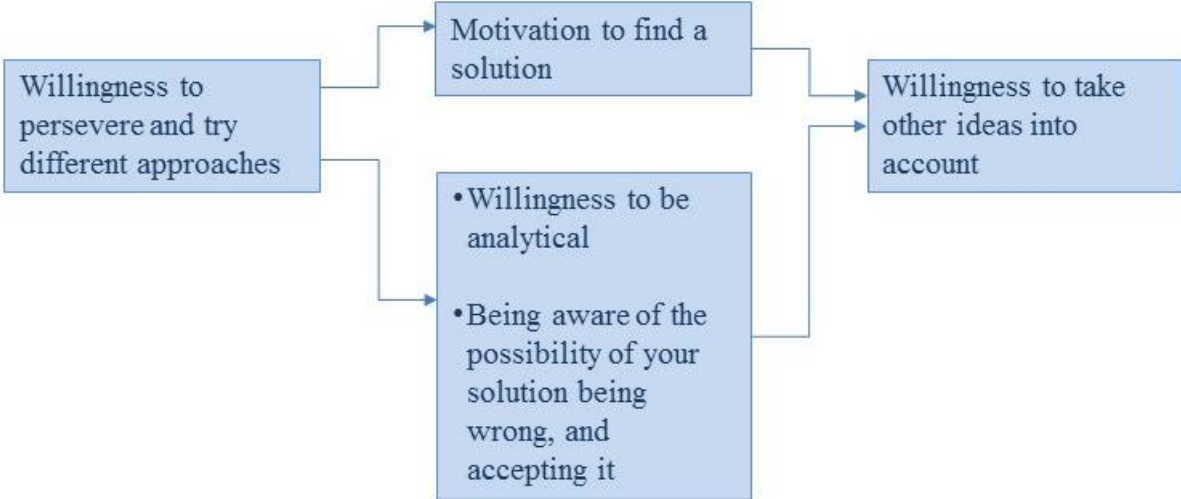
Appendix B: Remaining problematques from Study 3

Facilitator-driven condition



Appendix B: Remaining problematques from Study 3 (continued)

Peer-to-peer condition



Appendix C: Sample participant information sheet (Study 3)

Title of Project: Investigating the dispositions associated with good critical thinking and collaborative learning

Invitation

You are invited to take part in a research study. Before you decide to take part, it is important that you understand why the research is being done and what it will involve. This *Participant Information Sheet* tells you about the purpose, risks and benefits of this research study. If you agree to take part, we will ask you to sign a *Consent Form*. If there is anything that you are not clear about, we will be happy to explain it to you. Please take as much time as you need to read this information. You should only consent to participate in this research study when you feel you understand what is being asked of you, and you have had enough time to think about your decision. Thank you for reading this.

Taking Part – What it Involves

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this *Information Sheet* to keep and be asked to sign a *Consent Form*. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect your rights in any way.

What will happen to me if I take part?

During 2 x 2 hour sessions we will have a discussion about the dispositions associated with good critical thinking or good collaborative learning. We will then examine the interaction between these dispositions and discuss whether and how much they impact on each other. Using Interactive Management software, we will then vote on the significance of these relationships. The session will be recorded and the discussion will be transcribed and examined by the research team, for themes running through the dialogue, at a later date. You will also be asked to complete a series of questionnaires. All data will then be stored anonymously and securely.

Topic of the discussion

What are the dispositions associated with good critical thinking or good collaborative learning?

How long will my part in the study last?

The two sessions will take approximately two hours each.

What are the possible benefits in taking part?

This study involves discussing critical thinking or collaborative learning, topics which are relevant to all of you. During this discussion, we hope that you will gain a greater understanding of these concepts.

What are the possible disadvantages and risks of taking part?

These sessions require a good level of concentration, and engagement, so they may be mentally tiring, but we will try as much as possible to provide breaks between activities and keep everyone energised.

What happens at the end of the study?

At the end of this study you will receive a one or two page summary of our findings. We will use quotations from the IM session to elaborate various points but you will not be identified as the participant. Only general findings will be reported, without reference to identifiable individual results.

What happens if I change my mind during the study?

You are entitled to change your mind about participating in this at any time without disadvantage or penalty.

Who do I contact for more information or if I have further concerns?

If you have any questions about the study please contact: Owen Harney or Dr. Michael Hogan
Department of Psychology, N.U.I.G.

If you have any concerns about this study and wish to contact someone in confidence, you may contact: **The Head, School of Psychology, National University of Ireland, Galway.**

Appendix D: Sample participant consent form (Study 3)

Participant Identification No.: _____

Title of Project: Investigating the dispositions associated with good critical thinking and collaborative learning

Name of Researcher: Owen Harney; Dr. Michael Hogan, Dr. Christopher Dwyer, Cormac Ryan

Please initial box

1. I confirm that I have read the information sheet for the above study and have had the opportunity to ask questions.

2. I am satisfied that I understand the information provided and have had enough time to consider the information.

3. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my legal rights being affected.

4. I agree to take part in the above study.

Name of Participant Age Date Signature
(Years and months)

Researcher Date Signature

Researcher Date Signature

Appendix E: Sample perceived consensus measure

- 1) Generally speaking, my peers and I approach online social media in a similar manner
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 2) I understand Fear of Missing Out in the same way as my group
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 3) I feel I understand the nature of the impact of social media on attitudes and behaviours in the same way as my peers do
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 4) My peers have the same opinions of the negative aspects of social media as I do
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 5) I feel that I have a different opinion of Fear of Missing Out than the rest of the group
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree

Appendix F: Sample objective consensus measure

- 1) Increased impatience with others **significantly aggravates** increased dissatisfaction with one's life?
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 2) Increased dissatisfaction with one's life **significantly aggravates** increased impatience with others?
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 3) Increased impatience with others **significantly aggravates** increased uncertainty in relation to one's identity?
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 4) Increased uncertainty in relation to one's identity **significantly aggravates** increased dissatisfaction with one's life?
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 5) Increased dissatisfaction with one's life **significantly aggravates** increased uncertainty in relation to one's identity?
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 6) Increased irritation in relation to daily goals **significantly aggravates** increased uncertainty in relation to one's identity?
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 7) Increased uncertainty in relation to one's identity **significantly aggravates** increased irritation in relation to daily goals?
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree

- 8) Increased irritation in relation to daily goals **significantly aggravates** increased dissatisfaction with one's life increased impatience with others?
 ___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 9) Increased uncertainty in relation to one's identity **significantly aggravates** increased disconnection from the present experience?
 ___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 10) Increased disconnection from the present experience **significantly aggravates** inability to cope with demands (too much to do, too little time)
 ___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree

Appendix G: Perceived efficacy of the IM methodology Scale

- 1) I believe that Interactive Management can be used to solve problems effectively
 ___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 2) I believe that Interactive Management can be used to help a group achieve consensus about a problem
 ___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 3) I would use Interactive Management to structure my thoughts in the future
 ___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 4) I would recommend Interactive Management to others as a problem-solving tool
 ___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 5) I think more working groups around the world should use Interactive Management to solve problems
 ___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 6) I think there are some problems that Interactive Management will not help to resolve
 ___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 7) I don't think Interactive Management will help all groups to achieve consensus – there are some problems that are too difficult
 ___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree

Appendix H: Trust scale

- 1) Members of my class show a great deal of integrity
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 2) I can rely on those in my class
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 3) Overall, the people in my class are very trustworthy
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 4) We are usually considerate of one another's feelings in this class
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 5) The people in my class are friendly
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 6) There is no "team spirit" in my class
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 7) One should be very cautious to openly trust others when working with people
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 8) Most people tell the truth about the limits of their knowledge
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 9) Most people can be counted on to do what they say they will do
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 10) Most people are honest in describing their experiences and abilities
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree
- 11) Most people will act as "Good Samaritans" if given the opportunity
___ Strongly Disagree ___ Disagree ___ Neutral ___ Agree ___ Strongly Agree

Appendix I: Team orientation scale

- 1) What I typically get out of team projects is not worth the effort I've put in
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 2) I like explaining new things to people
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 3) Having to work in a group really detracts from my ability to learn new things
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 4) All else being equal, teams are more productive than the same people would be working alone
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 5) I believe that teamwork really unleashes the motivation and power of people
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 6) I'm more comfortable working by myself than with others
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 7) I always work hard to make sure my team is the most productive it can be
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 8) If given a choice, I'd choose to work in a team rather than by myself
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 9) Working in groups is frustrating because there are too many different opinions on how to do something
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 10) I generally prefer to work alone than with others
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 11) I really enjoy working in groups
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 12) I just end up getting confused working in groups
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 13) I find other people often have interesting contributions that I might not have thought of myself
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 14) I dread working in groups
___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree

- 15) Unless I'm confident that my team members will carry their weight, I tend to be leery of team situations
 ___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 16) It is easier for me to learn new information by working closely with team members than by myself
 ___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 17) I find that it takes too long to get anything accomplished when working in groups
 ___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 18) I like working in groups
 ___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 19) I think that many people simply "coast" and fail to carry their weight in group projects
 ___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 20) I really love sharing ideas and learning new perspectives during group projects
 ___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 21) I usually get more out of a project by working alone, rather than working with others
 ___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree

Appendix J: Discomfort in group learning scale

- 1) I sometimes feel nervous when I have to give my ideas or communicate within a group
 ___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 2) I often find it difficult to understand what the task is in group work
 ___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 3) I am often afraid to ask for help within my group
 ___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree
- 4) I rarely feel relaxed working within a group
 ___Strongly Disagree___Disagree___Neutral___Agree___Strongly Agree