The Trajectory of Computer Science Education Policy in Ireland: A Document Analysis Narrative

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The launch of a Computer Science curriculum specification in upper secondary schools in Ireland in 2018 was a landmark and a historic development in Irish education. Addressing the historical policy decisions adopted towards establishing the specification, this paper presents an analysis of developments from the 1970s as revealed in key policy and other documents. Positioning the policy change within the context of influences, context of policy text production and within the context of practices the paper presents an overview of the Irish Computer Science specification. Alongside the background to the evolution in computer science education over the period, the paper takes into account the national and cultural contexts and narrates the journey travelled to arrive at this pivotal position. Developments in a global context are presented in comparison with curricula in other countries and some similarities and differences identified. The paper uncovers consequences of the specification for the national curriculum, key skills integration and CS teacher preparation. The article provides an important analysis of the policy trajectory of computer science in Ireland based on a visibly relevant corpus of documents tracing the different stages of this policy and comparing it to similar experiences implemented in other European countries.

Keywords: computer science education; policy; contexts; curriculum; key skills

Introduction

The introduction of computing in secondary schools has been widely researched (Deek, 1999; Hubwieser, 2012; Keane, 2017; Yadav, 2016). In many countries the focus of computer science education at post-primary level has shifted from computer and ICT applications towards a more rigorous academic discipline (Bell, 2010; Brown, 2013; Hubwieser, 2012). This document analysis focuses on tracing the decisions adopted by the Irish government over the years, eventually leading to the development of the Computer Science (CS) specification introduction as an optional subject as part of the national curriculum.

Computer literacy, information and communication technology, education technology, digital citizenship and technology are all aspects of computing, but are distinguishable from CS because they are focused on using applications rather than understanding why they work and how to create the technologies (Denning, 2005; Knuth, 1974; McGarr, 2009). Subjects entitled “Computer Science” or relating to this discipline in national curricula now offer students the opportunity to move away from being passive users of computing to becoming designers of computer systems and applications. Indeed, increasingly, the era of digital education requires that everyone has a fundamental grasp of how computing works and how it is impacting upon our everyday lives (Selwyn, 2015, 2019). Ways of thinking, problem solving and creating in CS have become invaluable parts of life and are important beyond ensuring that we have enough skilled workers (Alano, 2016). Students who take CS in post-primary school learn CS concepts such as algorithms or data structures (Barr, 2011; Brennan, 2012), coding is a key way to enable computational thinking (Lye, 2014), and developing computational thinking practices has positive implications for a reflective and critical education (García-Peñalvo, 2018).

One of the early definitions of CS is accredited to Perlis, Newell and Simon in 1967 as the study of computing and all the phenomena associated with it (McGuffee, 2000). CS faces outward (Tartar, 1985) and incorporates more than just computer coding, often involving physical systems and networks; collection, storage, and analysis of data; and the impact of computing on society. It is an empirical discipline which comprises how computing technology and CS impact the world around us (Newell & Simon, 2007) and which has driven innovation in every industry and field of study. As Ensmenger (2010) and Hicks (2017) argued, computing is shaped by those with the power to set technological and economic priorities and is currently being introduced to many post-primary schools.

The development of education policies related to CS in post-primary education exemplifies how "educational policy-making and governance are no longer simply occurring within the prefigured boundaries of the nation state but now involve a diverse cast of new actors and organizations across new policy spaces" (Gulson et al., 2017, p. 1). Through "the dynamics of translation, alignments are forged between the objectives of authorities wishing to govern and the personal projects of those organizations, groups and individuals who are the subjects of government" (Rose, 1999, p. 48). Therefore, political and non-political mediators make their problems seem intrinsically linked to all citizens and the result of these translations has been the introduction and the recognised value of CS in schools. Curricular reform therefore is not simply a direct governmental imposition, but the product of a web of lobbying, negotiations, compromises and conflicts which have been blended into a shared longitudinal campaign (Williamson, 2016).

Describing the historical policy decisions adopted by the Irish government, specifically the Department of Education and Skills (DES) (formerly Department of Education, and then Department of Education and Science), leading to the establishment of the current CS subject specification in Ireland, this paper provides background to the development of the CS specification. Identifying the wider policy context – particularly the development of curriculum, underpinned by consideration of some of the foundational characteristics of CS as an emerging informatics discipline – the paper sets out to trace and analyse the journey in the design of Computer Science in Irish schools.

Theoretical Framework for Policy Analysis

Policy analysis is a “complex and multi-layered” endeavour (Hill, 2005, p. 4), and many theorists have suggested competing analytical frameworks (Ball, 1990, 1994; Bell & Stevenson, 2015; Taylor, 1997, 2004). Ball traces “policy formulation, struggle and response from within the state itself through to the various recipients of policy” (Ball, 1993 p. 16), thus emphasising the agency of individual practitioners in constructing policy at the local level. Vidovich (2007, 2013) added to Ball’s work in including *levels* that extend between “global” and “local” policy processes. Ball’s original policy trajectory focuses on five *contexts*: those of influences, policy text production, practices, longer-term outcomes and political strategy. In this paper they are examined as follows.

Within the context of *influences*, attention is paid to the conditions leading to interest in the new policy agenda and the influences of different stakeholder groups. For the purpose of this study, owing to the nature of curriculum design in Ireland, the context of influences and the context of *political strategy* are integrated. Following Vidovich (2001), questions can be asked about what struggles are occurring to influence the policy, over what time period did the context of influences evolve before the policy was constructed, and what were the prevailing ideological, economic and political conditions..

The context of *policy text production* focuses on the actual policy text and considers identifying dominant ideologies and power relationships, answering questions about “who, what, why, when, where and how” for the text that was constructed. An examination of the struggles occurring in the production of the text, the “how” regarding its construction, and the stated intention and purpose of the policy are presented (Vidovich, 2001).

The context of *practices* establishes the way in which the policy is enacted at local sites, including how it is resisted, negotiated, or reformed. The context of *longer-term outcomes* identifies possible longer-term effects likely to result from enacting the policy, including changing patterns or social justice and equity (Vidovich 2007, 2013). The CS specification in Ireland is recent, and so the context of practices and longer-term outcomes are combined (Rizvi & Lingard, 2010).

This structure aligns with the suggestion by Vidovich (2001, p.14) that one might "interrogate a particular policy process, grouped according to three of the different contexts of the policy cycle: 'influences', 'text production' and 'practices/effects.'"

In this paper, within the policy trajectory, the national level (Ireland) is addressed in detail, with a comparative international or global perspective also presented. The paper does not seek to elaborate the intent or reason of policy choices in any other country but makes broad reference to the similarities and differences in CS education policy development. Considering the different levels of policy trajectory (the local and global), and the three contexts (influences and political strategy, policy text production, and practices and longer-term outcomes), the following research questions were generated and adopted for this policy research.

1. Context of influences and political strategy: Where did the policy originate and what were the values directing the historical trajectory of the CS specification?
2. Global context: How does the Irish CS development compare to the trajectory of international CS education policy?
3. Context of policy text production: Why, when, where and how was the CS specification text generated? Who and what were involved?

4. Context of practices and longer-term outcomes: What are the consequences of the CS Specification development for the national curriculum, key skills integration and CS teacher provision?

Research Method

In order to answer our questions, the practice of qualitative document analysis (QDA) – similar to the work of Aesaert, Vanderlinde, Tondeur and van Braak (2013) and Owen (2014) – was adopted. As with other analytical methods of qualitative research, document analysis requires that data be examined and interpreted in order to elicit meaning, gain understanding, and develop empirical knowledge (Bowen, 2009; Corbin & Strauss, 2008). QDA is oriented to combine several steps to pursue concepts, data, and other information sources that emerge in the context of the thinking and discovery process of the research. Therefore, it is particularly suitable for qualitative intensive studies producing rich descriptions of a single phenomenon, event, organisation, or programme (Bowen, 2009; Stake, 1995) and is of relevance in answering our research questions surrounding CS education. Thus, QDA was applied to inform the conversation with numerous documents related to CS education in Ireland and internationally for a systematic and constant comparison.

The authors' positionality also influences this work, as they were participants in the process: one author in the past and other two in the design of the recently published CS specification. All three authors are CS educators and have been involved in post-primary teacher education and policy development. Their research and policy experience ranges from the 1970s to the present. This experience provides a rich source of information otherwise unavailable in the literature around the contexts of influences and political strategy, policy text production, and practices and longer-term outcomes identified above. The authors' involvement in the policy conversations from the 1970s to the present provides insight into the relevant documents that were central to the CS policy development in Ireland. These documents are used as the basis for exploring three of the research questions: on the “context of influences and political strategy” in terms of the historical development of policy in this area, on the “context of policy text production” with insight provided on the curriculum development process, and on the “context of practices and longer-term outcomes” in examining implementation issues and articulation with the whole upper secondary curriculum.

The interest in computing at schools in Ireland began around 1970 (Oldham, 1981, 2015). We therefore commenced our document search from that date. Based on the authors’ knowledge and experience of the policy landscape in this area, we selected for the analysis a sample of reports, pamphlets, Web sites and other government-related documents, spanning the period 1970–2018. Many were commissioned or produced by the State Department of Education or the National Council for Curriculum and Assessment; however, some key documents (especially from earlier years) are not in the public domain, so use was made of second-hand sources, notably those drawing on the authors’ first-hand experience. The culmination was the launch of the CS curriculum at the beginning of 2018, a landmark and a historic development in Irish education, representing the first time that CS was offered as an examinable subject in Senior Cycle (upper secondary).

In order to address the second research question, on “Global Context,” a literature review was conducted to explore the trajectory of international CS curriculum development. We again used the 1970–2018 timeline as an inclusion criterion. The documentary data was interrogated for underpinning assumptions and competing policy vocabularies. We analysed how the document authors articulated the discourse and aspirations around CS education and present the narrative in a chronological manner. Thus, the document analysis is informed by perceptions of the contexts in which the documents were produced, aligning to the work of Ball (1994).

Context of Influences and Political Strategy

The Irish Government's position in recent years indicates a belief that expertise in science, technology, engineering and mathematics (STEM), and centrally CS, is pivotal in supporting the innovation and future prosperity which the country aims to achieve (Department of Education and Skills [DES], 2016). To place the evolution of the CS specification in context, a brief account of the structure of the Irish education system is provided. Education in Ireland is centralized, and the Department of Education determines national educational policy and curriculum. Students typically start the first year of secondary school at the age of twelve, having completed their primary school education. The Irish post-primary education consists of a three-year Junior Cycle (lower secondary), followed by a two- or three-year Senior Cycle (upper secondary), depending on whether the optional Transition Year (TY) is taken. During the final two years of Senior Cycle students prepare for a high-stakes State examination, the Leaving Certificate (LC), taken when students are typically 17 or 18 years of age. There are over 30 subjects available to students at this level, and they are required to take at least five subjects, one of which must be Irish (https://www.education.ie/en/The-Education-System/Post-Primary/). Entry to higher education depends on the grades achieved in the LC.

As noted above, concern for computing at schools in Ireland began around 1970; the Department of Education, some universities and the Irish Mathematics Teachers Association expressed interest. The Department initiated professional development courses for teachers in the summers of 1971 to 1974, with a focus on programming, and a small pilot project supported by the Department established in 1974. The 1972 summer course led to the foundation of the Computer Education Society of Ireland (now the Computers in Education

Society of Ireland) (CESI), a network of teachers and other people interested in the topic; CESI has advocated for computing in the curriculum ever since then (Oldham, 1981, 2015; Millwood & Oldham, 2017). However, it was not until 1979 that a government committee was set up to examine possibilities for introducing a computing subject formally into the school programme (Department of Education, 1980). A supposedly temporary scheme began in autumn 1980, providing an optional section on Computer Studies in the LC Mathematics course. Schools had to register to take part. The work was monitored and certificates awarded by Department of Education inspectors; it did not figure in the LC examination papers. At that time, and indeed for some time afterwards, the perceived value of the subject for the Department, and indeed CESI, was far more concerned with the intellectual benefits to students as regards higher-order thinking, and preparing them to live and work in the information age, than with economic benefits for the country (Bresnihan et al., 2015). In 1981, the then Minister for Education, Mr John Wilson, stated in a speech at the Annual Congress of the Irish Vocational Education Association:

> It is my firm intention that Computer Studies will be formally introduced into second-level curriculum as a separate subject by the school year 1983/84 at the latest. To enable this to be done, a number of activities must first be undertaken, i.e. (a) the establishing of research and curriculum developmental projects in selected schools; (b) the development of appropriate syllabi; (c) the provision of appropriate teacher training courses; (d) the provision of hardware and software in schools. (Wilson, 1981)

Despite this well-thought-out plan, the standalone subject was not realised at the time, and "Computer Studies" maintained a somewhat ghostly presence, technically as an optional part of LC Mathematics, but in practice functioning separately. The original syllabus – typical of Computer Studies courses at the time – is shown in Fig. 1; later, when few teachers were taking up the option, they could specify their own syllabuses for approval. The option was finally abolished only in 2013 (Millwood & Oldham, 2017).

The syllabus should include the following aspects: –

Development of the computer; Social implications and use in everyday life; Careers in computing; Structured diagrams; Problem analysis; Communicating with the computer; one low level language, where feasible, such as CECIL or CSSP; one high level language such as COMAL; Emphasis on input, control, process, output, testing, branching, loops, functions; Types of input/output devices.

It is envisaged that pupils would spend about 35 hours on this section in the course of one school-year.

Each pupil should write and successfully run about ten programmes. Two or more pupils may undertake joint projects. Records of the work done must be available for monitoring by the Department.

Fig.1. Computer Studies option in the Leaving Certificate, 1980-2013 (Department of Education, n.d., p. 219)

In 1985, however, Computer Studies was introduced as a standalone subject for lower secondary education, although it was non-examinable in the State examination for that level (Bresnihan et al., 2015). The focus of the subject is illustrated by the list of aims and objectives set out in Fig. 2; this flags *information processing* as a core value (in fact addressed via use of applications packages as well as programming) and shows foresight that students needed to learn to use computers with "care and attention." For what looked to be a progressive syllabus, uptake is hard to establish as the non-examinable nature meant that no official statistics are available on how many students were taking the course. Moreover, around this time, interest was moving away from computing towards digital literacy skills, with greater emphasis on use of applications packages and ICT integration across the curriculum. Support for the subject faded out during the early 2000s (Millwood & Oldham, 2017).

The aims and objectives of the syllabus are that a pupil should:

- find the work interesting and enjoyable
- be skilled in the full use of the Computer System available in the School
- be able to receive, transfer and manipulate information
- develop algorithms and be able to communicate them efficiently to the machine using a high level structured language
- appreciate the role and the limitations of a Computer System
- be aware of issues such as security and privacy
- have some knowledge of the historical background associated with computer development
- develop habits of care and attention when using the computer

Note: It is envisaged that pupils would spend about 70 hours on this programme in the course of the Junior Cycle.

Fig. 2. Standalone Computer Studies as non-examinable course for lower secondary (Department of Education, n.d, p. 65)

The first official policy document for educational technology in schools, *Schools IT 2000*, was published by the Department of Education and Science in 1997 (Department of Education and Science [DES], 1997). IT (Information Technology) is not a replacement for Computer Studies; the government's perspective had shifted. The *Schools IT 2000* report stating that in Ireland, the IS Steering Committee report presents a challenging "strategy for action". The Committee believes that "our education and training system will have to be transformed in order to take advantage of the opportunities that the new information and communications technologies bring in meeting education objectives and to respond also to the scale and speed of re-skills that the Information Society will entail for Ireland labour force. This transformation will extend from policy making to curriculum development, teaching methods and teacher training. The courses of education and training must be extended beyond the traditional institutions to include the home, the community, enterprises and other organisations." (DES, 1997, p. 5)

Thus, the Steering Committee was now eager that all learners would be introduced to and accustomed to the emerging information and communication technologies and felt it would be of economic national interest that all schools incorporated these. The economic focus is a contrast to earlier thinking as described above. McGarr's review of policy and implementation suggests that there was governmental support for this approach from 1999 to 2002, but then support declined between 2002 and 2009 (McGarr, 2009).

In the early 2000s, the body by then responsible for curriculum development in Ireland, the National Council for Curriculum and Assessment (NCCA), commissioned a report entitled *Computers and Curriculum: Difficulties and Dichotomies* (O'Doherty et al., 2004). The authors recommended that all students be capable of basic computing skills, in part with a view to use of digital technology in teaching and learning ("ICT integration across the curriculum"), and that policy should not focus on introducing a new subject.

The perceived importance of "basic skills for all", because of the pervasiveness of computers, led respondents to stress the importance of putting current computer skills provision in post-primary schools on a more structured and formal basis. There was a general view that basic skills provision for all should take precedence over the introduction of a Leaving Certificate computer subject. Respondents argued that the effective integration of ICT across the curriculum would not happen until students acquired a certain level of basic skills. (O'Doherty et al., 2004, p. 35)

It should be noted, however, that the above assessment was based on all the stakeholders surveyed and interviewed. If the feedback from only the "University Computer Science Department" and the "First Year Computer Science University Student" respondents are considered, there was considerable interest in a dedicated CS or Computer Studies course as part of the LC (O'Doherty et al., 2004).

The focus within the DES up to and including 2015 remained on the use of digital technology in teaching and learning. This was reflected in the Department's *Digital Strategy for Schools 2015-2020*, in which it is stated that "ICT integration is at the core of the Strategy" – although "the concept of developing 'discrete' ICT skills also needs to be explored" (DES, 2015, p.22). The document also noted that some submissions called for the introduction of coding and programming into the curriculum. In fact pressure for their introduction was building up from business and industry, and from third-level CS departments; CESI (the Computers in Education Society of Ireland) supported such a development, but on educational grounds (Millwood & Oldham, 2017). The pressure was reflected in a report to the Minister for Education on STEM education in the Irish school system, *Education in the Irish School System,* which made the recommendation to "introduce computer science (including coding) as a Leaving Certificate curriculum subject. This is critical to address the ICT skills deficit in Ireland" (DES, 2016, p.9). Soon afterwards, that became the official policy. No longer was the government referring to ICT or digital literacy alone but was echoing John Wilson's early 1980s focus on programming again, now with a focus on the economic benefits.

The CS curriculum design, given its role in the provision of quality learning for all young people, is also of importance and crucial to the realisation of the STEM report. The introduction of CS at Senior Cycle, along with the introduction of coding at primary school level, would change the way Irish schools approach computing and information technology – replacing the idea of IT literacy and passive consumption of computing to understanding the how, where and why in regard to computing. The Senior Cycle CS specification was published in 2017, with the first cohort of students completing the course in 2020. The whole journey from 1981 is depicted in Fig. 3.

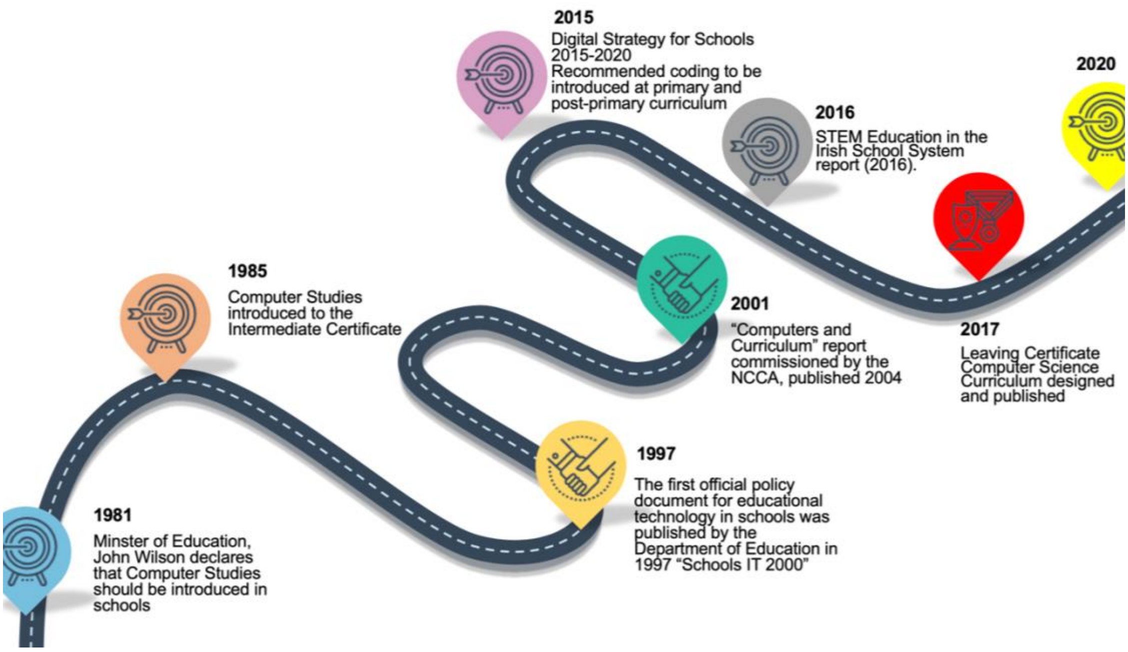

Fig. 3: CS in Ireland Policy Roadmap

Global Context

The Irish experience can now be set in wider context. The focus in many countries at post-primary level has shifted recently from computer and ICT applications towards a more rigorous academic discipline (Bell, 2010; Brown, 2013; Hubwieser, 2012). Allowing for the differing educational structure, curriculum and statutory obligations in the provision of CS in post-primary schools in different jurisdictions (Tenenberg, 2014), Ireland appears to share this trajectory.

In some cases, the similarities date from earlier. The Irish pattern traced above – Computing in the 1970s and 1980s, followed by a shift to digital literacies in the 1980s and 1990s, with a resurgence of interest in CS in the past decade – matches what has happened in England (Brown, 2013; Brown, 2014; Millwood & Oldham, 2017). The English national curriculum was changed in 2014, replacing Information and Communication Technology (ICT) by a new subject of Computing which has more emphasis on CS and programming principles. The move to CS is analogous to what has happened in Ireland. However, the removal of the ICT qualification in the UK has resulted in a decline in computing provision in English schools, in terms of both hours being taught and qualifications achieved by students (Kemp, 2019). The data from examination sittings also indicates that the change of subject content is having a particularly negative impact on female participation and attainment in computing (Kemp, 2019). Perhaps a similar path is being followed in Ireland; in a survey conducted in 2019, it was found that the while 38% of the teachers teaching the subject were female, only 22% of the students taking it were female (Lero, 2019).

The evidence from France, Italy and New Zealand is analogous. In France, a narrow form of computer programming was present in secondary education from the 1960s. Baron et al. (2014) describe a pendulum, swinging back and forth between CS (more precisely, informatics) and ICT. Currently, an optional CS course is offered in the last year of secondary education, and is built around four sections: data representation, algorithms, programming languages, and hardware architectures. Teachers build instructional sequences by combining knowledge and skills extracted from the four elements, (This is akin to the Irish CS specification outlined below, with respect to Strand 2 on Core Concepts.) New Zealand introduced CS in high schools nationally in 2011 (Bell, 2012). Prior to this, CS as a discipline had not been available formally in the NZ high school curriculum and the focus had instead been on the use of computers. The NZ CS content introduced a focus on programming and also gave students the chance to explore a range of CS topics beyond programming, including algorithms and complexity, human-computer interaction, encryption, artificial intelligence, formal languages, and computer graphics (Bell, 2014). The Italian comparable subject is “informatics”. There has been a focus on using computer applications, and according to Belletini et al. (2014) the discipline risks being perceived as a bag of “ready-to-use” applications, with almost no space for creativity or innovation. The learning objectives of the subject, set out by the Ministry of Education, are difficult to accomplish owing to a lack of teacher preparedness, teaching materials and expectation from parents.

In Sweden, Mathematics teachers did much of the experimental work. An analogy can be drawn with the placement of Computer Studies in the Irish Mathematics course in 1980. Informatics education evolved from programming knowledge offered as a vocational subject in the 1960s and 1970s to a complete subject (Rolandsson, 2014). In the 1980s the subject was introduced in secondary education and was much broader than in other jurisdictions, with the curriculum encompassing programming, system development and computing in regard to applied sciences and civics (Rolandsson, 2014). Currently the Technology Programme has some CS in information and media technology, which offers courses in computer communication, programming, digital media, web development, and computers and ICT; and the Electricity and Energy Programme has alternative CS, computers and ICT, with no requirements of programming (Skolverket, 2012). Optional programming courses are available in all programmes in Sweden, but a limited number of students choose programming (Rolandsson, 2014).

Past literature suggested that only highly able students are able to understand and develop programming language comprehension for successful interaction (Papert, 1980; Björk et al,, 1975). However, as described, over recent years computer programming and CS have been diffused into several national curricula and it is noteworthy that CS is being introduced where pre-established teacher education was absent in many of the countries reviewed. So, what is different this time? A number of factors were not a reality in the early 1980s, in Ireland and elsewhere: political will to introduce a dedicated subject or course, complementary policy documents (DES, 2008; DES, 2016; DES, 2019), industry calling for more qualified technical employees (Forfás, 2008), the digital and software-driven society we live in (Selwyn, 2018; Manovich, 2013), better computer infrastructure in schools (DES,

2015) and the tools used for programming having become easier to use, via languages such as Python and Scratch (Armoni, 2015; Sáez-López, 2016; Aiken, 2013). The last reason in particular has lowered the floor for entry and allows schoolchildren complete much more complicated tasks far more quickly than before. The introduction of higher-level languages reduces the complexity through abstraction and encapsulation. There is also a realization of the importance and value of computational thinking as a core concept in educational attainment (Wing, 2008; Yadav, 2017; Guzdial, 2008). These factors combine to support a sustainable interest in developing CS curricula. The concepts were embodied in the design of the Irish CS specification, to which attention now turns.

Context of Policy Text Production

The context of policy text production here encompasses consideration of when and how the CS specification text was generated and who was involved. As noted above, the State body responsible for curriculum development in Ireland is the National Council for Curriculum and Assessment (NCCA). An NCCA Development Group for CS at Senior Cycle was established in 2017. These Groups are representative of a broad range of interested parties, such as teacher unions and subject specialist associations, the parents' council, management boards, the State Examinations Commission, and the Department of Education and Skills, as well as University discipline experts. The cross-institutional, cross-body membership of a Development Group provides effective oversight in the design of the curriculum, and this was the case in the design of the CS specification, for which the teacher subject-specialist input was provided by CESI. The subject curriculum was designed and developed over a series of seven meetings, and was then published, all within a ten-month period (National Council for Curriculum and Assessment [NCCA], 2017). The timescale, one of the shortest ever in NCCA history in regard to curriculum development, demonstrates the cohesive determination of all stakeholders.

Three aspects of the specification and introduction are highlighted here: the “strands” of the curriculum specification, the design for assessment, and the intentions for teaching and learning. The description and analysis draw heavily on the specification document, but are informed also by the first two authors’ involvement in its development. The relationship of the specification to the “key skills” for the whole Senior Cycle curriculum, and its implementation via teacher accreditation and support, are addressed in the following section.

CS Specification Strands

A debate often arising with regard to introducing CS in schools is the nature of the subject (Griffiths, 1985). According to Newell and Simon (2007), CS is an empirical discipline and is the study of the phenomena surrounding computers; such a view frames the design of the specification.

CS as introduced at Senior Cycle level is a standalone discipline, independent of others but of value to many. The skills and competencies to be developed specifically include computational thinking, analytic reasoning, abstract thinking and mathematical comprehension. The basic structures of the CS discipline are the focal point of the specification and, within that, of the three strands “Practices and Principles”, “Core Concepts” and “Computer Science in Practice” as depicted in Fig. 4.

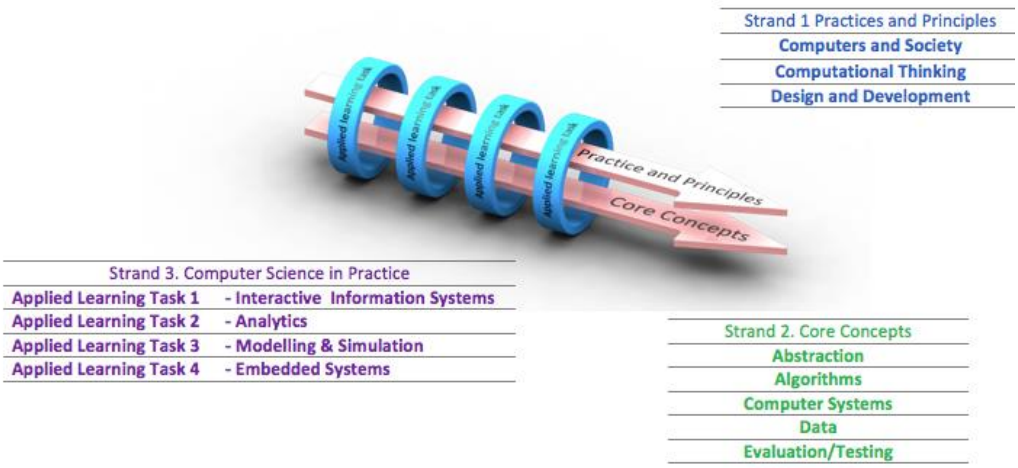

Fig.4. Computer Science Specification (NCCA 2017)

The “Practices and Principles” of the CS discipline are the foundation of all the learning activities in Strand 1. There are 23 learning outcomes in this strand, encompassing computational thinking, computers and society, design, and development topics. Students develop their ability to manage their CS learning and CS best practice as well as how the use of computing technology impacts the community.

The second strand, “Core Concepts”, represents the CS content areas of abstraction, algorithms, computer systems, data, and evaluation and testing. Developed theoretically and applied practically, the 22 learning outcomes in this Strand are addressed and reinforced continually. Classroom-based learning is intertwined with experimental computer laboratory-based learning throughout the two years of the course.

The third strand, “Computer Science in Practice”, has 14 learning outcomes affiliated to the NCCA key skills (see below). This strand provides the students with multiple opportunities to use their conceptual understanding of CS in practical applications known as Applied Learning Tasks (ALTs). There are four ALTs: Interactive information systems, Analytics, Modelling and simulation, and Embedded systems.

Assessment

Assessment was agreed with the State Examinations Commission (SEC) while the specification was being designed. It comprises two components, an end-of-course examination (70%) and coursework (30%). As well as traditional question types, the end-of-course examination requires students to demonstrate programming skills in a practical setting. This is the first time computerized examinations occur for the State examinations. The practical coursework project is completed under the supervision of the class teacher. The coursework, submitted in the form of a computational artefact, refers to the ALTs: for example, a web page, digital animation, game, simulation, app or robotic system.

Teaching and Learning

The specification supports the use of a wide range of teaching and learning approaches to encourage students develop the knowledge, skills, attitudes, and values that will enable them to become independent learners and develop a lifelong commitment to improving their learning. The specification is aligned with a constructivist approach in teaching, as promoted by the DES in the *Digital Strategy for Schools* (DES, 2015) and consonant with theories on developing concepts from concrete to abstract (Piaget, 1952; Dewey, 1938). According to basic constructivist theory, students learn most when they are given the opportunity to explore and create knowledge that is of personal interest to them (Papert, 1980). While Papert's work was developed largely using the computer interfaces and programming languages available in the 1980s, we are still adopting his pedagogical approaches and use of programming as a learning tool (with newer platforms, as noted above) to develop problem solving so that the students do not study concepts in isolation.

The specification uses a "spiral curriculum" approach. The spiral curriculum is one in which students' understanding of basic concepts and their interrelationships is intended to be reinforced by revisiting them in different contexts with ever-increasing sophistication. It differs from a traditional curriculum strategy of teaching related but compartmentalized subjects in a sequential order, where fundamental material is all too often presented once and assumed to be “learned” (DiBiasio, 1999). In a spiral curriculum, material is presented at appropriate times so as to be relevant to the particular projects in which the students will be engaging, and thus is learned within a context of application. This approach to curriculum development aligns with the work of Bruner, who advocated that the fundamental ideas should be constantly revisited and examined so that understanding deepens over time (Bruner, 1996). The CS specification is a coiled web of repeated engagement across the three strands, with topics improving and deepening skills, concepts, attitudes and values for the student in the learning process as shown in Fig. 5. Therefore, students are able to connect academic learning explicitly with areas of knowledge, skills and approaches needed both for professional work and for lifelong learning.

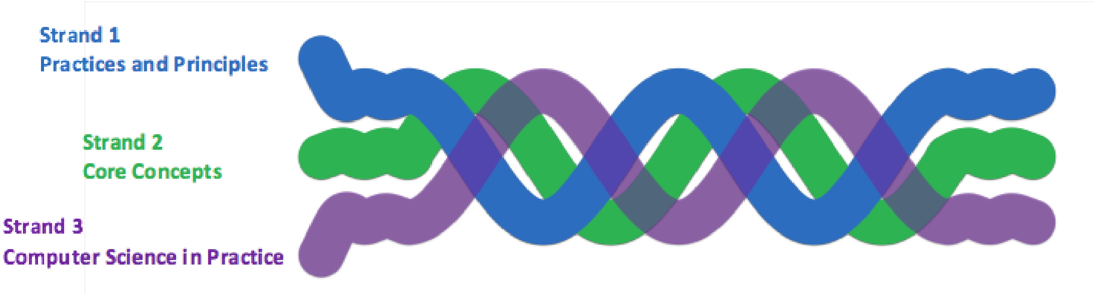

Fig. 5. Spiral CS specification (NCCA 2017)

Context of Practices and Longer-term Outcomes

The specification was introduced into forty schools nationally for “phase one”, starting in autumn 2018; the schools chosen represented the school and student population in terms of demographics and geographic location. Cohorts starting the course in 2019 and 2020 are larger. Unfortunately the assessment had to be modified for the first cycle of implementation in 2020 because of the COVID-19 pandemic; it should operate as intended from 2021 or 2022. Thus, longer-term outcomes cannot yet be observed. However, in this section, consideration is given to the way in which the CS specification addresses the "key skills" in the Senior Cycle curriculum and to the implementation of the course via teacher accreditation and support.

Senior Cycle Key Skills integration

The Irish curriculum overall has moved towards an emphasis on so-called key skills: "[the] embedding of key skills in the curriculum will thus involve building on current practice but it also involves increasing attention to the skills and their potential for actively engaging learners" (NCCA, 2009). The Senior Cycle curriculum, which culminates with the high-stakes LC State examination, encompasses five key skills: Information Processing, Critical and Creative Thinking, Communicating, Working with Others, and Being Personally Effective, as shown in Fig. 6.

Fig. 6: Senior Cycle Key Skills (NCCA 2009)

The NCCA stated that "Learners should encounter the key skills frequently and in an integrated way in many areas of the curriculum" (NCCA, 2009, p.3), so incorporating them and embedding them into lessons and activities in class are essential. In designing the CS specification, therefore, it was of paramount importance to embed them tightly within the learning outcomes. Ways in which the skills (NCCA, 2009) are related to the CS specification are described as follows.

“Information Processing” is concerned with accessing information from a range of sources, selecting and discriminating between sources based on their reliability and suitability for purpose, and presenting information using a range of information and communication technologies, and so is central to CS. The computing and computational thinking practices of decomposition, abstraction and modelling, which relate to the CS topics of algorithms, automation and data visualisation, align strongly to this key skill. The learning outcomes described in the NCCA Framework highlight the necessity for the learner, and thus the CS student, to recognise the wide range of information sources available within school, home and beyond, as well as to access information quickly, find appropriate sources of information and differentiate between information and knowledge. Computer programming teaches the student about accuracy in processing abstract information.

The elements of the “Critical and Creative Thinking” key skill include examining patterns and relationships, classifying and ordering the information; analysing and making good arguments and challenging assumptions; identifying and analysing problems and deciding outcomes. The nature of the CS discipline lends itself well to the analysis of patterns and relationships which develops skills of higher-order reasoning and problem solving, key components for Critical and Creative Thinking skills development. The sequencing and logic involved in programming, as well as problem decomposition, which is apparent in computing, could also enhance this skill. The CS specification aims to develop the problem solving and problem posing skills in students, encouraging students to be designers and creators of technology, and to be expressive through the creation of artefacts.

“Communicating” involves analysing and interpreting text and other forms of communication; expressing options, debate and emotions; performing in different ways as well as presenting using a variety of media. Although literacy skills are not explicit in the CS specification, they are required to participate fully in the learning experience and necessary in the collaborative ALTs, for example where both face-to-face and computer-mediated communication are enacted. Students learn to communicate, negotiate and present their strategies and the project work. The ALT brief provides flexible and open-ended challenges, giving students the opportunity to pitch their project at their own skill level, incorporating anything from analytics to embedded system to webpage design.

The CS specification has collaboration and team-based projects interwoven throughout the period of study. Equity, inclusion and diversity are critical factors in all aspects of CS, and important factors in working with others are to identify, evaluate and achieve the collective goals. Through their project work, students should gain some appreciation of the dynamics of groups and the social skills needed to engage in collaborative work, acknowledging difference, negotiating and resolving the inevitable conflicts. The skill of "Working with Others" contributes to an appreciation that working collectively can help with motivation, release energy and capitalise on all the talents in a group.

"Being Personally Effective" is concerned with being able to appraise oneself, evaluate one's own performance and receive and respond to feedback. This contributes to the personal growth of students, to their becoming more self-aware and to their using that awareness to develop personal goals. Being confident and able to assert oneself as a person is important. In CS, system failure, ambiguity and problem solving are issues that crop up frequently; consequently students should develop strategies for problem solving, and skills such as persistence, resilience and rigour emerge.

CS Teacher Accreditation and Support

As stated earlier, education in Ireland is centralized, and this applies at least in part to teacher education. Initial teacher education and that of practising teachers has undergone much reform in recent years (O'Donoghue et al., 2017). Factors contributing to this reconfiguration have been professional self-regulation via the establishment of the Teaching Council, accreditation of initial teacher education programmes, and changes to the professional life cycle of teachers in regard to initial, induction and in-service professional development. The Teaching Council, which maintains the register of qualified teachers, was established in 2006, and a raft of compliance-focused accountabilities was set in motion in terms of professional standards for teaching and accreditation of all teacher education programmes nationally. The requirements for accrediting teacher education programmes specify details such as the programme entry requirements, partnership model for school placement, staff-student ratios and curriculum content (Teaching Council, 2017a). The Teaching Council also maintains the subject requirements criteria (Teaching Council, 2017b). Criteria for CS were included while this paper was in preparation (November 2020). Teachers can now register as CS teachers, and a number of universities provide initial teacher education programmes.

However, echoing the international problem with teacher preparedness, the teachers in the forty "phase one" schools selected to teach the new subject in general would not have satisfied the criteria. Thus, they engaged in a reskilling programme delivered by the national body for provision of Continuing Professional Development (CPD) to teachers, the Professional Development Service for Teachers. Implementation of a new subject or discipline involves a change to teachers' practice in both their subject knowledge and their pedagogical knowledge (Thompson, 2013) and therefore the design of the CPD was very important. It was well constructed, consisting of national workshops, webinars, and MOOCS, as well as Python and web development fundamental skills supports, extending over the two years to support the teachers in the rollout. A modified programme is in place for subsequent phases.

Conclusion

Computer Science (CS) is a discipline which serves society, its people and our needs in a multitude of ways. CS education has developed from passive use of computing to design of computer systems and applications. Accordingly, students learn CS concepts instead of mere user skills. This paper used a framework derived from Ball (1994) and Vidovic (2001), focusing on contexts germane to tracing policy trajectory, to examine key documents from the 1970s onwards and problematise the policy origins and values that directed the evolution of the newly-introduced CS curriculum specification in Ireland. It also aimed to uncover consequences of the specification for the national curriculum, key skills integration and CS teacher preparation. Developments were set in global context through comparison with trajectories and resulting curricula in other countries.

Tracing the historic policy trajectory revealed that key drivers of policy changed from intrinsically educational to economic concerns. However, production of the CS specification document – designed to have a significant influence on students' key skills development – was shaped by educational research as well as by cooperation among stakeholders. The specification exposes learners to the scope of the discipline and areas of intrinsic interest. Broad similarities were observed between the Irish specification and that in other countries, but some innovative features should be observed: spiral curriculum, computational thinking and project-based assessment. Despite differences in education systems and culture, there are similarities also in trajectory and challenges across jurisdictions. A notable feature is that pre-established teacher accreditation and education was absent in many of the countries reviewed, being developed after the subject roll-out; this was the case for Ireland also. As only one cycle of implementation of the Irish specification has been completed at the time of writing, ongoing practices and longer-term outcomes should be the subject of future research.

References

Aesaert, K., Vanderlinde, R., Tondeur, J., & van Braak, J. (2013). The content of educational technology curricula: A cross-curricular state of the art. *Educational Technology Research and Development, 61*(1), 131-151.

Aiken, J. M., Caballero, M. D., Douglas, S. S., Burk, J. B., Scanlon, E. M., Thoms, B. D., & Schatz, M. F. (2013). *Understanding student computational thinking with computational modeling.* Paper presented at the AIP Conference Proceedings.

Alano, J., Babb, D., Bell, J., Booker-Dwyer, T., DeLyser, L. A., McMunn Dooley, C., & Phillips, R. (2016). *K12 Computer Science framework*. https://k12cs.org/wp-content/uploads/2016/09/K%E2%80%9312-Computer-Science-Framework.pdf

Armoni, M., Meerbaum-Salant, O., & Ben-Ari, M. (2015). From Scratch to "real" programming. *ACM Transactions on Computing Education (TOCE), 14*(4), 1-15.

Ball, S. (1990). Politics and policy making in education: Explorations in sociology. London, England: Routledge.

Ball, S. J. (1993). What is policy? Texts, trajectories and toolboxes. *The Australian Journal of Education Studies*, *13*(2), 10-17. https://doi.org/10.1080/0159630930130203

Ball, S. (1994) Education Reform: A critical and post-structural approach. Buckingham, England: Open University Press.

Baron, G. L., Drot-Delange, B., Grandbastien, M., & Tort, F. (2014). Computer science education in French secondary schools: Historical and didactical perspectives. *ACM Transactions on Computing Education (TOCE), 14*(2), 1-27.

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to K-12: What is involved and what is the role of the computer science education community? *ACM Inroads, 2*(1), 48-54.

Bell, T., Andreae, P., & Lambert, L. (2010). *Computer science in New Zealand high schools.* Paper presented at the 12th Australasian Conference on Computing Education, Brisbane, Australia.

Bell, T., Andreae, P., & Robins, A. (2012). *Computer science in NZ high schools: The first year of the new standards.* Paper presented at the 43rd ACM technical symposium on Computer Science Education.

Bell, T., Andreae, P., & Robins, A. (2014). A case study of the introduction of computer science in NZ schools. *ACM Transactions on Computing Education (TOCE), 14*(2), 1-31.

Bell, L. & Stevenson, H. (2015). Towards an analysis of the policies that shape public education: Setting the context for school leadership. *Management in Education, 29(4), 146-150.*

Bellettini, C., Lonati, V., Malchiodi, D., Monga, M., Morpurgo, A., Torelli, M., & Zecca, L. (2014). Informatics education in Italian secondary schools. *ACM Transactions on Computing Education (TOCE), 14*(2), 1-6.

Björk, L. E., Loftrup, B., & Nilsson, R. (1975). *An introductory computer programming course and some of its effects on the teaching of mathematics.* Paper presented at the FIP Second World Conference on Computers in Education.

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal, 9*(2), 27-40.

Brennan, K., & Resnick, M. (2012). *New frameworks for studying and assessing the development of computational thinking.* Paper presented at the American Educational Research Association, Vancouver, Canada.

Bresnihan, N., Millwood, R., Oldham, E., Strong, G., & Wilson, D. (2015). A critique of the current trend to implement computing in schools. *Pedagogika, 65*(3), 292-300.

Brown, N. C., Kölling, M., Crick, T., Peyton Jones, S., Humphreys, S., & Sentance, S. (2013). *Bringing computer science back into schools: Lessons from the UK.* Paper presented at the 44th ACM Technical Symposium on Computer Science Education (SIGCSE ’13), New York.

Brown, N. C., Sentance, S., Crick, T., & Humphreys, S. (2014). Restart: The resurgence of computer science in UK schools. *ACM Transactions on Computing Education (TOCE), 14*(2), 9.

Bruner, J. (1996). *The process of education*. Cambridge, MA: Harvard University Press.

Corbin, J. & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (3rd ed.). Thousand Oaks, CA: Sage.

Deek, F. P., & Kimmel, H. (1999). Status of computer science education in secondary schools: One state's perspective. *Computer Science Education, 9*(2), 89-113.

Denning, P. J. (2005). Is computer science science? *Communications of the ACM, 48*(4), 27-31.

Department of Education. (1980). *White paper on educational development*. Dublin, Ireland: The Stationery Office.

Department of Education. (n.d. [1989]). *Rules and Programme for Secondary Schools.* Dublin, Ireland: Stationery Office.

Department of Education and Science. (1997). *Schools IT 2000: A policy framework for the new millennium.* Dublin, Ireland: Stationery Office.

Department of Education and Science. (2008). *ICT in schools.* Inspectorate Evaluation Studies. https://www.education.ie/en/Schools-Colleges/Information/Information-Communications-Technology-ICT-in-Schools/Information.html

Department of Education and Skills. (2015). *Digital strategy for schools 2015-2020*. https://www.education.ie/en/Publications/Policy-Reports/Digital-Strategy-for-Schools-2015-2020.pdf

Department of Education and Skills. (2016). *STEM Education in the Irish school system*. https://www.education.ie/en/Publications/Education-Reports/STEM-Education-in-the-Irish-School-System.pdf

Department of Education and Skills. (2019). *Action plan for education 2019.* https://www.education.ie/en/Publications/Corporate-Reports/Strategy-Statement/action-plan-for-education-2019.pdf

Dewey, J. (1938). *Experiential education.* New York, NY: Collier Books.

DiBiasio, D., Clark, W. M., Dixon, A. G., Comparini, L., & O'Connor, K. (1999). *Evaluation of a spiral curriculum for engineering*. Paper presented at the 29th Annual Frontiers in Education Conference: Designing the Future of Science and Engineering Education.

Edmondson, J. (2004). *Understanding and applying critical policy study: Reading educators advocating for change*. International Reading Association, Newark, Delaware.

Ensmenger, N. L. 2010. The computer boys take over: Computers, programmers, and the politics of technical expertise. Cambridge, MA: MIT Press.

Forfás. (2008). *Future requirement for high-level ICT skills in the ICT sector*. http://www.egfsn.ie/media/egfsn080623_future_ict_skills.pdf

García-Peñalvo, F. J., & Mendes, A. J. (2018). Exploring the computational thinking effects in pre-university education. *Computers in Human Behavior, 80*, 407-411.

Griffiths, M., & Tagg, E. D. (1985). *The role of programming in teaching informatics.* Paper presented at the IFIP TC3 Working Conference on Teaching Programming, Paris, France.

Gulson, N., S. Lewis, B. Lingard, C. Lubienski, K. Takayama, and Webb, P. (2017). Policy Mobilities and Methodology: A Proposition for Inventive Methods in Education Policy Studies. *Critical Studies in Education*. 58(2), 2224-241. doi:10.1080/17508487.2017.1288150

Guzdial, M. (2008). Education paving the way for computational thinking. *Communications of the ACM, 51*(8), 25-27.

Hicks, M. (2017). *Programmed inequality: How Britain discarded women technologists and lost its edge in computing*. Cambridge, MA: MIT Press

Hill, M. (2005). The public policy process (4th ed). Harlow, England: Pearson Education

Hubwieser, P. (2012). Computer science education in secondary schools: The introduction of a new compulsory subject. *Transactions in Computing Education*, *12*(4), 161-164. https://dx.doi.org/10.1145/2382564.2382568

Keane, N., & McInerney, C. (2017). Report on the provision of courses in Computer Science in upper second level education internationally. National Council for Curriculm and Assessment. https://ncca.ie/media/2605/computer_science_report_sc.pdf

Kemp, P. E., Wong, B., & Berry, M. G. (2019). Female performance and participation in computer science: A national picture. *ACM Transactions on Computing Education (TOCE), 20*(1), 1-28.

Knuth, D. E. (1974). Computer science and its relation to mathematics. *American Mathematical Monthly, 81*(4), 323-343.

LERO (2019). *Leaving Certificate Computer Science teachers' CPD programme*. LERO, The Irish Software Research Centre. https://www.lero.ie/sites/default/files/Leaving%20Certificate%20Computer%20Science%20CPD%20Interim%20Report%20October%202019.pdf

Lye, S. Y., & Koh, J. H. L. (2014). Review on teaching and learning of computational thinking through programming: What is next for K-12? *Computers in Human Behavior*, *41*, 51-61.

Manovich, L. (2013). *Software takes command*. New York, NY: Bloomsbury Academic.

McGarr, O. (2009). The development of ICT across the curriculum in Irish schools: A historical perspective. *British Journal of Educational Technology, 40*(6), 1094-1108.

McGuffee, J. W. (2000). Defining computer science. *ACM SIGCSE Bulletin, 32*(2), 74-76.

Millwood, R., & Oldham, E. (2017). Computer Science in schools in England and Ireland - context and current developments in 2017. *Redin - Revista Educacional Interdisciplinar, 6*(1), 1-14.

National Council for Curriculum and Assessment. (2009). *Key skills framework*. http://www.ncca.ie/en/Curriculum_and_Assessment/Post-Primary_Education/Senior_Cycle/Key_Skills_Framework/KS_Framework.pdf

National Council for Curriculum and Assessment. (2017). *Leaving Certificate Computer Science specification*. http://ncca.ie/en/Curriculum_and_Assessment/Post-Primary_Education/Senior_Cycle/Consultation/LC-Computer-Science.pdf

Newell, A., & Simon, H. A. (1976). Computer science as empirical inquiry: Symbols and search. ACM Turing award lectures, 1975. *Communications of the ACM, 19*(3), 113-126.

O'Doherty, T., Gleeson, J., Johnston, K., McGarr, O., & Moody, J. (2004). *Computers and curriculum: Difficulties and dichotomies*. https://www.ncca.ie/media/1486/computers_and_curriculum_difficulties_and_dichotomies_rr4.pdf

O'Donoghue, T., Harford, J., & O'Doherty, T. (2017). *Teacher preparation in Ireland. History, policy and future directions*. Bingley, England: Emerald.

Oldham, E. (1981). *The new information technologies and education: Implications for teacher education – Country Report 1: Ireland.* Brussels, Belgium: ATEE.

Oldham, E. (2015). Setting the context: Developments in the Republic of Ireland prior to Schools IT 2000. In D. Butler, K. Marshall, & M. Leahy (Eds.), *Shaping the future: How technology can lead to educational transformation* (pp. 19-45). Dublin, Ireland: The Liffey Press.

Owen, G. T. (2014). Qualitative methods in higher education policy analysis: Using interviews and document analysis. *The Qualitative Report*, *19*(26), 1.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic Books.

Piaget, J. (1952). *Origins of intelligence in children*. New York, NY: International Universities Press.

Rizvi, F., & Lingard, B. (2009). *Globalizing education policy*. London, England: Routledge.

Rolandsson, L., & Skogh, I. B. (2014). Programming in school: Look back to move forward. *ACM Transactions on Computing Education (TOCE), 14*(2), 1-25.

Rose, N. (1999). *Powers of freedom: Reframing political thought*. Cambridge, England: Cambridge University Press.

Sáez-López, J. M., Román-González, M., & Vázquez-Cano, E. (2016). Visual programming languages integrated across the curriculum in elementary school: A two year case study using "Scratch" in five schools. *Computers & Education,* 97, 129-141.

Selwyn, N. (2015). Data entry: Towards the critical study of digital data and education. *Learning, Media and Technology, 40*(1), 64-82.

Selwyn, N. (2018). *Is technology good for education?* Cambridge, England: Polity Press.

Selwyn, N. (2019). *What is digital sociology?* Hoboken, NJ: John Wiley & Sons.

Skolverket. (2012). *Upper secondary school 2011*. Stockholm, Sweden: Skolverket.

Stake, R. E. (1995). The art of case study research. Thousand Oaks, CA: Sage.

Tartar, J., Arden, B. W., Booth, T. L., Denning, P. J., Miller, R. E., & van Dam, A. (1985). 1984 Snowbird Report: Future issues in computer science. *Computer, 18*(5), 101-105.

Taylor, S. (1997). Critical policy analysis: Exploring contexts, texts and consequences. *Discourse: Studies in the Cultural Politics of Education*, *18*(1), 23-35.

Taylor, S. (2004). Researching educational policy and change in "new times": Using critical discourse analysis. *Journal of Education Policy, 19*(4), 433–451.

Teaching Council. (2017a). *Initial teacher education: Criteria and guidelines for programme providers*. https://www.teachingcouncil.ie/en/Publications/Teacher-Education/Initial-Teacher-Education-Criteria-and-Guidelines-for-Programme-Providers.pdf

Teaching Council. (2017b). *Curricular subject requirements (post-primary)*. https://www.teachingcouncil.ie/en/Publications/Registration/Documents/Curricular-Subject-Requirments-after-January-2017.pdf

Tenenberg, J., & McCartney, R. (2014). Computing education in (K-12) schools from a crossnational perspective. . *ACM Transactions on Computing Education (TOCE), 14*(2), 1-3.

Thompson, D., Bell, T., Andreae, P., & Robins, A. (2013). *The role of teachers in implementing curriculum changes.* Paper presented at the 44th ACM Technical Symposium on Computer Science Education (SIGCSE '13).

Vidovich, L. (2001). A Conceptual Framework for Analysis of Education Policy and Practices. In W. Shilton, & R. Jeffery (Eds.), *Crossing Borders: New Frontiers in Education Research* (Fremantle, Western Australia ed., Vol. 1, pp. 22). Australian Association for Educational Research.

Vidovich, L. (2007). Removing policy from its pedestal: Some theoretical framings and practical possibilities. *Educational Review*, *59*(3), 285-298 https://doi.org/10.1080/00131910701427231

Vidovich, L. (2013). Policy research in higher education: Theories and methods for globalising times. In *Theory and method in higher education research*. Bingley, England: Emerald Group Publishing.

Williamson, B. (2016). Political computational thinking: Policy networks, digital governance and 'learning to code'. *Critical Policy Studies*, *10*(1), 39-58.

Wilson, J. (1981). *Speech at the Annual Congress of the Irish Vocational Education Association.* Dublin, Ireland: Government Information Services.

Wing, J. M. (2008). Computational thinking and thinking about computing. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *366*(1881), 3717-3725.

Yadav, A., Gretter, S., Good, J., & McLean, T. (2017). Computational thinking in teacher education. In P. Rich & C. Hodges (Eds.), *Emerging research, practice, and policy on computational thinking. Educational Communications and Technology: Issues and Innovations* (pp. 205-220). New York, NY: Springer.

Yadav, A., Gretter, S., Hambrusch, S., & Sands, P. (2016). Expanding computer science education in schools: Understanding teacher experiences and challenges. *Computer Science Education, 26*(4), 235-254.

Young, M. D., & Diem, S. (2017). Introduction: Critical approaches to education policy analysis. In M. D. Young & S. Diem (Eds.), *Critical approaches to education policy analysis* (pp. 1-13). New York, NY: Springer.