Curricular responses to computer science provision in schools: current provision and alternative possibilities

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Curricular responses to Computer Science provision in schools: current provision and alternative possibilities

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Abstract

This paper explores the rationales underpinning the introduction of Computer Science (CS) into school curricula and examines the ways in which educational systems have responded to these growing calls. In outlining the possible ways that educational systems can respond to this demand, the paper makes use of a conceptual framework through which the various possibilities for the provision of CS in school curricula can be categorised. The paper analyses and discusses possible modes of provision identifying the benefits and drawbacks of different approaches. Through this development, the paper aims to raise wider questions about the long-term positioning of CS within the curriculum and draws particular attention to the need for greater consideration of provision at lower secondary-level.

Keywords: Computer Science Education; Curriculum in Schools; digital competency

Introduction

In the past number of years interest in the introduction of Computer Science (CS) in schools has grown, evident in many initiatives across the globe. In the US for example, the growth of the *CSforAll* initiative attests to its interest (see: https://www.csforall.org/). Similarly, within a European context Ottestad and Gudmundsdottir (2017) observed that 15 countries (Austria, Bulgaria, the Czech Republic, Denmark, England, Estonia, France, Hungary, Ireland, Lithuania, Malta, Poland, Portugal, Slovakia and Spain) had included computer programming or coding as part of their national or local curricula. While CS has had a long history in secondary schools in some jurisdictions (Keane & McInerney, 2017), the current interest has a considerably broader base of support driven by economic, societal, educational and vocational rationales. This most recent interest in CS in schools has emerged from the ICT skills focus that was prominent towards the end of the 20th century and the start of the 21st century, where the focus on CS appeared to slip down the order of priority as a result of the networked technology boom of the 1990s (Brown et al., 2014). For example, Webb et al. (2017) note that, 'Computer Science became lost or squeezed from curricula in some countries in recent years' (p. 446). The range of terms associated with Computing and CS in schools used throughout the past number of decades may have contributed to this porosity. Terms including Information Technology, ICT, Computing, Digital Literacy, Informatics and Computer Studies have been used, sometimes interchangeably without clear definitions of their meaning or scope (Hubweiser et al., 2015; Denning, 2009). Within this confused mix of terminology, it is perhaps not surprising that the traditional understanding of CS became quite a malleable term which was frequently determined by a variety of institutional, regional and national interpretations.

As CS begins to reclaim a defined area of study and become more clearly understood and differentiated from more ICT skills-type practices, it nonetheless emerges from a plethora of interpretations and manifestations in schools and different jurisdictions. It is understandable in this context that questions are raised in relation to CS; particularly who it is for and what is the rationale for its inclusion in the curriculum. For example, does its study remain separate from traditional computer literacy courses or have traditional elements of CS become essential aspects of computer literacy for every student? As Bell et al., (2017) argue, the need for education systems to respond to changes brought about by technological developments is generally accepted, but the positioning and rationale for CS in the curriculum are less well understood. In their review of the areas of consensus and debate within the CS community, they found that whether CS should be an area of study for everyone remains a contentious issue. It is within this context that this paper explores the rationales for the introduction of CS in schools and examines the various ways it can be included within the school curriculum. In outlining the different approaches to the provision of CS in the curriculum the paper examines the pros and cons of these different conceptualisations and the dominant responses to its provision that appears to be emerging. In doing so, the paper aims to raise wider questions about the positioning of CS within the curriculum and highlight potential blind spots in its provision at lower secondary level in schools.

Rationales for its introduction – The 'why' question

> *The strength of the arguments for including computer science into school curricula will vary from nation to nation, and time to time. In the second decade of the twenty-first century, there are strong economic and social reasons for its adoption, culminating in an entitlement perspective benefiting both the individual and the society in which they live* (Fluck, 2016, p. 43).

Before exploring the different ways in which CS can be incorporated into schools this section firstly outlines the rationale for its study as described in the literature since the rationale for the inclusion of a subject in the curriculum can strongly influence how it is embedded in schools. In this regard, unpacking the 'why' is a necessary prerequisite before one considers the 'how'. In analysing the various rationales for the inclusion of CS in schools, a number of common themes emerge. Table 1 provides a summary of the various rationales presented for CS in the existing literature and as is evident, there are three dominant rationales for its inclusion, namely: Economic/vocational, Social and Educational, which will be briefly expanded on below.

Authors	Rationales for Computer Science in schools
Vogel et al., (2017)	• economic and workforce development, • equity and social justice, • competencies and literacies, • citizenship and civic life, • scientific, technological and social innovation, • economic, social and cultural. • school improvement and reform • fun, fulfilment and personal agency. •
Web and Reynolds (2013)	• economic reasons • social reasons • cultural reasons •
Keane & McInerney. (2017)	• Economic reasons • Social reasons • cultural reasons • educational reasons •
Ottestad and Gudmundsdottir (2018)	• foster logical thinking skills, • develop programming and coding skills • develop problem-solving skills

Table 1. Rationales for CS in schools

From an economic perspective CS is seen as an important element of STEM provision in schools aimed at encouraging greater uptake in STEM careers in order to serve labour market needs and strengthen national economic competitiveness. This reflects a wider economic/vocational focus in education, particularly within the STEM arena, which, 'stresses the need for technologically skilled graduates to fuel economic growth and enable the state to ‘stay ahead of the curve’ by harnessing the potential of new and emerging technologies’ (McGarr & Lynch, 2017). Turning specifically to CS, Fluck et al. (2016) identify two aspects to this economic/vocationalist agenda, the need to produce CS graduates and also the need for CS literate professionals in all areas of business and industry to support innovation and development. This economic rationale is frequently set within a neo-vocationalist ideology driven by concerns about labour market needs and supply of qualified graduates and hence is normally the most dominant argument within policy documents;

> The economic rationale is therefore compelling for governments devising national curricula, and who see future trade prospects dependent upon computers. Computers have also made previously un-tradable services such as banking become more globally mobile. This makes sourcing local talent more crucial in controlling and building the local national economy (Fluck et al., 2016, p. 40).

The social rationale for its introduction draws on much broader underpinnings. Similar to arguments related to the ‘digital divide’ of the 1990s, this rationale is rooted in the desire to provide exposure to CS for all as a consequence of the pervasive use of computer technology in all aspects of life and reflects concerns in relation to the promotion and potential achievement of concepts such as digital literacy and digital competence. This is captured by the National Council for Curriculum and Assessment in Ireland (NCCA) who, when setting out the rationale for the introduction of a new upper-secondary subject in CS in Ireland, argued that;

> The accelerated expansion of computing technologies and artificial intelligence into all our lives means students need to understand the principles of computer science now, more than at any other time. It is necessary for all students to understand the ethical and social role of computers in society. Computer Science is the foundation of

> this change and so the study of Computer Science at Leaving Certificate [upper secondary level] has become highly relevant to almost all aspects of modern life, and to every career choice (NCCA, 2018, p. 6).

This rationale is also driven by concerns relating to citizens becoming passive as opposed to active consumers of technology and by ethical issues raised by the encroachment of digital technologies into society: issues such as privacy, governance and equity (Fluck et al., 2016). Gender equality, and specifically female participation in STEM subjects, forms part of this social rationale and is increasingly being recognised as an important issue in this area. As Zohar, Benaya and Zur (2016) observe, 'computer Science (CS) seems to be one of the few remaining disciplines almost entirely dominated by men, especially among university faculty and in the hi-tech industry' (p. 67).

The educational rationale for the inclusion of CS in the curriculum has typically been less prominent than the economic and social rationales. This rationale has tended to focus on the broader set of skills or outcomes which may be gained from engagement with the discipline of CS. These skills include problem-solving, computational thinking and wider thinking skills such as analysis, planning and evaluating. The nature of students' engagement in tasks also can contribute to the development of important collaborative skills.

As set out above it may be argued that the three dominant rationales for CS in education are reflective of the justification for STEM subjects in general, such as Science and Technology. Similar to these subjects, it can be argued that the primary rationale for its inclusion in the curriculum is shifting towards more social and educational justifications which may reflect an emerging appreciation more generally of the potential contribution of such subjects to the achievement of wider educational outcomes. As such there is an emergent appreciation that being able to, for example, problem-solve and think computationally, is more significant than being able to programme per se, but that topics within CS, such as programming, can be the means to such an end rather the end it itself. Such an appreciation may account for much of the 'mainstreaming' of CS in curricula which has been evident in the most recent stage of its evolution.

The 'how' question

There is a high level of support within the research literature for the introduction of CS in the curriculum however, the question of how this should happen in practice raises many possibilities and there are a variety of approaches evident across different countries and regions. Reflective of this, Webb et al's (2016) examination of the position and roles of CS in five different countries (UK, New Zealand, Australia, Israel, Poland) found that, while there was consensus that the study of CS was needed in schools, there was no consensus in relation to who should study it or when it should commence. Keane & McInerney's (2017) review of provision in Ontario, England, Scotland, New Zealand and Israel did however find a trend towards the provision of discrete subjects at upper secondary school level. This focus, along with a relatively consistent body of content (Keane & McInerney, 2017), would suggest that a discrete subject is the most common response to the provision of CS in secondary schools.

Discrete subject

Where CS programmes have been developed these have tended to result in discrete stand-alone subjects particularly at upper secondary level (Keane & McInerney, 2017) and while it is inevitable that a system that is dominated by 'subjects' would respond in that manner, the growth of CS applications in all areas of life and work means that a more integrated response across the curriculum may be considered as equally valid. The gravitation towards a discrete specialist subject can be traced back to earlier iterations of CS in the late 1970s and early

1980s where it was closely associated with mathematics (McGarr, 2009). This close association with mathematics contributed to its perception as a 'male' subject and one for 'bright' students initiating the stereotypes now associated with the field (Cheryan et al., 2009; Beyer et al., 2003). That being said, there are advantages to delivering CS within a discrete specialist subject. Firstly, maintaining it as a discrete subject gives curriculum developers a clearer, arguably more manageable task, of developing a syllabus that is clearly mapped out in terms of its aims/objectives, content, pedagogy and assessment. In this regard there is a clear, long established 'roadmap' to follow. In addition, within schools where subjects compete, establishing a subject (as opposed to integrating elements of CS across the curriculum) provides the given subject with greater status and thus likelihood of success in becoming established within the system. In their investigation into the feasibility of introducing a CS subject in Irish schools, Doherty et al., (2004) found that, while there was recognition of the value of an integrated CS experience across the curriculum, participants in their research favoured a discrete stand-alone subject as it was the most feasible within the existing post-primary system. This reflects the significance of the established norms and organisational cultures within schools: new offerings or what might be described as 'curriculum innovations' are bound by certain established characteristics of the 'system'. These characteristics may be reflective of both practical and ideological leanings.

Having it as a separate subject also enables it to be aligned with other STEM subjects where potential synergies can be explored and developed. The status and identity associated with a discrete subject can also result in a stronger teacher identity (O'Gallchoir et al., 2018; Löfström and Poom-Valickis, 2013) and thus stronger advocacy by the given teacher(s) for the promotion and development of the subject within the school. Alternatively, if the subject was integrated across the curriculum the level of organisation and planning needed to cohere the CS activities and experiences across many different subject areas would be challenging.

Coupled with this is the challenge of teacher education and continuing professional development. If CS is confined to a single subject, the professional development needs with respect to the subject are limited to those deemed as ‘CS teachers’ whereas a more integrated approach necessitates the provision of professional development across a much wider pool of teachers.

Discrete provision in this manner is not without its drawbacks however. Providing CS as a discrete subject may further alienate it from the wider student population and maintain its perception as a specialist, advanced area of study suitable for the minority with an aptitude in the area. In the school context, it will also have to compete with other subjects on the timetable and therefore remain an optional area of study likely to be selected by a limited number of students. Stand-alone provision could also help maintain the gendered aspect of the subject due to the perception that it is a ‘male’ subject; whereas a more integrated approach would expose CS to a greater range of students of different genders and profiles (Zohar, Benaya & Zur, 2016). Also, a discrete approach means that other subjects will not benefit from the important role of CS in so many aspects of life and work by reflecting this within their subject areas.

It could be argued that a discrete stand-alone subject best addresses the economic/vocational rationale for the subject as it provides for in-depth study of the content for those that wish to progress into CS-related careers and third-level study. Aligned to labour-market demands and industry needs, it may be argued that such a subject, while providing targeted CS provision in schools, would do little to extend the exposure of CS to the wider school-going population. Instead it may become the domain of the relatively few and continue to be seen as a subject for more ‘able’ students, who have a particular interest and perceived aptitude in the area. This would contribute to the maintenance of existing stereotypes regarding those who take such a subject thus maintaining the inequality of provision as identified by Goode et al.,

(2018) who found that those from minority backgrounds were much less likely to participate in CS and when they did they were much more likely to perform poorly in the subject.

Integrated across the curriculum

The alternative to a discrete stand-alone subject is the integration of CS practices and principles across the curriculum in relevant areas. This response recognises the broad reach of CS in all areas and provides for much wider exposure to CS amongst students – hence it could be argued that such a response aligns with the social rationale for the subject as outlined above. This can not only help students see the ways in which CS is changing practices in a wide range of areas, but by giving them exposure to CS, it can help them make more effective career decisions (Webb et al., 2017). An integrated approach may also address the gender divide of the traditional stand-alone subject and heighten awareness of CS across the school community. As it becomes more difficult to ignore the role of aspects of CS in everyday life, an integrated approach would also contribute and extend students' general levels of digital competency.

Moving to explore approaches that have taken a more integrated approach to the inclusion of CS at post-primary level, there are two significant trends in this regard. Firstly, examples of integrated uses in the curriculum are less evident in the literature, those that are reported tend to emphasis coding and computation innovations targeted at students in various age groups. Many of these are in the form of funded projects from external funding agencies. These innovations are not presented as separate subjects but rather as innovations in the curriculum that exist outside the normal subject structure of schools. Heintz et al's (2016) review of different countries approaches to CS provision (see table 2.) highlighted that while it was compulsory at primary education in many countries, at secondary level it tended to be provided as a separate subject, more commonly as an elective subject rather than a compulsory subject.

Country	How?	What?	Primary	Secondary
Australia	Digital Technologies	Own subject and integrated	Compulsory	Compulsory
England	Computing	Replace existing subject	Compulsory	-
Estonia	Programming (Technology & Innovation)	Integrated	Compulsory	Compulsory
Finland	Programming (Digital Competence)	Integrated	Compulsory	-
New Zealand	Programming and Computer Science	Own subject	-	Elective
Norway	Programming	Own subject	-	Elective
Sweden	Programming and Digital Competence	Integrated	Compulsory	Elective
South Korea	Informatics	Own subject	Compulsory	Elective
Poland	Computer Science	Own subject	Compulsory	Compulsory
USA	Computer Science	Own subject	-	Elective

Table 2. Overview of the different countries from Heintz et al (2016)

There are a number of reasons why an integrated approach is less commonly found across educational systems (and thus there is a tendency towards provision in the form of a discrete subject). An integrated approach requires a significant level of curriculum change across many different subject areas. With that comes the challenge of teacher professional development, which remains one of the most challenging issues associated with CS in schools generally irrespective of the approach employed, whether a discrete subject or integrated across the curriculum (Brown et al., 2014). An integrated approach also demands modifications across a range of subject areas and the level of oversight and the logistical challenges of this are demanding for schools. Overall this type of response demands a level of organisational change that is quite significant, hence responses in the form of discrete subjects in CS, are the most practical response to this demand.

Discussion

As the paper has identified, there are a number of established arguments for the provision of CS in education including educational, social and economic justifications. Furthermore, it has also highlighted that the most common response to the need for CS in schools is through the provision of a discrete subject normally at upper secondary level. While this would appear to be the most obvious and straightforward response to this challenge, the introduction of a discrete subject is not the only option. Other options also exist, and each option has pros and cons. In looking at possible options a number of questions emerge, namely, is CS now seen as a subject for all students given the pervasiveness of digital technologies or does it remain a specialist area of study? In addition, should it be delivered within a discrete stand-alone subject or should it be integrated into other subjects where relevant? One way of categorising the various responses to CS was proposed by O'Doherty et al (2004) (see Figure 1). This organisational framework offers four overlapping responses to the provision of CS. Whilst recognising that these options are not mutually exclusive and that educational systems can adopt multiple and hybrid forms of provision, the framework nonetheless provides a useful means to identify the dominant trends in schools' responses to CS and how these responses are influenced by the different social, educational and economic rationales underpinning the inclusion of CS in the curriculum.

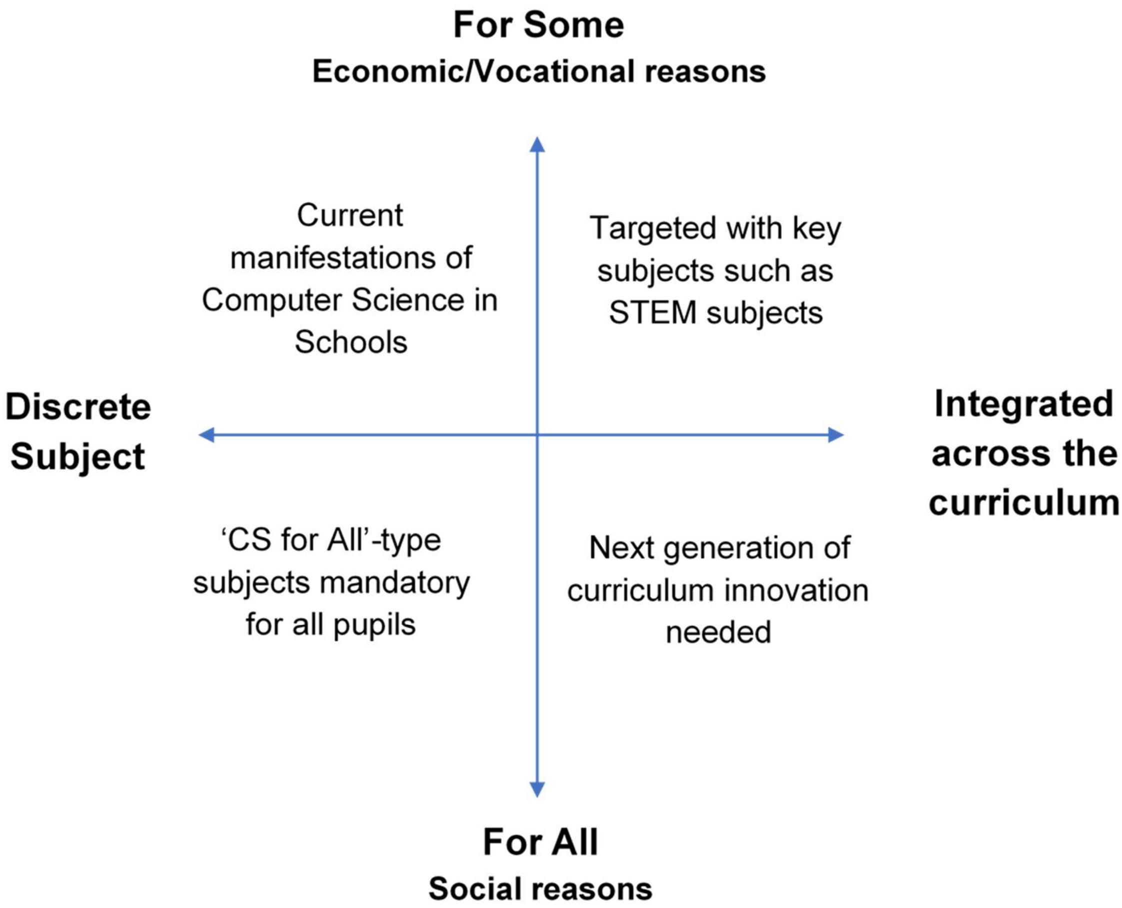

Figure 1. different possibilities for CS provision in the school curriculum (adapted from O'Doherty et al, 2004)

As outlined above, the discrete subject (provided for a minority of students) appears to be the dominant response in recent years in secondary schools as evidenced by the analysis of different countries by Keane & McInerney (2017) and Heintz et al (2016). While this response tends to meet vocational and economic needs, in doing so it tends to downplay the broader social and educational justifications underpinning a subject for all students. On the other hand, in primary schools, CS (in the form of coding or similar initiatives) is frequently driven by broader educational goals, aiming to develop problem solving and computational skills as opposed to preparing students for employment opportunities (Saez-Lopez et al, 2016).

The juxtaposition of the different rationales provides a stepping stone to consider an evident tension between those who advocate CS for all (based mainly on educational and social rationales) and those who view it more as an optional offering for some, guided by mainly vocational and economic rationales. This analysis highlights a contradiction in the provision of CS in schools globally. Whilst much of the literature emphasises the importance of CS and coding for all, the dominant response by educational systems at secondary level is to offer it as a specialised optional subject to a few at upper secondary level. This approach, we argue, does little to address perceptions of the subject as being elitist and the preserve of a certain 'type' of academic student. This dominant response does however confer certain benefits associated with subject status such as sustainability and the likelihood of greater longevity within the curriculum. In the absence of significant reform to the current dominant characteristics of school organisation and culture, curriculum offerings which are positioned outside the existing subject framework are likely to struggle to gain and maintain any significant 'foot holding' or 'traction' compared to those conferred with subject status. This analysis draws attention to the complexity of curriculum provision in this area and suggests that there is a mismatch between the dominant educational rationale underpinning such provision (for all) and the dominant response of education systems at upper secondary levels which is typically in the form of an optional subject. The shifting justifications and the nature of typical provision from primary to upper secondary levels are as reflected in Figure 2 below.

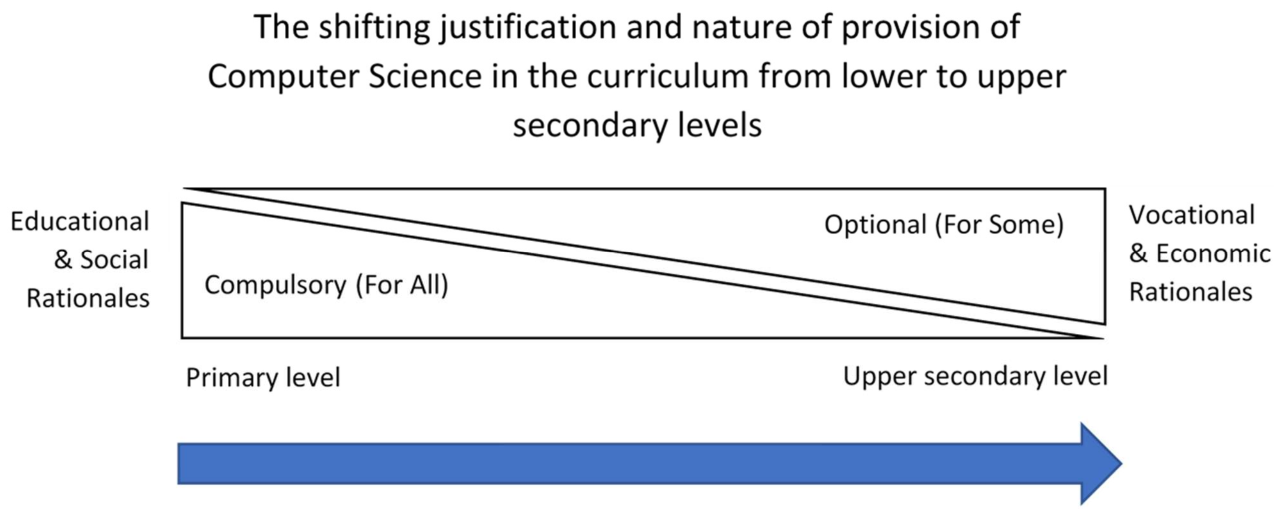

Figure 2. Justification and nature of provision of CS

At a time of significant interest in coding and CS, many innovations in this area at lower secondary and primary school levels remain as peripheral components, sometimes driven by external funding from the technology industry and by enthusiastic and committed teachers often working outside of their traditional subject area. While these initiatives have done a great deal to expose CS to a wider range of students, the initiatives are often dependent on the good will of interested and motivated teachers. In addition, such initiatives tend to be adopted as 'projects' in some schools, rather than being deeply knitted into the school as an established element or subject in the curriculum. In these circumstances when external funding supports cease, or when the committed teacher(s) can no longer commit to the initiative, it is likely that such initiatives will end. The analysis based on Heintz et al (2016) suggests that internationally CS (or a variation of it) is more likely to be a compulsory curriculum component at primary level and most likely an optional subject at upper secondary level (where subject status weights most heavily). This is reinforced by the work of Keane & McInerney (2017) who found that a discrete subject, based on CS content, was the most common offering at upper secondary level across the five jurisdictions within its review. Taken together these analyses suggest that 'for good or for ill' there is a 'typical' form of provision at primary and upper secondary levels. In addition, it casts a particular light on the dilemma of CS education at lower secondary level and the ill defined and potentially ad-hoc nature of provision across systems at this level where many variations of such programmes exist, often with limited actual CS content.

To many the current provision of CS as an optional subject at upper secondary school level is sufficient in addressing the need for graduates in the sector and for providing choice for students, but if knowledge of coding and CS is increasingly becoming part of what it means to be educated in the 21st century then the question arises as to whether this provision is sufficient. Notwithstanding the value of providing optional subjects in the area of CS at upper secondary school level, there is a need to provide a more solid footing in CS for all students at lower levels of the secondary school experience. While initiatives such as the CSforAll movement has aimed to achieve this, many initiatives of this nature are not embedded as specific subjects in the curriculum at lower secondary school level. For that reason, their future is less certain. This, we argue, is an emerging blind spot in provision in secondary schools, across education systems internationally.

This highlights the dilemma faced by schools in addressing CS provision. Provided to everyone, where it does not have the status of a typical subject is likely to maximise its reach to as many students as possible. This can address student misconceptions about the subject and begin to address the very significant gender divide in the subject's uptake. However, not being part of the established curriculum architecture of the schools renders such initiatives at risk of cessation in the short to medium term. On the other hand, providing CS as a subject in a traditional way ensures its longevity on the school curriculum. The payoff to this stability however is that it is likely only offered as an optional subject to a small number of students.

Conclusion

The aim of this paper was to explore the rationales for the introduction of CS in schools and examine the various ways it can be included within the school curriculum. In doing so, the paper has raised questions about the tendency towards provision of CS in the form of a discrete subject in secondary schools. In highlighting this trend, the paper aims to widen the debate in relation to the potential possibilities of CS provision in schools.

As the paper has argued, questions of how to address the need for CS in schools are not confined to logistical and organisational issues. How CS is addressed in the curriculum, whether as a stand-alone or integrated approach, raises broader questions of equity and what it means to be literate in the 21st century. If CS is seen as an area of study to prepare students for the CS-related careers, then the current focus on providing a discrete optional subject for some students at upper secondary level will continue to dominate. If, on the other hand, as elements of CS are eclipsed by a broader understanding of digital competency/literacy, and the need to provide exposure to CS for everyone gains greater credence, the questions shifts to one of integration across the curriculum or compulsory forms of provision for all. The decision of which way to go is not only determined by resource and logistical issues but also on deeper philosophical issues in terms of why CS should be studied and whether it is seen as an essential skill for all. This paper draws particular attention to the gap in clarity of provision at lower secondary level and argues that the current aims of establishing discrete CS subjects in schools, whilst a positive move, should not be seen as the end goal but instead the start of a much broader conversation about what it means to be literate in the 21st century and what skills and knowledge of CS is encompassed by this evolving notion of literacy.

Declaration of interest: None

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