Symposium: Moving on with informatics/computer science curricula – challenges and opportunities

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1 Introduction

Over recent years there have been significant changes regarding computer science/Informatics curricula in many countries. While some countries have retained and continually updated their computer science/informatics curricula as strong scientifically focused offerings, other countries moved towards a more user-oriented approach emphasizing basic digital literacy and digital skills. However, with the recognition that we are in a digital age where how we live our lives in leisure activities, engage in education and work are increasingly governed by technologies, policymakers have recognized the need to develop understanding of the digital world to enable creation rather than just use of new technologies. Computer science/Informatics as the scientific discipline that underpins the digital world, and is essential to all disciplines and professions, has become increasingly important as a school subject in many countries. There is a need to equip students with the knowledge and skills to bring about change, to contribute to the development of their digital environment and to ensure the evolution of a safe, secure, environmentally conscious and just society. In some countries these policy changes have resulted in major curriculum developments some of which have now been in place for several years and we are seeing some of their implications.

At the same time, computer science/informatics is a relatively new discipline and while many of its fundamental principles remain relatively stable there are also new and rapid developments that make specifying and maintaining curricula challenging. Furthermore, while there has been much research into how students learn concepts and techniques of computer science/informatics, progression pathways are less well understood in this subject than in other curriculum subjects.

In this symposium we will examine some recent developments in curricula relating to computer science/informatics in compulsory education. Furthermore, we will consider the implications for future development of curricula and what can be learned from experiences in various countries. We will also consider how recent technological changes need to be considered in relation to curriculum specifications. Thus we will provide some new perspectives on current challenges. More specifically we expect to address the following questions:

What is driving the emphasis of specifications for informatics/computer science curricula in different countries?

What do we know about how students learn some of the core concepts and processes of informatics/computer science that will enable us to design structure and progressions in curricula?

How should we incorporate new challenges associated with rapid developments in artificial intelligence and machine learning into informatics/computer science curricula?

What is the relationship between an informatics/computer science curriculum and other academic disciplines?

The symposium will comprise a series of short papers arranged in clusters with opportunities for questions and discussion at the end of each cluster of papers. In addition to the oral questions and discussion during the symposium we will also make use of a discussion board and Twitter feed to enable more extensive discussion to try to shed light on these important questions.

The first cluster of three papers focus on recent redevelopment and specification of informatics/computer science curricula in three different countries: Australia, India and Austria with different approaches to curriculum design. The next two papers discuss the issues and approaches for implementing curricula including challenges for identifying progression in conceptual understanding. The remaining four papers look ahead to how developments in machine learning and artificial intelligence need to be accommodated and how computational approaches can be developed across the sciences.

Changing computer curricula in Australia

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Curriculum responsibility in schools was vested with the states of Australia by the constitution of 1901. A nationally developed curriculum for school subjects was made available from 2014 and was incrementally adopted or appropriated by the states in various ways.

At that time, computers were in the curriculum as a general capability to enhance learning in all subjects. This was the Information and Communication Technologies (ICT) general capability. The core ICT capability is conceived as comprising Investigation, Communication and Creation. These elements are underpinned by 'managing and operating ICT' and 'applying social and ethical protocols and practices'.

Because different learning areas of the curriculum were developed along a staggered timeline, Technologies did not become available until 2016. This contains the Digital Technologies subject. At its core is the concept of creating digital solutions which is approached by processes and production skills. Underpinning these are Digital Systems and Representation of data.

Therefore, the Digital Technologies subject is quite separate from the ICT general capability. Very few teachers encountered it in their own schooling or have encountered it in their pre-service training. While 'creating digital solutions' is core to the subject, coding or programming are mentioned very sparsely in the document.

In 2020, the Federal Government agency responsible for the school curriculum announced the commencement of a Review. This review is expected to produce public consultation drafts of a new version of the curriculum in late April 2021.

The Review has a key task of simplifying the curriculum. Partly due to the staggered implementation, teachers focused on core subjects, and felt overloaded as other subjects were released. Consultation panels have hinted that ICT may be re-labelled as 'Digital Literacy'.

Recent indications are that principals and teachers confound the current ICT capability and the Digital Technologies subject. 30% of tools and websites used in Digital Technologies were seen to be content management systems, office suites and other generic tools rather than subject content specific software applications.

This session will show how the changes in the public consultation draft help to solve this problem or compound it. We will reveal the answers to the following questions about the proposed update for Digital Technologies:

1. Will Australia abandon the general ICT capability (as per the UK) to provide greater focus on Digital Technologies?
2. Will Australia put a greater emphasis on coding/programming than the current meagre mention?
3. What do pre-service teachers think about the proposed changes?

Computational Thinking in Indian K-12 schools: Opportunities and Challenges

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In the Indian K-12 education system computer sciences or computer applications have always been offered as optional subjects in the higher secondary (grades 9 & 10) curriculum across different school boards. These courses cover a range of topics like basics of Information Technology, HTML, Networking, and Scratch. While there is no set computer science curriculum for upper primary grades in Central and State boards, one of the International school boards covers topics like spreadsheet and program coding. Besides formal school setting, coding and adopting certain principles of computational thinking (CT) has been implemented in informal learning spaces like out of school camps and online coding classes by Ed-tech startups especially in COVID pandemic period. The education policy on ICT in schools of 2012 emphasized largely on ICT literacy and competency in schools across grades. For the very first time in Indian Education policy, coding is brought into focus and as early as 6th grade. The National Education Policy 2020 of India highlights the need of learning computational thinking and coding by students. The Ministry of Education, India plans to implement compulsory coding and other CT related topics in the curriculum by 2022 - 23.

Making CT and coding compulsory from grade six is a forward-looking move for many reasons. Firstly, it allows critical and creative problem solving (Wing, 2006; Shute et al., 2017) at young age, if designed well, CT components can be integrated with core subjects and connected to learners' context, confidence in competence to adapt technology through CT fosters a sense of digital agency (Passey, et al., 2018) and prepares young minds for 21st century careers and knowledge society (Dede, 2010). However, the implementation of CT and coding seems far more complex than the task of integrating technology within the curriculum in the start of this decade. Some of the challenges or aspects to consider for policy implementation would be:

- Adaptation in existing curriculum
- Teacher preparedness
- Tutoring and assessment
- Pedagogy as per Socio-economic status

Curricula for Digital Education as a Moving Target

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In Austria, since the late 1980s, the elective subject Informatics has been implemented in many lower secondary schools for interested pupils, dependent on engaged teachers. It was the time of pioneers among teachers and pupils when the “magic of the beginning” took effect and the upcoming curricular autonomy made possible an increased offer of Informatics/ICT classes. Within the process of profile building, Informatics and ICT have proliferated, and some schools still profit from this spirit of optimism until today.

Moreover, since 1990 an integrated use of ICT has been enacted by the Ministry of Education especially for German, English, Mathematics and Geometric Drawing as “IT-enhanced subjects”. This approach of implementing ICT at lower secondary level for about ten years was well-intended but not really effective. Interestingly, at that time the debate about Informatics as a subject in its own right and the integration of ICT in other subjects caused not more confusion than today.

However, at the turn of the millenium the Austrian Ministry of Education failed to anchor (basic) Informatics education at lower secondary level within a new curriculum. Within the so called “Curriculum 2000” which was valid until 2018, the only curricular reference for the overall use of ICT was expressed in a few sentences: "Innovative information and communication technologies and mass media penetrate more and more all areas of life. Particularly multimedia and telecommunication are determining factors for the evolving information society. As part of teaching, these developments have to be taken into account, […] and the educational potential of ICT has to be harnessed.”

After years of discussions and discourses, finally in 2018 a broad and comprehensive curriculum for a new subject “Basic Digital Education” for lower secondary education has been developed and enacted, forcing all schools to offer a certain amount of dedicated ICT and Computing hours, either integrated across other subjects or within a subject in its own right depending on the preference of the school.

Now, within the project “Curriculum 2020” a bigger reform affecting all subjects with digital references, accompanied by a completely new curriculum for “Basic Digital Education”, is in the review phase and is expected to be enacted in two years. This paper will describe and discuss these latest developments, as part of and with regard to the broader perspective of Austrian initiatives to digitize schools.

Refining granularity of the programming concepts specification in school informatics

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In our work, we design and develop interventions for school programming *for all learners* at primary and secondary, as we consider programming a suitable way for studying learning processes and cognitive complexity in the field. In this context we have pointed out too coarse-grained vocabulary in different curricula when specifying learning goals in the domain of programming. A curriculum for example states that pupils should be taught to *use sequences, selection, and repetition in programs*. But what exactly may such a broadly defined target mean? When can we consider it met? How can an intervention in the next stage follow up on such indistinct achievement?

When we in our design research projects iteratively develop interventions, we tackle this issue as follows: for each concept we strive to identify different *operations* which pupils will perform with them, properly order them by their increasing cognitive complexity and project these operations into the tasks pupils solve. We then specify learning objectives and assessment criteria not in the scale of concepts but in the *scale of operations* performed with the concepts.

For example, in the context of the concept of iteration, pupils: (i) directly control a sprite and notice a record which is being built simultaneoiusly, (ii) read such record and perceive its properties like the length or the presence of a certain command, (iii) execute a record by giving it step by step to the sprite, (iv) build such a record in advance – i.e., *program future behaviour* for the sprite, etc. In [1] we identified and assessed a gradation of seven levels of operations with iteration.

In this paper we present our approach to programming concepts and the operations corresponding to them, together with an overall *gradation of tasks* that we iteratively design, develop and evaluate in our design schools for each year of upper primary and lower secondary school. Within this overall gradation we can identify *threads of tasks*, which systematically implement developmentally appropriate and carefully graded steps supporting pupils to create their deep understanding of the concepts.

Creating evidence-based interventions is just one of the two goals of our design research activities. The other one is to expand our understanding of the cognitive complexity of identified operations. In the paper, therefore, we also present our methods and findings when working with a sample of teachers in two countries during a pandemic (when our PD sessions and collaboration were run online). Namely, we research whether and how teachers themselves perceive cognitive complexity of the operations associated with each programming concept.

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Implementing CS curriculum in K-12

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I am working on a book “Computational thinking – in educational practice”, which is supposed to bring and explain CT to teachers and educators. The book is not going to be a pedagogical or didactical guide which will show teachers how to design and organize lessons on CT topics, such a guide is planned next. In fact, I am convincing a reader that there shouldn’t be any lesson with CT as a theme. The book starts with a warm-up, a collection of Sudoku which show that very young students are easily able to use CT mental tools: abstraction, decomposition, algorithmic thinking, debugging and generalization with no priori a formal introduction. Then we comment, with the reference to CT, unified aims and attainment targets of the core CS curriculum for K-12 (announced in 2015 and introduced in 2017-2019 to our education system [1, 2]), and discuss fundamental issues behind the successful implementation of the curriculum: thinking before programming, spiral approach, CT, the role of programming, CS applications and CS in other school subjects, problem and project-based learning.

In this talk, we will focus on integrating unplugged CS approach and Bebras tasks with students’ activities on particular topics of lessons. The unplugged approach, originally introduced as an outreach to CS novices, we prefer to call “computer stand by approach” and apply at any level of instruction as a step at which students learn a concept or algorithm before they sit at a computer. In fact, I have already used this approach in 1970-1980’s when with students we learnt and executed algorithms before writing their computer implementations. Regarding Bebras tasks, they are used as a kind of a thematic warm-ups. The tasks are first transformed to open versions (interactive or with open window) and then we ask students to generate their solutions. We expect that students produce a solution as an effect of applying a problem-solving strategy which in fact corresponds to the operational definition of CT.

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Curricula considerations resulting from recent developments in machine learning and artificial intelligence

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Developments in machine learning (ML) and artificial intelligence (AI) have been accelerating in recent years to the extent that they are pervading every part of our lives. These developments have important consequences for school curricula because everyone needs to understand the opportunities provided by AI and the potential issues and threats of these technological developments. At a meeting of experts in Quebec, Canada in October 2019 hosted by EDUsummIT, a global community of researchers, policymakers and practitioners committed to supporting the effective integration of Information Technology (IT), recent developments in machine learning were examined and their implications for education were analysed [1]. A particularly challenging issue pinpointed was the importance of explainability and accountability of machine learning systems for different educational purposes. This work identified what teachers and students need to understand in order to make appropriate use of machine learning for their own learning and to understand the broader uses in society and the associated challenges. Furthermore, outcomes from the recent IFIP TC3 webinar, "Social Impacts of Big Data Analysis and Machine Learning – Educational Implications" identified a broad range of challenges associated with such developments. These challenges include: the meanings of key terms have been drifting so that they can be misleading or confusing; AI is complex and pervasive but often hidden; ambient AI together with 3D visualisations, intelligent agents, biometric recognition of learners and cognitive AI could enable greatly increased sophistication and personalisation of learning but how such complex technology supports and empowers both teachers and learners still needs much research.

In this paper we draw on these recent discussions to focus on the curriculum implications of developments in ML and AI focusing specifically on the needs and challenges for the informatics/computer science curriculum but also considering how knowledge and skill development in AI and ML can empower learners and develop their agency as citizens.

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Beyond Computer Science – Science+Computing: the integration of computational tools and processes into academic disciplines

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While the U.S. has engaged in significant efforts to grow computer science (CS) education in K-12, state-based decision-making has made approaches to computer science vary widely from stand-alone CS courses to the integration of computational thinking into disciplinary learning. Ongoing attention on equity points CS program developers towards compulsory education as a means to reach all students and a home for the development of foundational competencies.

This session shares progress of Science+C (Computing), a National Science Foundation project funded to create and institutionalize Computational Biology, Computational Chemistry and Computational Physics courses for schools to adopt as replacements for traditional science offerings. Science+C courses connect students' experiences in school with the skills and knowledge used in the contemporary scientific enterprise; help students explore scientific phenomena as they develop skills to use, decode, and modify computer models and analyze data; and better understand both scientific processes and how computational methods and tools have changed the nature of scientific inquiry.

This session highlights curriculum examples and shares lessons learned from the ten modules per courses piloted. A quasi-experimental research study is evaluating the impact of the intervention on student computational thinking and science outcomes, and changes in teacher skills and capacities. Results will inform how we prepare students to use computational approaches to solve real-world problems in science and other fields, and through scientific exploration made possible by computational approaches, how Science+C improves or enhances student understanding of science.

Key Words:
Computational Science; Computational Thinking; CT-integrated STEM; Modeling and Simulation; Computer Science; Workforce of the Future;

Integrating the New Zealand Digital Technologies curriculum across the curriculum – The current, future and potential

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The effective integration of digital technology to support learning is not a new concern. Its integration, especially across the curriculum, has been a focus since computers became more readily used and adopted in schools [1]. In recent years, however, there has been a push to reconceptualize and reinforce the role of digital technology within the classroom, whereby emphasis is placed on supporting students to be creators and producers rather than passive consumers of technology. Around the world many countries are evaluating their curriculum to explore how digital technologies can be better integrated into the schooling curriculum [2]. New Zealand has recently undergone a change to better situate the use and adoption of digital technology. These changes have emphasised the role digital technologies, and related CS concepts of Computational Thinking (CT), as core concepts to be integrated in the curriculum from the first year of schooling. The change has also emphasized the design and development of digital artifacts cannot remain siloed in one subject but rather integrated across the curriculum.

Supporting teachers to develop their own competencies, where technology usage in schools moves beyond consumption, will be important for the effective reconceptualizing and placement of digital technologies inside schools [3]. In NZ the siloing of subjects has made the integration of these new aims especially difficult. However, by providing teachers with an opportunity to explore way to integrate digital technologies across different subject domains, may mean teachers are better supported in driving learning, where technology is situated as a fundamental component of the learning.

This presentation explores the current, future and potential for effective cross-curricular integration and how emerging technology can potentially be the catalyst to support cross-curricular learning. The presentation explores the outcomes of a one-year project undertaken with two high schools in NZ, exploring how the new curriculum outcomes can be achieved. The study explores how new technologies, such as mixed reality (MR), can provide unique and creative opportunities to draw learning across different subject domains. The presentation will draw out the opportunities and barriers these changes have had on teaching and learning and the future potential this brings to better engage learners.

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What to Teach in Computer Science and How to Teach It

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Adding computer science as a separate school subject to the core K-12 curriculum is a complex issue that involves many legislative, administrative, political, and educational challenges. The latter will be the focal point of this talk. In particular, there are two major educational challenges related to: (a) what computer science content to teach across different educational levels, and (b) what body of knowledge do teachers need to have to be able to teach the computer science curriculum.

Over the years, a variety of computer science curricula, representing different views about what is important to teach in computer science and when, have been proposed in the literature and or enacted in different countries, such as UK, USA, Austria, Germany, Israel, Greece, Cyprus, and recently Australia. While, during the last two decades, a lot of work has been done by the computer science education community in promoting computer science as a school subject in secondary education, not a lot of work has been done regarding the integration of computer science in the elementary school curriculum (grades K-6, approximately from 6 to 12 years old). Despite the fact that a number of computer science education researchers have written about their concerns in regards to teaching computer science in K-6 because of learners' very young age, recently, there has been much impetus in bringing computer science experiences to elementary school children. Clearly, early computing education is now at the forefront, and, studies toward this line of research are urgently needed in order to develop an informed body of knowledge about learning and teaching computer science starting from elementary education. Accordingly, in this talk, we will explore the prospects of a curriculum framework with a focus on promoting computational thinking skills for the age of 6 and above, before covering more theoretical and applied concepts of computer science in secondary education.

Specifically, in this talk we will address the following two questions: (a) what computational thinking skills should a computer science curriculum promote? and (b) what knowledge do teachers need to have to be able to teach computer science? The first issue will be discussed from the perspective of designing an authentic computational thinking curriculum with a focus on real-world problems. The second issue will be addressed within the framework of Technological Pedagogical Content Knowledge (TPCK), and, it will be argued that TPCK is an important body of knowledge for the field of computer science, because technology is at the center of the computer science domain, either, as a means in itself, or as a means for achieving or teaching something else.