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Computers and education – recognising opportunities and managing challenges

IFIP TC3 – Technical Committee on Education

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Abstract. IFIP's Technical Committee 3 (TC3) is dedicated to concerns about uses of computing and digital technologies in education. TC3 covers the interests of those who are concerned with policy, practice and research in the fields of digital technologies and computing used for educational purposes, whether for management, teaching or learning, and whether by teachers, learners, parents, policy makers, developers, or the wider adult population involved in lifelong

[1] All present and past members of IFIP TC3 and its WGs are recognised in the work presented in this chapter. Specific contributions to this text were provided by the authors listed.

learning. This chapter considers the shifting focus of IFIP TC3's concerns for computing and education over the past 60 years, the reasons for those shifts, and the challenges that educators have faced in developing appropriate uses of computers in their practices. The chapter explores the roles and influences of TC3 conferences, its academic journal, its working groups, and its current task force. Separate sections provide an overview of important TC3 visions and declarations that have highlighted contemporary and future issues, and the status of an evolving declaration focusing on future sustainability and computing. The chapter concludes with an overview of the impact of TC3, and signposts next steps in its ongoing journey.

Keywords: Educational Technologies, Education and Technologies, Digital Technologies and Education, Information Technologies, Communication Technologies, Educational Technologies and Research, Educational Technologies and Pedagogical Practices, Educational Technologies and Policy, Educational Management and Technologies, Professional Development and Educational Technologies.

1 The shifting focus of IFIP TC3's concerns - education for, with, and through computing

It has not always been agreed that computing should be linked to education, or in what ways. Authors from a range of countries [1] describe how, in the 1980s, a range of national initiatives focused on early computers being made available to educational institutions (schools, colleges and universities) to provide for 'learning about computers'. This focus through early initiatives was succeeded in many countries by the wider integration of subsequent models of computers into educational institutions but more focused on 'learning with computers' [2]. As time has progressed, arguments have become stronger for links between the disciplines of computing and other subjects, and whilst there are already a number of important ways in which computing and education are linked, more are emerging as time goes forward. Recently, many countries have introduced computing curricula into schools [3] that focus more on, again, 'learning about computers' and 'learning to program computers'; however, with the vastly increased computer facilities now available in educational institutions, this focus has been supplemented with 'learning with computers', and importantly, 'learning to be productive with computers' [4]. IFIP TC3 has been involved in not just monitoring these shifts of focus, which have occurred just as much in higher, vocational and adult lifelong learning settings as in schools, but on actively supporting its members and wider international participants in gaining awareness and direction in using computers for educational purposes in their individual contexts.

This chapter explores the shifting focus of IFIP TC3's concerns for computing and education over the past 60 years. In the following section, Section 2, reasons for those shifts and the emerging challenges that educators have faced in developing appropriate uses of computers in their practices will be discussed in more detail. Section 3 describes the important roles and influences of TC3 conferences, and how these have not only mirrored contemporary concerns for computing and education, but have also pointed to

future issues and benefits. In Section 4, TC3's academic journal is discussed; this journal has played a major role in dissemination not only of the work of TC3 members and its groups, but also in the context of a wider related academic literature. In Sections 5 to 8, the important contributions of TC3's four working groups (WGs) are detailed, showing how each group focuses on a core area of interest. Section 9 details the work of the current TC3 task force on the computing curriculum, and Section 10 includes separate sub-sections that each provide an overview of salient TC3 visions and declarations, all arising from deliberations and outcomes of major TC3 conferences and highlighting contemporary and future issues; in the last sub-section, the status of the currently evolving declaration focusing on future sustainability and computing is described. The chapter concludes with Section 11, which provides an overview of the impact of TC3 over the last 60 years, and indicates next steps in its ongoing journey.

2 Challenges in developing awareness and practices of computer uses in education

In terms of enhancing awareness and understanding of how computers can be effectively used to support educational practices and policy, IFIP TC3 has undoubtedly faced the same form of challenges in finding ways forward that other organisations and institutions have sought to address over the past 60 years. Enabling educators and those in education to be aware of the potential, benefits and issues arising when using computers in educational practice has been an ongoing concern for members of TC3. Part of the challenge of introducing and integrating computing (a term used in this chapter to refer to the technological dimensions of digital activity and use, and the writing of programs) into educational practice has been concerned with the nature of the subject of computing itself. Computer science (a term used in this chapter to refer to the study of the principles and uses of digital technologies) has been strongly identified as a science and technology discipline, whereas education (and many specific subject areas within it) has been identified as a social science or humanities discipline. This form of identification has led many teachers and educators to question the roles and abilities of computers to support specific disciplines or subject areas, through pedagogical processes. In itself, this disciplinary difference does not lead to a natural rift between the subjects, but the difference does mean that those who broach that rift may come from quite different disciplinary backgrounds. Whilst computer science has been regarded or perceived as a discipline that has tended to rely in the past upon positivistic or quantitative approaches to its development and research, education has emerged as a discipline that was initially influenced by positivistic approaches, but has latterly become more influenced by post-positivistic, interpretivistic, and critical constructivist approaches. These disciplinary differences and the implied, evolving and emerging approaches have been paralleled by different ways that education has been seen in relation to computer science.

Initially, for TC3 and a number of countries who took up a policy or initiatives on computers and education at an early stage, education was seen as a way to teach and learn about computers, computing and computer science. A shift over the next 10 or

more years was then towards education being seen as ways to teach and learn with computing and digital devices and resources. More recently, the shift has been towards teaching informatics or computer science, and most recently, there has been an emergence resulting in education being concerned with ways to teach and learn to influence computer science practice and development. Over the same time period, computer science itself has shifted in its concerns for development, research and evidence that are increasingly socially related, concerned with the ways that its outcomes can be used, how they influence and can be integrated with social practices. While computer science artefacts were often initially concerned with actions outside human behaviour and consciousness (although they have increasingly influenced them), the trends now are concerned more with their integration with human behaviour and consciousness. These shifts have resulted in a greater focus over time on inter- and multi-disciplinarity for those concerned with development and research into computing and digital technology destined for educational purposes. This has resulted in an increasing reliance and need for computing and technology expertise to be matched and supported by social science and humanities expertise.

The trends that we see today are already enabling uses of computing and digital technologies to provide wider access to education and learning, to provide widening opportunities for management of education, teaching and learning, and to enhance practices for teachers, learners, developers and policy makers. In this chapter, we show how TC3 has continued to focus on key challenges and issues in these evolving contexts, how it has sought to identify ways in which computing and digital technologies can be used most effectively for educational purposes, and how TC3 has played its part, and continues to play its part, in that journey.

3 Involving and influencing – TC3 conferences and their focus

TC3 has run international conferences for many years. Conference titles and focus have been pertinent to the contemporary issues of their time. The shift in titles and focus over the last 50 years has been important in terms of maintaining an up-to-date perspective but also to highlight future possibilities; in this respect, the shift highlights key issues and challenges that have emerged and are emerging.

TC3 and its Working Groups (WGs), through their many international conferences over the years, have led to the sharing and wider dissemination through presentation and publication of many leading-edge, accepted papers in proceedings and in books. In the case of some conferences, the papers have appeared in university publications, but in most cases, they have been published in book form by international publishing houses including Chapman & Hall, Kluwer and Springer. In recent years, most have been published by Springer, and the papers accepted have been double-blind peer reviewed before a selection is made of the most pertinent and leading articles. For post-conference publications, authors of accepted articles are given opportunity to improve their papers following discussion within the conferences, giving opportunity to take advantage of additional and important contemporary leading perspectives.

TC3 has run a range of different conferences, but the flagship conferences for TC3 have been World Conferences on Computers in Education (WCCEs). Since 1970, eleven of these conferences have been run. Whilst the first conference (Amsterdam, The Netherlands, 1970) focused on conceptions of computer education [5], the second conference (Marseille, France, 1975) focused more on how computers could be integrated and used in education by teachers [6]. A greater focus was placed on learners at a later stage, in 1995 (Birmingham, United Kingdom) [7] for example, while concerns for how computers could support education worldwide has been a focus since 2013 (Torun, Poland) [8]. The most recent WCCE (Dublin, Ireland) has focused on the wider range of users – learners, teachers, developers, researchers and policy makers - with an increasing concern for those users with specific educational needs or in disadvantaged situations [9].

TC3 has additionally run streams within the wider IFIP World Computer Congress (WCC) conferences. Since 2002, four of these TC3 streams have been run. On each occasion, specific topics have been explored: the development of TelE learning in 2002 [10], the building of the information society in 2004 [11], learning to live in a knowledge society in 2008 [12], and the key competencies needed for living in a knowledge society in 2010 [13].

Within TC3, individual WGs, or WGs working collaboratively, have also run their own conferences. The conferences for current WGs are reviewed in later sections of this chapter, which focus on emerging concerns and themes of those WGs. One conference of note, run by a WG that no longer exists, focused on the online or distance provision of education using technologies as early as 2003 [14]. This highlights how TC3 has identified and often led on discussions and sharing of perspectives that can contribute to a wider understanding of how computers can be used in different and emerging educational practices. From the titles and themes across these conferences, it is clear to see that the interests and focus of TC3 have shifted in line with contemporary concerns. Across the timeline, this can be summarised as follows:

- 1970 – an initial focus on computer education (teaching and learning the subject of computing, about and with computers), followed within five years with a focus on computers in education (teaching and learning in other subjects, using computers)
- 1980 – the focus is on the increasing range of subjects where computers could be used in teaching and learning, the developing and emerging forms of digital technologies such as videodisks, and the impact of uses of computers and digital technologies on teaching and learning
- 1990 – the focus is more on the learner, and how computers and digital technologies are enabling learning, widening approaches to learning, and impacts from digital multi-media resources
- 2000 – the focus is on the widening impact of computers and digital technologies on society as a whole, on approaches to education that are linked to a knowledge society, and addressing and developing lifelong learning needs and approaches
- 2010 – the focus is more on the possibilities arising from communication, how computers and digital resources enable widening interaction, communication

and collaboration, and impacts on conceptions of education and social and socio-cultural learning approaches

- 2020 – the focus is more on the possibilities arising from features of computer science and digital resources that support the individual, the individual with specific educational needs, and the role of individuals in being enabled to be producers as well as consumers, linked to greater focus on the teaching and learning of informatics and computer science

4 The TC3 academic journal, its articles and their focus

While conferences have provided opportunities for researchers, practitioners and policy makers to share and discuss their findings and challenges, TC3 has also been instrumental in supporting a wider sharing through an academic journal route. Education and Information Technologies (EAIT) is the official journal of TC3, published by Springer. The EAIT journal has played a vitally important role in enabling key research to be channelled and disseminated. The focus and range of articles over time portrays elements that researchers have regarded as challenges or problems to be solved or shared, so having a view across the period of the journal offers another important perspective of how the field of computers and education has shifted and continues to develop.

EAIT covers the complex relationships between information and communication technologies and education, from the micro-concerns of specific applications or instances of use in classrooms to the macro-concerns of national policies and major projects; from classes of five-year-old children to adults in tertiary institutions; from teachers and administrators to researchers and designers; from institutions to open, distance and lifelong learning. The journal's breadth of coverage allows EAIT to examine fundamental issues at all levels, discuss specific instances and cases, draw inferences and probe theory, while being embedded in the research and practice of professionals.

EAIT was first published in 1996. EAIT has unquestionably grown over the years. While early volumes had four issues per year, the later volumes (in 2019, for example) had six issues, with a total of 184 articles, selected from 708 submissions. Springer publishes all accepted articles as *Online First Articles* before they are assigned to an issue. In 2019, there were 313,606 EAIT article downloads from the website. EAIT has been edited by a succession of international editors, and currently, the editor-in-chief is supported by three associate editors, and an active international editorial board of 29 members, from: Australia, New Zealand, the United Kingdom (UK), the United States of America (USA), Germany, Israel, South Africa, Greece, Finland, Switzerland, Bahrain, Hong Kong, France and The Netherlands. EAIT has become a truly international journal, with articles received in Volume 24 (2019) from authors in: Australia, Bahrain, Belgium, Canada, China, Colombia, Croatia, Cyprus, Egypt, Estonia, Fiji, Finland, France, Germany, Ghana, Greece, India, Indonesia, Iran, Ireland, Israel, Japan, Kazakhstan, Kuwait, Libya, Malaysia, Morocco, Nicaragua, Nigeria, Northern Ireland, Norway, Oman, Pakistan, Poland, Russia, Rwanda, Serbia, South Africa, South Korea, Spain, Sweden, Tanzania, Thailand, Tunisia, Turkey, the UK, Ukraine, the United Arab Emirates and the USA.

An idea of how research interest and attention on specific topics in the field of education and information technologies has changed over the years can be gained by exploring the titles of articles from several volumes across the journal's history. The topics also reveal how certain topics have remained the same over the years, while specific technology attention has often changed. So, for example, whilst one article [15] offered a framework for teaching a specific topic area, *the social and ethical impact of computing*, more recently, such frameworks have been offered on specific topics concerned with computing and computer science education. Studies that have explored uses of computers from teacher and teaching perspectives have remained over time (such as Chitiyo [16], and Voogt, Knezek and Roblin [17], as have studies that have explored learner experiences (such as Dillon [18], and Tiernan [19]). The need for connection between developers and practitioners has also been highlighted over time (such as Hinostroza, Rehbein, Mellar and Preston [20], and Rennstich [21]). Concerns for reconceptualisation of educational policy and practice have also regularly arisen; for example, the need to explore lifelong learning dimensions [22], and the need to review copyright regulations in a digital context [23]. Papers have also not always indicated positive outcomes for uses of computers in education; for example, papers that indicate the rejection of uses of integrated learning systems [24], and social media [25]. Most recently, topics have highlighted emerging technologies for education, such as the use of immersive virtual reality [26] and machine learning applications [27]. Special issues of the journal again show topics that have persisted, while others arise from the development of emerging technologies and the functionalities that they offer for education. A continuing concern has been the role that research plays in identifying the value and benefits of computers in education; for example, a focus on evaluation [28], on factors that are important [29], and on how students, computers and learning are connected [30]. The application and integration of technologies into educational practice has also been a theme that has persisted over time; for example, the topic of secondary informatics education [31], integrating mobile and panoramic video into education [32], and developing computing in the curriculum [33]. Uses of emerging technologies have been represented as they have emerged; for example, virtual realities [34], uses of serious games to support learning [35], and teaching and learning with social network sites [36].

5 WG3.1 – Informatics and digital technologies in school education - emerging themes

WG3.1 was established in 1966, focusing on "Informatics and Information and Communication Technologies (ICT) in Secondary Education". In 2014, the WG was merged with WG3.5 (which focused on "Primary Education"), creating a WG that covered "Informatics and Digital Technologies in School Education". The current aims of WG3.1 have been reflected in recent IFIP TC3 conferences, providing international perspectives on the debate of developing and integrating informatics education (where the term informatics is used in some countries that is in this chapter the equivalent of the term computer science used in other countries) at all school levels. Such perspectives have

included those from research activities as well as those from best practice experience, promoting acquisition and updating of appropriate knowledge and expertise for any whose teaching environment requires contact with computer-based systems. Such knowledge and experience considers the nature, content and method of delivery of school education, both within informatics (computer science) and digital technologies (digital humanities, and media literacy). The overall aims of WG3.1 are to enable learners to become discerning digital citizens who are able to act in a complex and digitalised world.

Current themes within the work of WG3.1 cover: early childhood and school education, including related informal learning contexts; computing education and digital literacy; the integration of digital technologies in education; the professional development of teachers; and the provision of pre-service and in-service teacher education. This range of work aims to enable educators to use and contribute to the development of digital educational resources, including professional learning networks.

WG3.1 has been involved in a number of conferences in recent years, organised with other WGs. The aims and focus of WG3.1, as discussed above, are clearly demonstrated by the themes of a number of recent conferences. These include: empowering teaching for digital equity and agency [37]; empowering learners for life in the digital age [38]; a new culture of learning: computing and next generations [39]; key competencies in informatics and ICT [40]; ICT and learning in the Net Generation [41]; and ICT and the teacher of the future [42]. Over the years, there has been an increasing interest in the role of communications technologies, informatics and computer science, interconnectivity and international perspectives, social and special educational needs, and digital equity and agency.

6 WG3.3 – Research into educational applications of information technologies - emerging themes

This WG provides a forum to identify issues and priorities for research into educational applications of information technologies and to map research policies arising from the differing approaches and cultural contexts in IFIP member countries. It aims to: identify research needs and topics in the field of education; improve research approaches and methods; synthesise research on major topics in the field; and disseminate research, in partnership with educational research communities. The group, with members from over 40 different countries, has many interests that relate to national issues and recent educational technology trends such as bring-your-own-devices (BYOD), artificial intelligence and the computer science curriculum. These themes relate to policy makers' interests in harnessing educational technologies to address national and international concerns such as improving attainment, supporting inclusive pedagogies, and skilling the workforce to meet the demands for digital expertise.

WG3.3 has a close working relationship with EDUsummIT, with representation in 11 of the 13 thematic working groups at the most recent EDUsummIT event in 2019. This international summit covered topics such as machine learning, learning analytics,

and research approaches for educational technology, curriculum and knowledge building [43]. Other topics of research interest that group members currently study include mobile learning, computational thinking, teacher education and professional development, and cultural differences in the conceptualisation and delivery of ICT and computer science curricula. The growing interest in computer science and digital skills over the last decade led to the creation of a specific task force on the computer science/informatics curriculum, established in 2014.

Research from WG3.3 is well represented in many TC3 conferences, providing state-of-the-art findings that are accessible to other researchers, as well as policy makers and practitioners. Particular themes that have been supported by research papers from WG3.3 include: learners and learning contexts - new alignments for the digital age [44]; empowering learners for life in the digital age [38]; rethinking learning in a digital age [45]; mobile learning [46]; technology enhanced quality learning for all [47]; and addressing educational challenges - the role of ICT [48]. These themes indicate the important focus that has been and continues to be an ongoing concern of WG3.3, in monitoring the uses, outcomes and impacts of educational technologies on learning and learners.

7 WG3.4 – Professional and vocational education in ICT - emerging themes

WG3.4 was founded in 1971, and is focused on higher, professional and vocational education in ICT – education leading towards careers or professional development in some form of computing. The membership of WG3.4 comprises academics (in fields of computer science, information systems, etc.), ICT trainers and ICT practitioners from all over the world. Members' interests range from the use of computer-mediated education, the on-going professional education of both ICT and non-ICT professionals, the activities of national ICT professional bodies, the delivery of effective ICT vocational education to post-secondary learners and the integration of ICT into other tertiary curricula.

WG3.4's goal is to promote the acquisition and updating of appropriate ICT knowledge and expertise by all. Its aim is to consider the nature, content and method of delivery of professional and vocational education within the ICT sector, which will enable learners to achieve their employment expectations, and to foster lifelong learning in the contemporary and evolving networked environment.

Regarding professional education within ICT, of particular note was the production in 1998 by a small working group of WG3.4 members of the document entitled "Harmonisation of Professional Standards" (an Appendix in Thompson [49]). At IFIP's World Computer Congress held in Beijing in August 2000, the harmonisation project was re-considered, and over the next 5 years a significant number of international activities were undertaken to promote the IFIP harmonisation document and evaluate its relevance to the discipline of software engineering. These activities were reported at the IFIP TC3 WCCE in 2005 and summarised in a paper presented at the IFIP 19th World Computer Congress [49].

Regarding wider educational issues, WG3.4 has, since 1993, run nine working conferences, either as a single WG or jointly with other group(s), which have reflected particular contemporary interests at those times. The themes of those conferences have covered: software engineering education [50]; software quality and productivity [51]; the place of information technology in management and business education [52]; educating professionals for network-centric organisations [53]; e-training practices for professional organisations [54]; information and communication technologies and real-life learning [55]; education, training and lifelong learning [56]; open and social technologies for networked learning [57]; key competencies in ICT and informatics [40]; and sustainable ICT, education and learning [58]. Members of the group had a major input to IFIP sub-conferences held at the World Summit on the Information Society (WSIS) 2003 addressing education and the knowledge society [59], and at the IFIP World Computer Congress 2006 addressing education for the 21st century [60].

The emphasis of the work of WG3.4 over this period has shifted from technical, managerial, and business education towards issues related to networked and mobile learning and sustainable development goals. WG3.4 is keeping abreast of the application of latest methods and technologies in ICT learning, both in the Global South and the Global North. WG3.4 aims at encouraging mobile and creative solutions to the challenges of lifelong learning through our research and knowledge sharing.

8 WG3.7 – Information technology in educational management (ITEM) - emerging themes

The origins of WG3.7 go back to 1994. That year, an international working conference on information technology in educational management was organised in Jerusalem, Israel by WG3.4. An outcome of the conference was to establish WG3.7. The meeting brought together an important number of researchers and practitioners concerned with what could be the best practices to enhance educational management with the support of information technology. At that time, personal computing had experienced a widespread acceptance and the continuous development of communications foretold how information and communications technologies would have a large impact on all aspects of education, including that of management and administration of educational centres. The participants in the first meeting agreed that much was still to be done in this field, and jointly proposed to seek to create a new working group under the umbrella of TC3. Two years later, in 1996, the group was officially acknowledged by IFIP as WG3.7, with a chair elected by members in 1998. The first international conference on information technology in educational management organised by the newly constituted WG3.7 was held in Hong Kong, China in 1996.

The main aim of WG3.7 is to promote effective and efficient use of ICT within management, policies, development of and planning of educational institutions. The scope of WG3.7 is focused across the whole range of educational institutions concerned with education, from kindergartens to higher education, adult education, and those in professional development and training settings at a local, regional, national or international level.

Since 1994, 11 conferences have been organised exclusively by WG3.7, held on six continents (excepting Antarctica). WG3.7 has also participated in international conferences organised by other WGs. The topics of these conferences indicate emerging concerns of this WG: information technology in educational management [61]; information technology in educational management for schools of the future [62]; the integration of information for educational management [63]; pathways to institutional improvement with information technology in educational management [64]; information technology and educational management in the knowledge society [65]; knowledge management for educational innovation [66]; information technology and managing quality education [67]; and stakeholders and information technology in education [68].

More than 250 papers related to information technology in educational management have been published by WG3.7 members across the 1994-2020 period. Main themes have evolved over the years, as technology has developed and new issues in education and in educational management have arisen. The topic that has received most attention is assimilation and integration of IT into educational management. Other emerging themes over the years have been those of strategies to integrate IT into educational management and IT applications in educational management. Recently, several members of WG3.7 have participated in the publication of the *Encyclopedia of Education and Information Technologies* [69], a huge knowledge repository covering many aspects of the interaction between education and information technologies, including IT in kindergartens, primary and secondary schools, universities, training colleges, industry training, distance education and further education.

Interests in overcoming problems derived from adapting a new and changing technology such as IT to educational management has set the standards for WG3.7's ITEM research during the more than 25 years of its existence. Nevertheless, it is recognised that ahead is a task of continuing to complete a compact body of knowledge and adapting to new challenges as a result of the ever-changing educational and technological arena.

9 TC3 Task Force - Deeper understanding of the roles of computer science and informatics

A TC3 Task Force is intended to focus attention on emerging developments in education that are fuelled by technological or societal need. The TC3 Task Force on the Computing Curriculum was established in July 2014 in response to calls for change in computer science and informatics curricula in many countries. The Task Force researched key issues and considerations for the curriculum and made recommendations for curriculum design and implementation. This work was summarised in 2016 in a short report, while more recently, the Task Force's work has focused on advances in conceptualising, developing, and assessing computational thinking and analysing how developments in artificial intelligence and machine learning need to be addressed within the curriculum.

At the outset of the work of the Task Force, a series of reviews and reports from different countries identified a need for major reform of the curriculum for computing,

computer science, information and communications technology (ICT) or informatics - depending on the terminology used in each country (for example, [70-73]). These reports and papers emphasised a refocusing of computing/ICT education to incorporate computer science as the underlying subject discipline. In some countries where curricula had often previously contained strong computer science, it was argued that they had become weakened and often refocused on educating young people as *users* of new technologies rather than *creators*. In some countries, such as Israel and Cyprus, computer science had been retained since its emergence in the 1980s, but rationales for its presence in curricula and curricula themselves were nevertheless under scrutiny [74, 75].

The major rationales for including computer science in the K-12 curriculum put forward in reports from many countries were economic, social and cultural [76]. The economic rationale rested on the need for a country to produce computer scientists to sustain a competitive edge in a world driven by technology, but also on the requirement for professionals in all industries to have sufficient understanding of computer science in order to deploy technology to support innovation and development. The social rationale emphasised the value in society of active creators and producers rather than passive consumers of technology. Such capability empowers people to lead, create and innovate within society and in curriculum terms, so that this knowledge is part of the "powerful knowledge" [77] needed to enable people to choose their role in society. The curriculum rationale rested on enabling people to be drivers of cultural change rather than having change imposed by technological developments.

Many educators have identified the importance of people studying elements of computer science in order to support their learning of other subjects - in particular, being able to engage in "computational thinking" and other forms of thinking promoted by engaging in computer science, such as systems thinking, as well as developing understanding the capabilities and potential of new technologies. This new thinking and understanding is not digital literacy (whose importance was already well-established), but a set of skills, understanding and thinking that can be developed by engaging with and understanding computer science, understanding how computers work and designing and creating computer-based solutions, including through programming. Considerations for developing curricula leads to implications for teacher professional development [78]. Broader recommendations for addressing key challenges for curriculum change in relation to computer science have been developed by the Task Force [75], further developed in relation to a wider range of country contexts in a report arising from a meeting between the Task Force and UNESCO [79]. Key recommendations were to adopt a globally agreed statement of computer science/informatics as a discipline in its own right, to articulate the nature, importance and relevance of computer science/informatics to society and education, and to disseminate and communicate a clear rationale to different stakeholders about the need to have computer science/informatics as a distinct subject in school curricula. Recommendations for policy and practice were to promote computational thinking through the means of a computer science/informatics curriculum which aims at making computational thinking commonplace, to design computer science/informatics curricula based on a content analysis, and then continue to research students' learning as well as the effects of different pedagogical approaches, and to identify clear learning outcomes, assessments and standards for

computer science/informatics. Important caveats were to encourage more computer science/informatics graduates to become teachers and provide professional development for existing teachers, and to identify and allocate resources for teaching computer science/informatics.

More recently, the Task Force has focused on how developments in machine learning need to be accommodated in curricula for computer science/informatics. The implications of such developments are relevant more broadly across the curriculum, and members of the Task Force have contributed to an international discussion and report [80]. A key recommendation of this report, in relation to curricula for computer science/informatics, was to ensure that all students develop a strong background in machine learning. It was argued that in order to develop their conceptual understanding of how machine learning works, students must have opportunities to use and apply machine learning and to create their own examples. Furthermore, as a powerful tool that may not be used to its full potential, a need for students to understand how machine learning can be used to identify and solve real-world problems was recommended.

Currently, while many countries have made major changes to their curricula for computer science/informatics, others are still in the process of change. Implementing such curricula is still a major challenge for many countries. Rapid technological developments, especially in machine learning and quantum computing, mean that ongoing curriculum change continues to be inevitable.

10 Education and computing - visions and declarations

TC3 has generated a number of visions and declarations over the years, arising from an analysis of outcomes from conferences, often WCCEs. Key declarations and visions were the Stellenbosch Declaration (arising from WCCE 2005), the Bento Gonçalves Declaration (arising from WCCE 2009), the Torun Vision (arising from WCCE 2013), the Dublin Declaration (arising from WCCE 2017), and the latest is the Zanzibar Declaration (arising from SUZA 2019). The identification of key themes and trends from these previous WCCEs and their declarations led in all cases to the production of a series of recommendations and actions, for policy, practice and research. The Stellenbosch Declaration called for actions to support digital solidarity, learners and lifelong learning, teachers and decision-making strategies, networking, and research. The Bento Gonçalves Declaration called for actions to support the learner and teacher through curriculum initiatives, to develop research, learning environments, professionalism, and collaborative communities. The Torun Vision set out two key challenges for the future. The first was to move from consuming to innovating; to create, conceptualise and produce using programming and computer science (CS), as well as using information and communication technology (ICT) applications. The second was to deploy digital technologies to better support different interactions with different stakeholders, according to technologies selected and used (such as those with online or haptic features), accommodating institutional diversities, gender, cultural, native language, cognitive and social backgrounds. The Dublin Declaration followed this vision, and pro-

vided recommendations and actions to take these key needs forward. The latest declaration, the Zanzibar Declaration, highlights the need to consider sustainable education in the context of emerging technologies.

The Stellenbosch and Dublin Declarations resulted from formal processes undertaken within respective WCCE conferences, and the Zanzibar Declaration is a current initiative instigated across TC3. As these Declarations are key documents in identifying contemporary issues of their times, they will be discussed in more detail in the subsections following.

10.1 The Stellenbosch Declaration

In 2005, TC3 held its WCCE in South Africa. The theme was *"40 years of computers in education: what works?"* Seven hundred delegates from more than 30 countries from six continents gathered for 4 days. Having many of the main actors of ICT in education in the world was a unique opportunity, not only to listen to each other's presentations, but to engage them to think and produce together and then to deliver an "address to the world". Consequently, all delegates were asked to contribute to a common reflection about education in the next decade. Each speaker was asked to provide one key idea, recommendation or suggestion. In each conference session, the chairperson was asked to provide three ideas, suggestions or recommendations as an output of that session. All delegates were also asked to contribute with one idea. The main aim was to generate a wide view about the "hot topics", what was being done around the world about ICT and education, at the research level, as well as in teaching and learning practice. Every day, a committee gathered and studied the contributions. At the end of the conference, a text, synthesising the contributions, was presented to the audience and adopted as the Stellenbosch Declaration. A researcher studied the Declaration and the way it was produced: "The IFIP Stellenbosch Declaration: Browsing the researchers' and practitioners' core ideas on ICT in education" [81].

The preamble of the Declaration stated that:

> *We, the members of the group, hope that this Stellenbosch Declaration will improve the integration of ICT in Education as a resource for both better teaching and learning and as a preparation of citizens for the Knowledge Society. We address this to all stakeholders in ICT in Education: teachers, practitioners, researchers, academics, managers, decision-makers and policy-makers, in order to increase the access to Education for everyone around the World. [...] As educators, we know that information and knowledge are not the same. We want not only an Information Society, but also a Knowledge Society in which Knowledge can be shared and distributed all around the world, enabling all children and all people to access Knowledge and to benefit from being educated.*

The Declaration addressed six topics: digital solidarity; learners and lifelong learning; decision-making strategies; networking; research; and teachers. For each of these topics, the Declaration made a statement and proposed some recommendations, at the

societal level, at the learning and teaching level, and at the technological and infrastructure level. An annex to the Declaration offered a list of 107 possible actions, chosen from among the suggestions offered by the participants.

The Declaration was translated into many languages and was published in many journals. Fifteen years later, reading again the Declaration shows that even if the world has changed, the core issues and the main recommendations remain totally accurate. While a lot of progress has been made since, many questions are still open.

10.2 The Dublin Declaration

Twelve years later in 2017, the Dublin Declaration stated that in terms of computing, computer education and uses of technologies for teaching and learning, these were considered to be at a pivotal point of change. It was clear from evidence in the WCCE 2017 presentations that international, national and local computer and educational technology strategies, policies and curricula were shifting. Earlier and ongoing outcomes from the activities of important initiatives such as the European Computer Driving Licence (ECDL) clearly contributed to the then current state of play with regard to user practices and uses of ICT. The then current status of computer access and uses across countries, and the identification of key underlying development needs, was clearly shown by widespread monitoring of international and national comparison data, for example, from the Programme for International Student Assessment (PISA) results run by the Organisation for Economic Cooperation and Development (OECD) and from the International Association for the Evaluation of Educational Achievement's (IEA) International Computer and Information Literacy Study (ICILS) focusing on computer and information literacy. Given the wide evidence base at that time, it was clear that learners of all ages and levels could benefit from and should be enabled to develop opportunities that such technologies offer, not only for their individual futures but also for the future of our wider communities and society as a whole. However, it was highlighted that young people need to have sufficient opportunities to be creators and not just consumers of ICT. The theme of WCCE 2017 reflected a focal concern - to seek ways to assure the inclusiveness of technologies to support education, teaching and learning for all social groups. It was clear that teaching about computing should not replace the use of ICT to enhance learning across the curriculum, but that the balance between computing and ICT to enhance learning across the curriculum should be fully considered and accommodated. Importantly also, the balance between educational activities that involve non-computer use as well as computer use was an issue that needed wider consideration, as communities and societies moved towards increased digital ubiquity.

Recommendations put forward in the Dublin Declaration in 2017 are still pertinent today. Those recommendations covered a number of specific areas. For future direction with computer science education, it was recommended, for example, an entitlement for young people to be educated in computing, incorporating computer science and computational thinking as the underlying academic discipline, as well as digital literacy – as all young people have a right to become creators and not only consumers of ICT for their future. Importantly, to support these young people, there is a need to create more and well-trained computer science teachers.

It was recommended that, to address the gap between developing and developed countries in the use of ICT in education, there should be a focus on new pedagogical opportunities offered by mobile learning applications and their adoption in the education field. From an infrastructure perspective, it was recommended that infrastructure challenges should neither be considered as a matter of funding nor as a technocratic approach; school administrators and parents should be included in developing creative support and maintenance, as part of a wider holistic approach to development. To support this approach, there should be co-operation with countries with a high degree of ICT development in education, to share their experience in IT usage/skills in the educational domain.

To support inclusiveness and student engagement, recommendation was made to encourage schools to implement problems and ideas from real life and from students' out-of-school interests, activities and hobbies, to allow children to enjoy solving them in a challenging way, even in their free time. Some caution was also recommended, to develop emotional intelligence of our students, as this is often a missing component of all virtual learning environments and other digital resources. A goal should be to pay closer attention to implementing this aspect into pedagogies that involve educational software.

Importantly, to support teacher education and continuing professional development, recommendations were made to develop educators who can teach computational thinking rather than just teaching programming from standard lesson plans and textbooks, and to build further capacity in digitally-literate teachers in every discipline. The approach recommended was to provide professional development for teachers, which should be problem-based and adopt project-based approaches supported by and supplemented with communities of practice, as these latter facilities provide enormous potential for effective professional development. It was recommended that teachers should become more aware of the importance of learning analytics as potential instruments to improve learning processes, but considering the need for such data to provide useful and important feedback to improve educators' work. To support teacher professional development, international groups can promote ways of developing communities of research-active teachers to develop and disseminate their own evidence of the impact of ICT on teaching and learning.

To develop appropriate game-based learning and gamification, a recommendation was made to promote further research to set the basis of a comprehensive framework to support game-based teaching and learning at all levels of education. The need was recognised to train pre-service and in-service teachers in the use of game-based learning approaches.

To move towards e-evaluation, recommendations were made to consider stealth assessment as an approach to formative (rather than summative) assessment that is seamless - woven deep into the fabric of the activity such as a game and not taking away the 'fun of learning'. Further, it was recommended that the assessment approach from research be examined, to see how it can be taken into mainstream learning, and to study the rapid rise in e-examinations, for authentic assessment that matches modern workplace practices and many student learning experiences.

It was considered that, for any of the recommendations above (and others in the full Declaration) to be taken forward, there needed to be greater levels of international co-operation and collaboration between researchers and practitioners, through appropriate research processes, from design to dissemination. In addition, research approaches in this field should continue to integrate and combine the expertise of education, psychology, sociology, computer science and economics to provide robust, well-rounded, critical perspectives to ensure the most appropriate outcomes to drive the future of education forward. High-quality interdisciplinary research was felt to be needed to establish a strong and informative evidence base before adopting large-scale implementation and investments in educational technology initiatives. For implementation, an evidence base should be established to assess the impact and integration of technology in the classroom through a synergy between quantitative and qualitative methods, where studies are framed in appropriate theoretical terms, with consistency between theoretical position, design, methodology, data collection and analysis. Conceptions of research, policy and practice should be revisited in this field in this context. While teachers need to be considered to be producers of knowledge, maintaining the variety of uses for learners of all ages, identifying outcomes that relate to contexts, and measuring impacts where purpose and future developments are fully considered, were identified as all essential elements that need to be integrated into contemporary and future research, policy, teacher education, teaching and learning practices in this field.

10.3 Issues that we face internationally - the Zanzibar Declaration - sustainable education in the digital age

Looking outwardly and internationally, the perturbations, changes, and problems observed during the last decades reveal that we are certainly not living anymore in a static, but in a dynamic, world. Numerous disruptions in many domains have arisen, and the relationship between ICT and education has continued to receive increasing attention in many countries and regions. The importance of the relationship between ICT and education is also reflected in the current (2020) Coronavirus (COVID-19) pandemic crisis; home office and e-learning have become part of everyday life for many employees and students in 2020, and ICT-supported communication is becoming an essential part of social life.

For the educational field, it is possible to identify specific changes that have arisen over the past decade, such as modifications in pedagogy, demands from societies, and the emergence of new technologies. Thinking about what requirements will arise in the future in different areas of ICT and education, what strategies will be appropriate for research, development, and practice? What kind of information and knowledge do politicians, stakeholder researchers, and practitioners need to base their decisions and work on?

In the April 2019 annual general meeting, TC3 initiated a Declaration on “Sustainable Education in View of Rapid Emerging Technologies in the Digital Age”. This Declaration describes future challenges and proposes approaches to their resolution. The Declaration followed discussions and presentations at an international conference

(SUZA 2019, April 25–27, on Sustainable ICT, Education and Learning, run in Zanzibar, Tanzania). This Declaration is now in the process of being formulated and detailed. In this sub-section, an overview of the intended process and outcomes is outlined, to indicate key focal topics that TC3 is highlighting.

In developing the Zanzibar Declaration, TC3 draws on the many years of experience and relevant resolutions of international organisations (e.g. the World Summit of the Information Societies (WSIS), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the International Telecommunications Union (ITU), and the World Intellectual Property Organization (WIPO)). Through the experience and exchange of views with experts from these organisations and through additional relevant meetings, it was important to incorporate substantive positions of various stakeholders from different countries within IFIP in this Declaration. To be able to consider as many local contexts and experiences as possible, as many IFIP experts and practitioners as possible are given the opportunity to contribute their ideas to the document. In this way, the various experiences regarding current technological ICT developments and the resulting demands on education in different national contexts can be taken into account. As this will be a dynamic process, collected contributions and data will be supplemented and updated from time to time. In this respect, the outcomes will represent a current status and describe different development paths towards an end status in different countries.

Whilst the Zanzibar Declaration is a work-in-progress, details of the current process and procedures to take this initiative forward are offered here. This will provide an idea of the range of current concerns that TC3 is exploring from an international perspective, relating to the future of computing and education. A matrix to provide an orientation through identified key contemporary topics has been developed (see Fig.1). This matrix contains, in the left-hand column, emerging ICT technologies (T1 to T16), and in the top two right-hand rows, the possible social impacts of different applications in areas of societies (S1 to S11). Educational requirements resulting from the relationship between the technologies and the social impacts in specific contexts need to be appropriately considered and addressed. Possible contributions to the Declaration can be made by respondents; contributions can be assigned to a specific cell in the matrix, preferably addressing in the response all three components (technology, social impacts, and educational requirements). Both positive and negative aspects of the respective topic should be included, so that each contribution in a cell of the grid can be referenced, and indeed based, on everyday practice.

Création : 2019-05-16, par RMO Révision : 2019-07-03, par JSI Version : 02	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
	(Cyber)Security	Privacy	Social / Surveillance	Decent work	Health Care	e-government / e-administration e-law	environment / ecology / sustainability	ethics / deontology / governance / code of conduct	mobility	Digital equity	Gender Equity
T1 IoT - Internet of Things	MLM		JSI					JSI			
T2 Quantum Computing											
T3 Communication (eg 5G)					FIA				FIA		ISM
T4 Implication of Big Data											
T5 Blockchain											
T6 3D / 4D Printing											
T7 VR virtual reality - AR Augmented Reality					KNS						
T8 Autonomous Systems	MLM							GDU	GDU		
T9 Cloud Computing											
T10 Humanoids								GDU		GDU	
T11 Transhumanism			FIA								
T12 Nano Technologies											
T13 Technologies of Recognition (tracking)	MLM										
T14 Future Technologies										RMO	
T15 AI (artificial intelligence) activities			JSI		KNS			RMO GDU	GDU		
T16 Robotics			FIA		FIA						

Fig. 1. Orientation matrix of key themes relating to sustainable and future education with computing.

As an example of a possible contribution, for T8 Autonomous System with S9 Mobility, it would be possible to consider from a perspective that is *Positive*: Autonomous Systems will change public and private transportation; they may lead to reduction of traffic and emission of carbon dioxide; they will speed up transport and better tailor it to individual needs. From a *Negative* perspective: there is high expenditure on technical infrastructure; responsibility shifts from humans to algorithms; ethically difficult conflict situations can arise; the wealth of data generated could be used for social surveillance; destruction of workplaces (reducing onsite work) is considered possible. From an educational requirements (ER) perspective: IT basic understandings of autonomous systems should be integrated into curricula in an appropriate form and with suitable tools at different age levels (for example, algorithms, robots, autonomous vehicles constructed by students, (visual) programming language), and contextualised social impact should be considered using story-telling examples (e.g. jobs of taxi drivers).

The view on this topic (T8/S9) would possibly look quite different from the perspective of another country, a developing country, for example. When exploring the details in the matrix, it is, therefore, essential to consider the context-specific conditions in the examples, as these may reveal diversities between different locations, different cultural traditions, and institutional conditions. It will also be possible to view perspectives through the impact of a specific ICT technology on societies by selecting a row and addressing different areas of application. It will also be possible to freely add any combination of technology or social impacts not contained in the matrix, and to describe a corresponding example.

It might be that entries will not be completed for all fields of the matrix, but, conversely, there could be accumulations and clustering of content in and around some cells. Thus, a heat map with example clusters on future relevant challenges could be created, which could then be addressed more fully in the Zanzibar Declaration. In addition, a collection of context-specific examples of the social impacts of future ICT technologies and a consideration of their resulting educational challenges could be created in this way.

Members of an initial working group have made first entries in some of the cells of the matrix (see the 3-letter abbreviations in Fig.1). From these, it was found that a high degree of diversity arose when looking at specific topics. When the content of the matrix is further completed, the concept and the results of the initiative will be evaluated and presented at future conferences and meetings of TC3. It is planned that these events will include the (postponed) WSIS Forum 2020 and the next WCCE. WSIS is a natural platform to exchange perspectives gained on all the topics linked to this initiative with policy makers, politicians and other stakeholders. Each year, in Geneva, Switzerland, the WSIS Forum takes place with some 3,000 participants, supported by key international organisations. One of the key outcomes of the WSIS events has been the adoption of an agreed document entitled 'Sustainable Development Goals (SDG)'. As WSIS states:

> *The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.* [82]

Having worked for four years with these guidelines, considering the local charitable aims of the SDGs, it has become evident that in the 17 SDGs three of these are prerequisites to meet real-world challenges of future 'Information and Knowledge Societies'. These three are concerned with: Education (SDG 4); Security (mainly addressed in SDGs 11, 16); and Ethics, Governance, and Code of Conduct (mainly addressed in SDGs 11, 16). Effectively, without those three together, it is considered that there is limited chance to realise socially just and environmentally friendly 'Information and Knowledge Societies'. Thus, education is one of the central fields and needs of activities of the United Nations and the WSIS Forum, and the three SDGs are inherently related to the topic of the Zanzibar Declaration that TC3 will develop to support its members and wider communities worldwide.

11 The impact we have had – and where we go from here

The work of TC3 over the years has had impact on research, policy and practice as well as more directly on IFIP and TC3 members. Impact on research is clear – the number and range of conferences, published books and academic papers through its journal EAIT are all a testament to the deep and broad contributions TC3 has made to the field. Citations and downloads, references and identification of future work, have all been strong indicators of the impacts on research in this field. TC3 has also been instrumental in running doctoral consortia that have been associated with conferences, supporting young researchers in developing their practice and contacts.

Impact on policy is also clear. Members of TC3 and its WGs have often been key stakeholders at policy level, either directly working in policy roles, or advising key

stakeholders in ministries and governments. In this respect, members of TC3 have contributed to government and ministry policy discussions and decisions in countries including Botswana, Denmark, France, Italy, Israel, Lithuania, Norway, Poland, Switzerland, and the UK. Policy support through TC3 work at institutional levels should also not be ignored here. Members of TC3 have often been in key positions within their own institutions, whether that be at school, college or university level. In all of these policy cases, those individuals have been supported through insights they have gained from TC3 conferences and meetings. In some cases, international collaboration has additionally resulted at policy level.

Impact on practitioners is also apparent. There have been a range of educational practitioners that have been members of TC3 and its WGs. In many cases, conferences have been supplemented with workshops, specifically designed to support and inform teachers, school leaders and school administrators. Feedback from these workshops has been positive, and it is clear that TC3 and WG members have been active in disseminating their expertise and experience at much wider international levels through routes such as these.

TC3 has continued a tradition of offering opportunity for discussion and sharing of expertise and experience – across the domains of research, policy and practice. In its current and future work, TC3 will continue to focus on three important areas of concern:

- Monitoring and assessing the potential of emerging new technologies, as their development will certainly not cease in the immediate future, and their application to education will need to be continually and carefully considered.
- International sharing and contextual discussion will support a wider application of new technologies to education, through an ongoing appropriate relationship between research, practice and policy.
- The application of new technologies to support social and individual diversity and needs will continue to be considered in the context of individual and community needs.

TC3 has a continuing major role to play in the future. It can be argued that, in view of contemporary challenges and contexts, there has never been a more important time for sharing, for exploring ways and means to enable and empower further the important working arenas of different stakeholders. Through implementing fundamental research, policy and practice, we may allow the fields of education and computing to come together to support our future (in the arena of what is now being termed ‘digital education’).

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