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Editorial

Information Communication Technology (ICT) and Education

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1. Introduction

COVID-19 has accelerated the shift to blended or fully online learning environments, enforcing educational institutions to embrace technology and offer their students an online or at least blended learning experience [1,2]. A large amount of data became accessible through learning management systems (LMSs), but, as of yet, this has not been generally analysed in a proper manner nor used to improve the efficiency of teaching and learning [3]. Institutions usually do not consider such data to drive their strategy, nor are teachers required to use the data to improve their teaching practice [4–6].

In this respect, in this Special Issue, we would like to tackle new approaches in creating learning environments that should be smarter, more inclusive, and involve emerging technologies that will boost the digital skills of students and bring them a more personalised experience. In this Special Issue, we included in total 14 contributions from 56 authors from 25 institutions from 13 countries across Asia, Europe, and North America. An impressive 13,512 students and educators were included in these studies, consisting of over 700 different groups, classes, institutions, and/or contexts, thereby providing rich and diverse insights into how ICT is currently being used in various educational contexts.

We arranged our Special Issue based upon six topics, namely artificial intelligence in learning [7–9], applied robotics in education [10], automated approaches to create smart and inclusive learning environments for blended and online learning [11], emerging technologies in education [2,11–14], learning analytics, and big data in learning environments [6], and learning strategies for smart learning environments [15,16]. In terms of the methodologies used, beyond more common survey approaches [2,13,15], there were several innovative approaches, such as a pluralistic walk-through of learning analytics applications for practitioners [6], playing poker with robots [10], and log-data from interactive knowledge representations [12]. After we describe the three systematic literature reviews [9,16,17], we will briefly describe the main insights of these studies based upon these topics, after which we will provide some further recommendations for future research.

Three systematic reviews on ICT skills, learning with plants, and NLP and Chinese language

Several studies were so-called systematic literature reviews, including focussing on ICT skills as part of 21st century education [16], learning with plants [17], and automatic Chinese Essay Evaluation [9] using Natural Language Processing (NLP) techniques. Given the worldwide distribution of telecommunications devices and an apparently unstoppable drift toward integrating ICT throughout workplaces and everyday life, it seems indisputable that everyone needs to develop skills to happily and effectively use these affordances. But when should children first explore and begin to play in this area? Can young children be taught about using technologies in a way that paves a smooth path toward competence across the spectrum of 21st century skills?

Weber and Greiff's [16] research suggests that children can launch their development of these skills between the ages of 3 and 6 years provided that care is taken to adjust

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learning activities to recognise children's development in key areas: inductive reasoning, deductive reasoning, abductive reasoning, causal reasoning, scientific reasoning, executive functions and computational thinking, fine motor skills and language, self-regulation, and social skills. Weber and Greiff do not fall into a trap of proclaiming that achievements in these areas are sufficient, however. They note that issues relating to emotional, social, and motivational development also are important, nudging new work to use a wide lens when examining ICT skills and how they can be fostered in early childhood.

In the second systematic literature review (SLR) of this Special Issue, while much attention has been given to new technologies, topics that students and teachers examine when they use technologies in learning and teaching are often given less attention. Leo-Ramirez, Alvaraz, Pérez, Greller, and Tabuenca [17] shine light on one unique and captivating topic: plants and roles plants can play in learning activities where technologies have more often drawn most of our attention. These researchers' systematic review partitioned the literature by level of education, pedagogical approaches, topics relating to plants, purposes of a learning activity, group vs. individual work, roles adopted by students and their teachers in learning activities, and measures existing research used to examine the effects of technology-supported learning activities involving plants. Findings show that plant-related studies use wide-ranging measures of outcomes. These studies also mainly involve students using apps and virtual reality implementations running on smartphones and adopt a perspective about studying plants that under-emphasised students' exploration of needs plants have in comparison to just observing plant growth. This very early stage work could advance more robustly in proportion to widening the research community interested in plants as a topic of study and accessories for learning.

In the third SLR, Yang et al. [9] made a case that with the advancements of NLP, an increasing number of applications and organisations are implementing automatic essay evaluation (AEE). This is particularly beneficial for learners as it might provide automatic feedback and reflection on written work. While for the English language there are already a wealth of NLP and AEE tools available, particularly with generative AI tools like ChatGPT, for other languages this is limited due to a lack of multiple publicly available corpora and tools. In their SLR focussed on automatic Chinese Essay Evaluation (ACEE), Yang et al. [9] showcased that rapid progress has been made in the Chinese language context. They found 29 articles and concluded that there are still substantial limitations in extracting grammatical errors and features related to syntax and traditional Chinese literary style. In part, this is attributed to challenges in obtaining local student essay corpora across different educational stages, and in part, there is a lack of a common unified research platform and community to improve the scoring results. In a way, this is comparable to other non-English languages that may struggle from a critical mass of researchers to ensure a reliable AEE.

(1) AI in learning

Alongside rapid and sometimes disruptive introductions of advanced technologies purportedly designed to make life easier and more fulfilling, some worry that humanity's special qualities—creativity among them—might be eroded. In this context, Choi, Kim, and Park [7] report on a program designed to achieve the double goals of advancing peoples' technology "savvy" at the same time as attention is given to expanding their creativity as they use technologies. The education program they evaluate, the Hyper Blended Practical Model, blends prior advances to "help learners develop creativity" at scale. With a large and diverse sample, including elementary and secondary students, school faculty, school administrators, and the general public, a 4-year project surveyed participants' satisfaction about wide-ranging activities, including collage art, physical exercise, and tours juxtaposed with conventional online learning activities. The scope and novelty of this research shines new light on supporting adaptations to new technologies without submerging attention to a fuller scope of human concerns in technical education.

In the second application of AI in learning, Choi et al. [8] illustrated with a software and a so-called AI camp with 314 students from a multicultural background in Korea how to increase their digital competences in software and AI. In a wonderful and unique study context, the authors argue that given the relatively mono-ethnic society in South Korea and the lower uptake of digital competences of children from multicultural backgrounds, educational AI and software camps could be used to encourage these competences.

(2) *Applied robotics*

Ilona Buchem [10] provides an interesting approach to encourage in-person social learning experiences using a social robot NAO. By playing a poker game with NAO with 46 students, the aim of this study was first and foremost to provide scalable collaborative learning experiences in small groups of 5–6 students; second, to prepare students for robotic interactions in future workplaces; and third, to explore how social robots can be used on campus to enhance in-person, social learning. The results indicate that most students value both the social learning experience and the robotic facilitator. This is an important study as with the scaling of higher education and the labour market, robotics will become increasingly a daily experience, and this study shows that providing early experience with robots might be beneficial for learning with robots.

(3) *Automated approaches to create smart and inclusive learning environments*

Automated approaches are used in Self-Organising Maps (SOMs) to be representative of a neural network in the context of programming education and content organisation [12]. SOMs are flexible applications in education, object-oriented programming analysis, clustering students based on academic grades, thus showing the potential to achieve transparency in programming education by categorising and clustering source codes based on structure and complexity. Google Colab was used for the experimentation, and GitHub served as the source of the training data. This study used Abstract Syntax Trees (AST) to represent programming concepts objectively and to automate the transformation of source code into binary vectors for SOM training. The training process, quantisation error, and topographic error are discussed, showing that SOMs can effectively analyse and cluster programming code.

(4) *Emerging technologies in education*

Beyond the previously mentioned robotics and AI in education, this Special Issue includes several interesting established as well as emerging technologies such as smartphones, interactive knowledge representations, and open education resources. As already mentioned in the SLR by Weber and Greiff [16], smartphones and tablets are everywhere. However, as argued by Lang and Šorgo [13], not much is known about how secondary school students use them for educational purposes in general, and biology classes in particular. In various countries, there is a continued debate as whether to ban these devices in class or embrace them as a powerful learning tool. While most students use smartphones before starting secondary school, there is limited support of the impact of smartphones on biology classes in the study of Lang and Šorgo [13]. In part, this is attributed due to the lack of authentic situations when the use of smartphones would provide a stronger impact than, say, a microscope. This links to wider EdTech research findings that state that having a nice tool in place may not lead to expected impact when the design of learning activities is not aligned to incorporate the potential affordances and limitations of that tool.

The second example of emerging technologies in education is the use of knowledge representations. In the contribution from Bredeweg et al. [12], an interactive knowledge representation is studied as a versatile vocabulary for expressing and modelling knowledge, enabling automatic inferences. This approach, once reserved for researchers, is now widely accessible due to contemporary computing capabilities. In education, these representations, including graphical and symbolic formats, play a pivotal role in enhancing learning by making complex information more accessible to learners, improving the comprehension, retention, and application of knowledge. Moreover, technology in education, such as educational software and online platforms, offers interactive tools and multimedia resources that facilitate learners' understanding of complex concepts through structured knowledge representations. This shift towards the active construction of representations, particularly in science education, promotes deep learning and meaningful understanding, though it is associated with challenges, such as the need for learners to grasp the semantics of representations.

A third example of how emerging technologies in education are addressing the challenges of providing inclusive and accessible online learning experiences comes from Iniesto et al. [18]. In the context of open educational resources (OERs) and massive open online courses (MOOCs), they highlight the importance of considering student variability and feedback in the design and evaluation of online courses to bridge the gap between design principles and student needs in the realm of emerging online education technologies. While MOOCs offer a wide range of open-access courses, they face issues related to completion rates and accessibility. To improve the accessibility of MOOCs, Iniesto et al. [18] focused their research on learning design and evaluating accessibility through frameworks like universal design for learning (UDL). User feedback, collected through tools like YourMOOC4all, allows students to assess MOOCs for UDL principles. UDL aims to remove barriers to learning and make education accessible to all, aligning with the pedagogical perspective of MOOCs, where students are expected to be self-directed in their learning. By addressing accessibility barriers and leveraging UDL, MOOCs can offer more inclusive and equitable learning opportunities, benefiting students from diverse backgrounds and abilities.

Related to Iniesto et al. [18], Batanero-Ochaíta et al. [14] explore how much additional time students with accessibility needs (e.g., visual and motor abilities) might require in order to explore these emerging technologies. Using an experimental design with 60 students, their findings suggest that compared to students without disabilities, additional time ratios of 2.92, 1.88, and 1.58 times for blind, partially sighted, and reduced motor capability students, respectively, would be needed to complete an online survey related to two online courses.

(5) Learning analytics

While the above emerging technologies and approaches such as learning analytics show great promise, as argued by Knobbout et al. [6], even with clear empirical evidence of the affordances of learning analytics, not every educator or manager is keen, able, or willing to actually adopt these technologies and approaches. Using a so-called capability model amongst 26 participants at five institutions in Belgium and the Netherlands, the authors argue that while most participants find the learning analytics roadmap to implementation easy to understand and use, several questions remain about how to forward their respective organisations on this roadmap. This links with wider studies that have implemented learning analytics and related EdTech solutions at scale, but nonetheless find that less than half of their users regularly use these ICT tools and approaches [5,19,20].

(6) Learning strategies for smart learning

Programs designed to help people develop skills to use digital tools must address a key question: do learners develop competence? While normative views of digital competencies have an important place in forging policy, program architects and individuals enrolled in programs care much more about whether and how well competencies are fostered. In this light and recognising competence assessment ranges beyond conventional metrics representing reliability and validity, Guàrdia, Maina, Mancini, and Martinez Melo [15] forward a Competence Assessment Model (CAM). CAM synthesises multiple methods and a student-centred view of assessment operationalised in competence assessment scenarios. Primary and secondary teachers whose students worked with the scenarios for approximately six months judged how well the scenarios tracked students' growth in digital competencies. Overall, teachers' judgments represented four factors: efficiency in time, student tracking support, and assessment; fairness and cognitive complexity; meaningfulness and authenticity; and reproducibility and transparency. The CAM offers guidance for practically implementing competency assessment to meet the needs of teachers and learners.

2. Recommendations for Future Research

With the rapid advancements of AI and ICT in education, it is evident that we need to develop strong and robust frameworks and approaches to help the current generation of learners, as well as the next generation of learners. This Editorial was written just at the time that world leaders and tech companies met to agree on the Bletchley Declaration [21]. Amongst others, it is stated that:

"AI presents enormous global opportunities: it has the potential to transform and enhance human wellbeing, peace and prosperity. To realise this, we affirm that, for the good of all, AI should be designed, developed, deployed, and used, in a manner that is safe, in such a way as to be human-centric, trustworthy and responsible. We welcome the international community's efforts so far to cooperate on AI to promote inclusive economic growth, sustainable development and innovation, to protect human rights and fundamental freedoms, and to foster public trust and confidence in AI systems to fully realise their potential."

While education is mentioned twice in the Bletchley Declaration, we would argue that more needs to be done to understand how we can safely and effectively support our current and future learners and educators with how to effectively use ICT and AI in education. We therefore hope that this Special Issue will spark more ideas and research, and would welcome your thoughts, contributions, and ideas.

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