Exploring what Formal Learning Involves in the Digital Era

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Abstract

Children need to learn at school the things that matter in the 21st century. What does really matter though and what does 21st century's primary school learning involve? Assessing the impact of technology use in education is a complex topic with many factors and variables involved (such as social, cultural, economic and political). At the same time, it is important to develop technologies to assess what matters, rather than what is easy to assess. This paper seeks to explore what this involves and the role that educational technology plays particularly in primary school mathematics. Nowadays children learn through connections and collaborations facilitated by technology that could then lead to knowledge creation. Nevertheless, there is no technology that has an impact on learning on its own. This depends on how it used. In order to address this further we present, in the second part of the paper, a set of recommendations that could be relevant to educators, researchers, policymakers and the industry.

1. Introduction

Few people would nowadays disagree that technology plays an important role on primary education success and children's future. Children need to learn at school the new things that matter in the 21st century and it is important to find new ways to teach and assess them. Assessing the impact of technology use in education is a complex topic with many factors and variables involved (such as social, cultural, economic and political). At the same time, it is important to develop technologies to assess what matters, rather than what is easy to assess. But what does really matter and what does 21st century's primary school learning involve? Nowadays children learn at school through connections and collaborations facilitated by technology that could then lead to knowledge creation.

2. About Learning

Over the last 20 years, psychologists are trying to understand the influence of the social and cultural environments that are involved in someone's learning and cognitive development and more emphasis is now being placed on seeing learning as a very social process [1]. This idea of learning as a collaborative and socially situated process has led to a number of researchers, focusing today on how educational technology could act as powerful social resources in someone's learning context [2] [3].

When learners acquire information in a meaningful context and are able to relate it to their prior knowledge and experiences, they could form connections between the new information and their prior knowledge to develop larger and better linked conceptual understanding [4]. This notion of learning occurring in some particular context and that this context consequently affects learning, consists of the concept of situated learning.

Instead of focusing on individual learners the main focus should be on complex social organisations containing learners, teachers, curriculum materials, software tools and the physical environment [3]. Such complex social organisations, Greeno defines as "activity systems" [3]. Asking someone if they have learned a specific topic in mathematics (e.g. numerical multiplication), without considering the kind of activity system in which the learner's 'knowledge' is to be evaluated is in essence meaningless [3]. According to Greeno, "learning that occurs in one kind of activity system can influence what one does in a different kind of system, but explanations in terms of overlapping aspects of activities in practice are much more promising than explanations in terms of transfer of knowledge structures that individuals have acquired" [3].

This situative approach focuses on the importance of the activities that take place in different learning environments not only because of the variations in how effectively they teach content knowledge but also due to the fact that participation in practice is an important part of what students learn. Learning environments should provide opportunities for the students to participate in such practices [3]. Therefore, it seems logical how some knowledge – that has been formed in a particular situation (i.e. context) might be difficult to transfer. The significance of the situated learning theory is that a

well-designed (i.e. meaningful) learning context increases transfer to another context.

There are some underline themes that are emerging as to how learning has changed nowadays, how it could be defined in the digital era and whether there is anything innovative in education. There is currently a shift towards learner-centred approaches as opposed to the previous teacher-centred ones. Furthermore, researchers are attempting to explore whether the definition of knowledge has changed and how learners could construct knowledge today. Learning theories are underpinned by epistemological beliefs and therefore as ideas about knowledge evolve learning theories evolve too [5]. The way knowledge is perceived changes over time and between contexts and as a result perspectives of knowledge and learning theories will carry on influencing learning in the 21st century and beyond [5].

The 21st-century digital era signifies the need for a learning theory that focuses on knowledge creation and knowledge community and where the role of the teacher translates into the mediator between the learners and the knowledge community. As Harasim highlights, "the challenge is how to engage learners in creative work with intrinsic rewards, within the context of the Internet and the Knowledge Age, and how to bring the gap between 21st-century environments and 20th-century pedagogies" [6]. The 20th-century pedagogies "focused on narrow individualistic tasks with simple sets of rules and clear destinations" while the 21st-century age focuses on "creative, conceptual work where there is no clear right or wrong answer, or where there may be many right answers", requiring learners to collaborate in order to indentify or create the best possible option.

3. Learning at the 21st Century School

3.1. Connect

We are currently living in the digital age where learners can connect and collaborate with other learners (or people in general) beyond their physical environment. Today, the plethora of information and ideas rapidly available to each of us through the Internet is remarkable when compared with access in the past [6]. Siemens developed a learning theory for the "digital age" that aims to take into consideration "how people, organizations and technology can collaboratively construct knowledge" [5] [7]. This theory is called connectivism. "Connectivism is driven by the understanding that decisions are based on rapidly altering foundations. New information is continually being acquired. The ability to draw distinctions between important and unimportant information is vital. The ability to recognize when new information alters the landscape based on decisions made yesterday is also critical" [7].

A learning theory for the digital age needs to examine learning as a continuous process within a complex environment. The continual growth of knowledge as innovative connections open new interpretations and understandings to create new knowledge plays a crucial role in this theory [5]. As a learning theory, connectivism is still being developed and evolved through online debates and discussions. Connectivism maintains a significant role in the emergence of new pedagogies as nowadays control is shifting from the tutor to a progressively more autonomous learner [8].

Siemens asks how learning changes when knowledge growth becomes overwhelming and technology replaces many basic tasks we had to perform previously (without technology) [9]. "The connections that enable us to learn more are more important than our current state of knowing. Connectivism is driven by the understanding that decisions are based on rapidly altering foundations". It offers a new perspective of how learning takes place in the digital era. It is the application of network principles to define both knowledge and the process of learning. Such networks could be internal (e.g. neural networks) and external (networks in which we communicate) [10].

Through the Internet and digital revolution people interact with others all over the world and the online communication has transformed the way we learn and the way we create knowledge collaboratively [7].

3.2. Collaborate

In the same way that Siemens suggests a new learning theory, Harasim emphasises the need for a theory of learning for the 21st century [6]. Harasim introduces a new theoretical perspective, Online Collaborative Learning (OCL) in order to address the need for "a theory of learning that emphasises knowledge work, knowledge creation and knowledge community" and the fact that "the speed of intellectual change and knowledge construction has increased". Through to the Internet and digital revolution people nowadays interact with others all over the world and the online communication has transformed the way we learn and the way we create knowledge collaboratively [6].

While Harasim accepts that Online Collaborative Learning theory encourages the learner to be active and engaged, she does not believe that this is sufficient for knowledge construction and learning as the role of the teacher is not taken into account [6]. On the other hand, in the Online Collaborative Learning theory, the role of the teacher is very important as the teacher becomes the link to the knowledge community. A key aspect of knowledge

creation, according to the Online Collaborative Learning theory, is discourse. Collaboration and discourse are crucial aspects in building knowledge and this theory attempts to introduce the learners into the processes of conversation i.e. discourse employed by knowledge communities to construct knowledge and develop ideas [6].

Technology is offering new ways for individuals to communicate and share information as well as constructing new kinds of knowledge. Such technologies can reconnect formal and informal learning. Outside formal learning (i.e. school environment) children are empowered by personal devices and technology [11]. They communicate and they collaborate through social networking which enables them to develop powerful skills. However, within the school there are still limits as to how children could engage with such digital activities. Collaborate learning becomes more and more important for students. Technology supports such experience in a powerful way unlike in the past when the research community investigated whether educational technology in the classroom would isolate students! [12]. Today not only it can encourage students to work together but most importantly it can help them learn about things that would be difficult to learn alone [12].

In the primary school classroom, collaboration is a significant factor towards positive learning outcomes. Technology can create networks within and outside the classroom as well as make use of communities and social interactions outside the school. As Luckin et al highlight, although there is currently a significant number of research innovations on this type of learning, i.e. learning with others, such ideas have not filtered through to classrooms [12].

3.3. Create Knowledge in the Digital Era

At school, children develop knowledge a) within the constructivist learning theory and b) within the learning theory of connectivism i.e. through connections and analysis [5]. In the digital age the growth of accessible knowledge is exceptional. Starkey believes that although students will continue to need to learn subject based concepts (for example, regarding mathematics: trigonometry, numbers, fractions, etc or regarding science: atomic structure, force, circulatory system, etc), skills and methodologies, they will also be making the connections between and across subjects and as a result create knowledge [5].

A practical example could be addressing a mathematical principle such as long multiplication. Having been first taught in class of long multiplication, children could then work in small groups producing video footage of the teacher demonstrating how the mathematical principle work and then the children themselves could create a commentary that describes what is happening [13]. Once this is done it could be then uploaded to an online resource such as Teacher Tube (this is a media sharing website such as YouTube but for educational purposes). The groups then could watch the videos in class and critique them (for example, identify the most effective elements, etc) with a final goal to decide on a single video/podcast. Such activity combines video and audio through which students could demonstrate their understanding of a process, while using (and perfecting) an appropriate mathematical vocabulary. Such in class activities through the use of digital/online technologies (e.g. use of podcasting, publishing resources online, digital story telling etc) could support children's development as producers of knowledge.

Further research is needed in order to explore how such technologies could help stimulate students' creative potential and how it could support collaborative work among students in order to form learning communities. "This is not simply a question of producing materials, the mechanical process of editing and publishing a photograph for example, but how these kinds of activity can aid in the development of understanding in the attainment of curriculum objectives" [13].

This type of knowledge creation could be powerful within (and beyond) the classroom context. Understanding how knowledge is constructed with educational technology and reconsidering what does learning mean in the 21st century is crucial.

We are currently witnessing a) a reconfiguration of pre-existing learning activities and opportunities for the majority of children and b) some genuinely (although very limited) new learning opportunities focusing on possibilities of child-oriented digital creativity and on collaborative communication with those who share like-minded interest and expertise [14]. If we succeed in embedding such learning opportunities within the school and curriculum the benefit of all children will be substantial.

Educational technology can help formal learning by providing opportunities to apply and use mathematics in real-life problems and everyday contexts, to make connections across the different areas of the subject. For example, technology could help students interpreting a wide range of mathematical data (e.g. in graphs, diagrams, spreadsheets) in order to recognise patterns and trends. At the moment the opportunities for powerful data visualisations are great. It could also help learners applying logic and reasoning in order to predict, plan and test ideas and options. Mathematics in school has often been perceived as hard, too abstract and complex to grasp and understand. Technology has the potential to control or simplify such complexity through powerful visualisations, manipulation and modelling that

could facilitate understanding as well as offer imaginary worlds where learners could try out ideas [15].

Beetham and Sharpe highlight that the effectiveness of technology in relation to pedagogy involves issues of value [16]. Similarly to the way educational technology is altering the way knowledge is value within our society, it is also altering the way we value diverse kinds of learning and achievement and diverse models of "learning organization".

3.4. Contextualise

The nature of context is crucial for someone's development and different contexts will lead to different social interactions and consequently to the development of different mental processes within the individual [2]. Luckin defines a learning context as an ecology of resources: a set of inter-related things/elements that provide a particular context [17].

Past research has confirmed the importance of exploring the learner's context but has been largely limited to specific environmental locations. Nowadays, the capacity to create learning context is widely available and the challenge is to develop ways in which technology can support learners to effectively create their own learning contexts [17]. At the same time, the main purpose should focus on the interactions that need to be supported before proceeding with identifying appropriate types of technology and what role they might play [2].

There is no doubt that the context in which learning takes place has a significant role in this learning. Context is an essential part of our psychological development. Many teachers appear to use computers in isolation from a meaningful context and they focus on the development of computer awareness instead of integrating the computers (and technology in general) as tools into their teaching and learning across the curriculum [18]. During an empirical study in a school environment there was an indication that children might experience some form of anxiety due to unfamiliarity with the applications in relation to the required task they had to perform or even with the computer environment in general [19]. In that particular case, although the school was using at that time a couple of computer applications related to mathematics the children were not using these applications during their mathematics class but only sometimes during their Information and Communications Technology (ICT) class. Therefore, these students lacked important experience of using such applications in acquiring mathematical thinking and understanding.

Despite significant investment in educational technology in UK schools, the evidence from the classroom suggests that there is still emphasis on using applications mainly as presentational, visual and computational aids instead of "instruments to facilitate mathematical thinking and reasoning" [20].

However, there is a need to use technology at school to acquire a better understanding of how children learn and consequently help children to learn better. There is no technology that has an impact on learning on its own. This depends on how it used. In order to address this further we provide a set of recommendations below that we hope will be relevant to educators, researchers, policymakers and the IT industry.

4. Recommendations

4.1. Empowering Teachers to Become Orchestrators of Children's use of Technology in the School Classroom

Teachers should be confident enough of the significant role they have in creating learning opportunities through educational technology that children may otherwise not have the chance to participate in. Teachers need to support and scaffold children's learning through technology. However, in order for them to be able to do the above within their current increased workload, they need support themselves and suitable provision to be in place. The need for continuing professional development offers a great opportunity for schools and industry to work together towards keeping on updating the technical skills of teachers who they will then be able to explore the full potential of the educational technology available in their classroom and school.

Teachers should be encouraged to share among colleagues best practices as well as have the time to try and explore new educational tools that they could not only use in class afterwards but most importantly they could become inspired to use these tools in innovative ways and improvise.

There is no doubt that there has been a great enthusiasm on the transformative potential of educational technology supported by specific research or practice-based evidence. At the same time, somehow educators continue to only make inconsistent use of technology for a number of reasons, such as technical, professional or personal [1]. Therefore, there is an urgent need for greater change regarding governmental, political, institutional arrangements and policies in order for school teachers to be able to have the opportunity to become orchestrators of children's use of technology in the classroom. It is not enough to be repeatedly given a number of justifications of the lack of impact such as lack of funding, resourcing, bureaucracy or generally blame teachers for resisting innovation [1].

Technologies such as tablets and other mobile devices combined with learning analytics could offer

new affordances for collaborative learning in the classroom since they could provide teachers with better control and awareness about classroom performance.

Learning analytics allow teachers enhanced access to the way students have discussions (in relation to subject matters) online and as Laurilard highlights, such data and analytics can describe how students progress through a course of learning activities and as a result "the teacher can learn about teaching from their exchanges with students" (p.xviii) [21].

4.2. Empowering Ideas Through Technology to Become Learnable and Meaningful

Children need to learn at school the new things that matter in the 21st century and we need to find new ways to teach and assess them. New technologies (like tablets, mobile computers and powerful visualizations) have the potential to turn the "unlearnable" ideas into learnable and we should find new ways to represent such ideas [22].

Research should guide the production of educational technology that fosters learning and transfer of learning i.e. empowers children to apply what they have learned at school to real-life problems or situations.

Looking at the role of educational technology on children's learning at school should not be confused with looking at commercially successful educational technology trends. As Buckingham et al explain, "what counts as a valid educational use of technology is, it would seem inextricable from what sells" [23]. Livingstone, shares a similar view and calls for "a shift in the entire educational establishment as well as its relation to the home, state and the private sector" [14]. This is why there is need for teachers, researchers and industry to work closely together.

4.3. Facilitating Close Collaboration Between Academia, Schools and Industry

It is important that industry, academia and schools work together to explore ideas, evaluate and try different types of technologies (hardware and software) as early as possible in order to identify the strengths or weaknesses of such technologies and consequently end up with a real educational product in the market. Unfortunately, it appears that currently very few such commercial products are backed by rigorous academic research and clear evidence of their educational effectiveness. More effective interaction and collaboration between researchers, industry and teachers is needed towards innovation on educational technology.

4.4. Empowering Children to Apply Mathematics in Real-Life Problems and to make Connections across the Different Areas of the Curriculum Subjects

Teachers and researchers should try and understand how children use digital technology outside the classroom in order to overcome any divide between these two different settings. As Noss emphasises, "what people learn in formal education has to be as powerful and engaging as they do at home" [22]. We should also aim to study further learning through technology of what matters (i.e. what counts as learning) in the 21st century.

Technology could provide opportunities to apply and use mathematics in real-life problems, to make connections across the different areas of the subject.

There is still lack of strong evidence regarding the impact of educational technology on mental and cognitive development and performance remains so far mixed and inconclusive. Therefore it is important to highlight that:

- We should not judge educational technology on such outcomes/impact and such perspective might be incorrect.
- A more appropriate question to ask could be: how can technology support learning that would not otherwise take place?

The President of the Royal Society, Paul Nurse, emphasised in a report that analysed the current state of computing education in UK schools that we need "to ensure that the next generation of young people in this country can be creators of technology – not just consumers of it" [24].

It is time that we use the capacity of the current technology to really meet the needs and requirements of education. As Noss et al state, for a long time until now "learning has been subsisting on the crumbs of technologies designed for other purposes [11]. It is too important and too complex for that to continue". The power and uniqueness of current technology could be understood if we use it in order to teach school children ideas and topics that are currently difficult to understand or even "unlearnable" because of the way they are represented; a view shared by other researchers [25].

4.5. Matching Specific Types of Technology with Specific Types of Learning

It is also important to match specific types of learning and learners with specific types of technology. As Selwyn points out, there is no "one-size fits-all" solution for applying technology to learning [1]. Technology in education should not be offered as "a solution in search of a problem" [1]. As educators, we should use technology to solve a specific problem (e.g. ask what can the technology

do for us?), not finding the problem that the technology is a solution for (i.e. rather than asking what can we use the technology for?) [25].

As Mayer highlights, different people learn in different ways and therefore it is recommended to present information in various formats [26]. New and emerging technologies provide great opportunities in achieving this (e.g. Augmented Reality or embodiment and ubiquitous computing, gesture or tactile interfaces etc). However, the focus should always be on the learning activity and not the technology [13]. New technologies can facilitate learning if they are specifically designed for specific kind of activities and domains of knowledge.

As Sutherland emphasises, learning within a subject area involves learning about the discourses, practices and tools related to the specific subject discipline [27]. In a school environment students have the opportunity to participate together with their teachers who are more experienced and who can provide support in exploring new subject domains. Knowledge in mathematics and science appear to share characteristics that may not probably apply in other disciplines. For example, such knowledge is rigorously articulated; it has gained a high degree of consensus and there are detailed representational formalisms to represent such knowledge. Knowledge in history, art or literacy is likely to be different and consequently, these latter forms of knowledge may be learned in fundamentally different ways than the former [4].

Knowledge is not just a list of unrelated facts but it is connected and organised around important ideas within a discipline and includes information about the appropriate conditions for applying key concepts and procedures [28].

The potential of learning becomes clear when we consider the possibilities of the new and emerging technologies such as tablet computers, mobile devices and ubiquitous computing in new and innovative ways of knowledge construction. Researchers at Brown and California universities developed an embodied-interaction instructional design, the Mathematical Imagery Trainer (MIT), in order to help young students develop grounded understanding of proportional equivalence (e.g., 2/3 = 4/6). MIT has taken advantage of the low-cost availability of hand-motion tracking (e.g. Nintendo Wii remote) and involves an application of cognitive-science findings that mathematical concepts are grounded in mental simulation of dynamic imagery that is acquired through perceiving, planning and performing actions with the body [29]. The early results from this research study concluded that remote manipulation appears to be an opportunity for the mind to reflect on what the body could already do. Interestingly, this research concluded that an educator should also be present as they could play a critical role in the learning process with the MIT application.

5. Conclusion

Learning in the 21st century primary school could be significantly enhanced if children are able to use innovative and powerful technologies to construct meaning and enhance their learning experience. However, in order to achieve this, there is an urgent need to start considering the requirements of education and then challenge technology to meet them [27]. As Laurilard argues, with learner access to the increasing online resources and advanced digital skills “we should remodel education so that learners can take control of their own learning” (p.xvi) [21]. At the same time, learners need guidance.“Pedagogy is about guiding learning, rather than leaving you to finding your own way”, (p. xvii).

Lastly, we should also consider what Selwyn points out; that “the implementation of technology in educational settings is the result of human actions, decision-making, expectations and institutions – not simply the result of the relentless march of educational progress” [1].

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