DigiMaths Literature Review

1. Introduction

As the 21st century progresses, technology is having more and more impact on the daily lives of individuals throughout the world. The way in which individuals interact has changed dramatically in recent times through the rising use of computer mediated communication and emerging digital technologies (Fullan & Langworthy, 2014). Such changes are evident in all aspects of life and education is no different. Students increasingly expect to be able to access information, and interact with course work wherever and whenever they want. Furthermore the emergence of technology has coincided with a philosophical shift in classroom teaching and learning approaches. This shift is particularly evident in mathematics education. Traditional 'talk and chalk' and 'paper and pen' methods of teaching mathematics are being replaced by innovative, practical methods, many of which are supplemented by a digitalised, interactive approach (Parmar & Rathod, 2014).

2. Benefits of Integrating Technology in the Mathematics Classroom

The importance of using of technology to support mathematics learning is now widely recognised (Bennison & Goos, 2010). "Technology is essential in teaching and learning mathematics, it influences the mathematics that is taught and enhances students learning" (NCTM, 2000, p.24). Through the use of technology teachers have the opportunity to promote students' learning of mathematical concepts through new and exciting techniques. It enables students to concentrate on more interesting and important aspects of content (Oldknow & Taylor, 2000) and can also facilitate their understanding of relationships among numerical, graphical, and algebraic representations. The flexibility and capacity of software programmes such as Microsoft Excel, enables teachers and students alike to be involved in meaningful mathematics activities such as analysing, organising and exploring data. Advanced mathematics computer packages such as DERIVE and GeoGebra are vibrant, dynamic software, which in addition to being more interesting and enjoyable for the students, often lead to better understanding. Furthermore such technologies enhance the opportunity for individualised and group learning, both inside and outside the classroom (Lawrenz, Gravely & Ooms, 2006). Through tools such as discussion boards and chat rooms, students are able to interlink with students of their own age and abilities in other parts of the world. Virtual classrooms can be entered anywhere at any time. Sinclair (2005) in her account of mathematics on the internet suggests that it provide opportunities for curious students to investigate non-school related mathematics independent of the school situation. The use of digital technologies in mathematics education can also allow for diverse routes for learners to solve problems and reach their goals (Hoyles & Lagrange, 2010), giving students control over their progress through the material (Olive et al., 2010). This is particularly beneficial for students who are unable to mainstream into regular classrooms, as well as those students who wish to learn at their own pace (Santoro, 1995). Such flexibility can enable individuals to assume greater responsibility for their own learning and according to Handal and Herrington (2003), foster a culture of self-learning, problem solving, and activity-based learning. Furthermore supporting students' autonomy over their learning in this manner has the potential to strengthen their mathematical confidence and increase their enjoyment of the subject (Noss et al., 2009).

3. Barriers to the Integration of Technology

Although the potential for mathematics teaching and learning to be transformed by the availability of digital technologies such as computers, graphics calculators, and the Internet is well accepted, research in many countries has found that technology still plays a marginal role in mathematics classrooms (Bennison & Goos, 2010). While students undoubtedly engage in the creative use of digital technologies on a daily basis, they do so less frequently in an educational context (Oldknow, 2009). In many educational settings technology is still frequently used as it was in the 1990s, to simply convey information to students (Conole, 2008) and to "transfer the traditional curriculum from print to computer screen" (Kaput, 1992, p. 516). In order to explain this, Knezek et al. (2000) found several barriers to the integration of technology in classrooms. These included cost, access and logistical problems. There are also issues centred on the confines of curriculum and assessment and the structures imposed by the infrastructure of the educational organisation (Oates, 2011; Olive et al., 2010). However while all of these factors play a role in discouraging greater use, it is teachers' lack of skill and confidence and their uncertainty about the benefits of technology for students' mathematics learning that may be most significant (Olive et al., 2010). Means (2010) points out that many teachers will only expend the effort required to integrate technology into their teaching practice when they can see that there are significant benefits in terms of learning outcomes.

4. Overcoming these Barriers

Many of the barriers mentioned in the previous section, although complex and wide ranging, can be overcome. There is no doubt that access to digital technologies has increased considerably in the past two decades. For example in March 1998, only 17% of primary schools across the United Kingdom (UK) had access to the Internet. In 1999, this figure had risen to 62% (Wheeler, 2001). However the availability of technology in a classroom environment will not necessarily ensure its effective use (Geiger et al., 2010; Olive et al., 2010). The curriculum must be developed to work as a mediation for these technological tools. Dick and Hollebrands (2011) state how the strategic use of technology strengthens mathematics teaching and learning within a balanced mathematical programme. In addition, as discussed in the previous section the role of the teacher is fundamental for the facilitation of any resource. Olive et al. (2010) make the point that "it is not the technology itself that facilitates new knowledge and practice, but technology's affordances for development of tasks and processes that forge new pathways" (p154). Teachers must be equipped with the skills to decide when and where to use the tools in order to enhance students learning effectively. This is not a trivial task (Conole, 2008) and is where professional development for teachers in the use of technology must come to the fore. Teaching is a complex practice that must be learned and continually improved (Ball, 2001). Mathematics does not remain static and changes in technology impact both on the subject matter and on possible modes of teaching and learning. Hence teaching must be a lifelong, active process, starting with initial training and continuing until retirement (Ball, 2001). The aid of effective professional development is essential in providing teachings with ongoing opportunities to upskill and develop their practice. Such opportunities are not readily available and this is one of the main challenges facing education at present (Smith, 2004).

5. Lessons to be Learned - A Focus on Algebra

Perhaps more than any other area of mathematics, the study of algebra has the possibility to change dramatically through the introduction and use of currently available and emerging technology. In a technological world, algebra more than ever, becomes a language of representation using a function approach (Heid, 1995). Students have free access to graphing tools, to symbolic – manipulation programs, and to spread sheets of ever increasing sophistication. Such technology allows a shift towards more conceptual understanding and meaningful representations of functions, variables and relations. Oates (2011) highlights that the use of technology can change the relative value of routine algebraic skills, often reducing their usefulness and even questioning their place in the development of mathematical knowledge. Lesson after lesson of 'simplify these expressions' or 'solve these equations', may no longer characterise the school algebra experience. Such symbolic manipulation, which is a treasured skill of the traditional curriculum, can now be carried out by the click of a button (Macgregor, 2004). However, while such technology can open the door to many exciting new possibilities for teaching, it also has the potential to diminish some algebraic skills. An example of this occurred in France in the mid 1990's where the use of DERIVE in classrooms became widespread and led to a situation where students were doing hardly any symbol manipulation (Sutherland, 1997). The hope was that, in focusing on algebraic understanding, the techniques would take care of themselves. However this was not the case. Researchers found that the teachers were emphasising the conceptual elements while neglecting the role of the procedural work in algebra learning (Kieran, 2004). However this was producing neither a clear understanding of the procedural aspects, nor a definite enhancement of students' conceptual understanding, "*easier calculation did not automatically enhance students' reflections and understanding"* (Lagrange, 2003 as cited in Kieran, 2004:28). While routine mathematics procedures are often stripped of meaning, they do require many favourable traits and skills from students and are vital in progression to more complex areas of mathematics. Hence while the use of digital technologies are undoubtedly beneficial, they should not prevent teachers focusing on basic mathematics skills and procedures (Sutherland, 1997).

6. Surveying the Technological Landscape

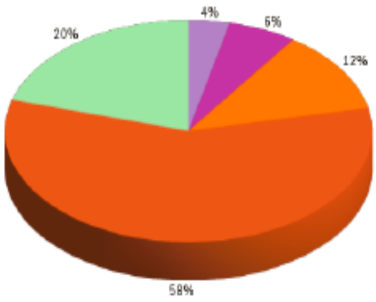
The importance of using technology to support mathematics learning is now widely recognised (Bennison & Goos, 2010). Hence its use in mathematics education is becoming increasingly prioritised in international curricula (Geiger et al., 2010). This section will survey the technological landscape of a number countries involved in this Erasmus + research.

6.1 Denmark

The new curriculum for the Danish school system (primary and lower secondary) contains many learning-goals involving digital technologies. The government has focused on this since 1993, but the schools are not capable of buying hardware for 'one-to-one' teaching. Some schools/provinces are providing the pupils with hardware until grade 7 or 8, and from there they have to bring their own device. Other schools/provinces do not provide 'one-to-one', but buy some PC's that can be booked and brought to the classroom for some time. In high school, almost every student brings a PC – if not, they must buy one through the school. Everybody uses PC's in high school. If the schools or provinces want to buy software, the government pays half the price if a department in the Ministry of Education approves the software. In teacher training, students have to work with different programs and part of their assessment is on a PC.

In vocational education it is an overall part of the legislation that digital tools must be included in the teaching wherever appropriate. In most trades, digital solutions are a part of the aims and goals, because the use of specific digital tools is a part of the profession that must be learned. For example, there are many vocational educations that use CAD-programs for drawing. These develop every year and demand quite strong PC's. The vocational schools are therefore relatively well equipped, because they need to be updated with the technology of the vocations. Teachers are encouraged to use digital technologies as a didactical tool to improve learning in the various subjects. For example the teacher in mathematics is obliged to include the mathematics used in the specific trade, where he teaches, and to plan his teaching so that it connects to that of the teachers in the other subjects in a holistic way. Therefore the vocational math-teachers tend to use the same digital programs that are already in use in the trade, i.e. CAD-programs or spread-sheets. In the higher levels the introduction of CAS-calculators or CAS-programs such as TI-Inspire is increasing. The use of digital solutions as a didactical tool to improve the learning of mathematics varies a lot, not only from school to school, but from teacher to teacher. Most schools have a digital strategy, but it is implemented differently within the different subjects and educations systems. Danish legislation in the vocational area is a framework for the schools to fill out, so it is much up to the schools to decide, how they teach and what tools they use. Furthermore vocational education is be free for the student, so the digital equipment must be provided by the school. Yet students, who prefer to use their own, are allowed and can have the programs on these. Teachers in mathematics may use equipment, which the students already possess, typically smartphones.

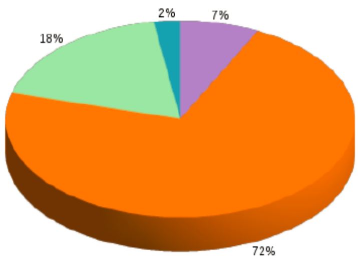
A recent study Danish conducted by Bundsgaard and Hansen (2016) investigated into what happens to the way teachers teach, when digital technologies are involved in teaching in primary and lower secondary. The results are worrying given that 75% of the time, pupils are sitting doing tasks on their own.



Matematik

Pupils telling
pupils reading
Working in groups
Working in groups with common responsibility
Working individually
Working individually in groups
Teaching a whole class
Different activities

In connection to this the study also found out, how the time was spent on:



No particular kind of task
Tasks made including problem solving
Training
Real world problems

Teachers are improving their skills in using digital technologies by courses either at CFU, or at their own school, where CFU consultants in maths and digital technology are paid to teach some afternoons during a period.
A recent report from the OECD (2012) has found that digital devices are becoming more commonplace in schools. In 2012, more than nine out of ten 15-year-old students in Denmark used computers at school at least on a weekly basis. However, there is no positive association between the extent to which computers are used at school and students' performance in mathematics (OECD, 2014).

6.2 Finland

There have been multiple national studies during the past years made in Finland about the use of ICT and digital materials and the teacher education for using digital technologies in Finnish schools. Also several European studies on digitalisation in education include results from Finland. A study by the European Commission: Survey of Schools: ICT in Education (2013) showed that in Finland there are more computers for students in primary, secondary and upper secondary schools compared to European average and the situation was good especially in vocational education. Furthermore, the Finnish schools have high levels of virtual learning environments and a smaller number of students per interactive whiteboard, digital camera or data projector, in general ICT devices of high quality, fast Internet connections and experienced teachers with ICT who have confidence in their use of social media. Despite having high levels of equipment in classrooms, students in Finland at some grades, however, stand out on a European level as least likely to be using technology in lessons. Reasons for not using ICT were reportedly timetable issues and that teachers do not always agree about the relevance of ICT use for learning processes. The students' opinions were most frequently positive, especially in vocational education, towards using ICT at school. The national Trade Union of Education in Finland made a nationwide study in the autumn of 2015 on the state of digitalisation in education from primary school to universities. The study that surveyed over 1500 teachers and education professionals showed that teachers have in general a positive attitude towards digital technologies and the majority of them thought that ICT brings more pros than cons in teaching, but the challenge is the need for teacher education in this area. Although most teachers participate in further training courses organised by the employer, these courses are often short term or seminars. According to the European Commission study, in Finland the use of ICT has been taken well into account on a strategic level in general, even better than in average in the EU. In the autumn 2016 a new national curriculum for compulsory education is launched. The Finnish Government has prioritized digitalisation of education as one of its top projects and aims to develop learning surroundings and digital learning in education in Finland and also develop teacher education in this area. Government initiative is made to ensure equality in education, that students at all levels around Finland have equal possibilities to learn through digital media. Finland is known to have high rankings in PISA results. Interestingly, an OECD (2015a) study looked into the connection of using ICT and PISA results. The results showed that there was not so much difference in learning results in literacy, mathematics or natural sciences skills in countries that invest heavily in ICT in teaching. Even though the ICT use at school is more common in general in Finland than the OECD average, Finland, together with other high-performing countries in PISA, show the least frequent use of computers in mathematics lessons. Even though evidence from PISA only shows a weak association between the use of ICT on mathematics lessons and performance in mathematics scale, the ability to use computers as a mathematical tool, a skill that is often assessed in the computer-based assessment of mathematics, appears to benefit to a certain degree from greater use of computers in mathematics classes.

6.3 Ireland

In the Irish context, recent years have seen a particular focus on digital technology, with The National Digital Strategy for Ireland highlighting the centrality of ICT and e-learning developments and potential across the education system (DCENR 2013). However, this followed a period of relatively little focus on this issue – with a considerable lag between the expiration in 2003 of the Blueprint for the Future of ICT in Irish Education (2000) and subsequent national policy papers. This lag in policy turned into practice. Comparisons drawn in 2003 by the OECD for 15 year olds in 30 countries revealed that Ireland had the highest proportion of students (49 per cent) who made 'rare or no use' of computers in school (PISA, 2003). Mulkeen (2004) confirmed this by reporting that just 17 per cent of post primary schools used ICT in mathematics monthly or more in the year 2002. In 2004, the Broadband for Schools Programme was launched as a means to 'significantly enhance the potential of ICT in teaching and learning' (DCMNR 2004). Beyond small scale pilot work, the role and potential of ICT in education received relatively little focus until some years later. In June 2009, as part of The National Digital Strategy, the 100Mbit/s broadband initiative for post-primary schools was announced. The role of ICT in education was subsequently emphasised by the Next Generation Broadband Taskforce which recommended that government continue to invest in broadband for schools and that 'digital skills be a fundamental part of the school curriculum' (DCENR 2012). A recent Irish study carried out by Coyne et al. (2016) found that approximately half of teachers use ICT to support different learning styles and 39% to support students' own-pace learning. This supports Gleeson, Johnston and McGarr (2001) earlier findings that Irish teachers are using ICT to enhance their existing pedagogies but are not yet fully exploiting the potential of ICT for innovative teaching practices.

6.4 Northern Ireland

A key priority for the Department of Education (DE) in Northern Ireland is that all children and young people develop the skills to use ICT effectively, confidently and safely. In order to achieve this, ICT is an essential component of all the current education policies implemented by DE such as the curriculum and the literacy and numeracy strategy. From 1 April 2012, DE, through the Education Authority has supported the infrastructure and services required to deliver Europe's first education cloud environment to schools across Northern Ireland. Teachers and learners are able to access the 'digital classroom' and resources 24 hours a day through any internet connected device.

<u>Cross-curricular skills</u>

Since September 2012, assessment of the cross-curricular skill of Using ICT has been in place. Schools are required to assess and report on learners' progress in Using ICT at the end of Key Stage 3 (approximately 14 years of age).

At Key Stage 4, learners studying the General Certificate of Secondary Education in mathematics are specifically tasked with developing effective ICT skills in a wide range of contexts to access, manage, select and present information, including mathematical information such as: researching data online; analysing data and working with formulae in spreadsheets; and, using various software applications such as GeoGebra to explore geometry and algebraic functions.

<u>Current developments – Literacy and Numeracy Key Stage 2 and Key Stage 3 CPD Project</u>

A major professional development project, funded by DE, has been rolled out across Northern Ireland. The project began in September 2014 and will last two years. One of the main aims has been to promote the development of high quality teaching and learning with a focus on innovation in practice and improving provision for learners. Post-primary mathematics teachers have received two days of training and opportunities to share best practice in more innovative approaches to teaching and learning through the use of digital technologies. The evaluations to date have been very positive and encouraging.

6.5 Scotland

School-age learning

In Scotland, Curriculum for Excellence (CfE) is the curriculum set out by the Scottish Government for children and young people from ages 3 to 18 years.

CfE identifies curriculum subject areas and also identifies learning that should be delivered across all subjects. One of these subjects is numeracy and this means that numeracy is the responsibility of all teachers, no matter what their subject specialism may be.

Glow is Scotland's free-to-use schools intranet, used for teacher professional development as well as delivery of learning to learners in schools:

> Glow helps learners to benefit from social and collaborative tools and services in a safe online space through the use of technologies that are already embedded in daily lives.[1]

The Scottish Government plans to publish a digital learning and teaching strategy in summer 2016, and focuses on the use of digital technologies to deliver learning in schools in Scotland.

Scottish Survey of Literacy and Numeracy 2013 (Numeracy)

The Scottish Survey of Literacy and Numeracy is a sample survey which monitors national performance in literacy and numeracy in alternate years. The survey assesses pupils at Primary 4 (P4, age 8-9), Primary 7 (P7, age 11-12), and Secondary 2 (S2, age 13-14). 10,500 pupils and their teachers in the 2,200 schools took part in Scottish Survey of Literacy and Numeracy 2013 (SSLN 2013).

In 2013, around 70% of P4 and P7 pupils were working well in numeracy at the relevant Curriculum level for their stage. This figure was lower for S2 pupils, with about 40% of pupils working well. At P7, boys were found to have performed better than girls, but there were no statistically significant differences at the P4 and S2 stages. Pupils living in areas of least deprivation were more likely to be performing well than pupils living in areas of most deprivation, across all stages. The disparity was largest at S2, where the proportion of pupils performing well from the least deprived areas was almost 30% higher than pupils from the most deprived areas.

At both P4 and P7, there were statistically significantly lower levels of attainment in 2013 compared to 2011. The difference in S2 performance between 2011 and 2013 was negligible.

Enjoyment of learning was high throughout the survey stages with over 85 per cent of pupils agreeing with the statement 'I enjoy learning'. The percentage of pupils was highest in P4 and decreased as stage increased. Pupils were also asked about their enjoyment of working with numbers and the responses to this showed a similar trend to learning in general.

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1 http://www.educationscotland.gov.uk/learningandteaching/approaches/ictineducation/glow/index.asp

Adults

Scotland's adult literacy and numeracy strategy, *Adult Literacies in Scotland 2020: strategic guidance (ALIS2020)* states that all learners must be entitled to high quality and effective learning programmes. It states:

> E-learning (using a range of technologies including computer-based learning, web-based learning and virtual tuition) can help learners progress more quickly in their learning and extend the scope of learning. Learning can be customised to meet the needs of individuals in terms of time, place and pace. Many learners may also need support to develop their IT skills in order to successfully access these modes of learning.

ALIS2020 requires that:

- learning environments are 'fit-for-purpose' for adults, and are accessible and appropriate for learners' needs; and
- learners have access to high quality resources including e-learning technology

Greater than the Sum

Greater than the sum … Report of the action research project: The Use of ICT in Adult Numeracy Teaching in Scotland, Phase 2 (Coben et al., 2007) was an action learning project to develop the skills and reflective capabilities of adult numeracy workers in adult learning (including colleges) in Scotland. One of its conclusions was that pedagogical skills are more important that the teaching resources being used: in other words, digital technologies would not make teaching and learning more effective unless the teacher is skilled in teaching and learning, and in the use of digital technologies.

Digital Agile National Principles

Adult learning in Scotland is embedded within policy for Community Learning and Development (CLD), alongside youth work and community development. A partnership project in Scotland has developed "digitally agile" national principles for people working in CLD. These guide professional practice in the use of digital technologies for a sector working with many disadvantaged people.

6.6 Switzerland

On the political and legal level, the Swiss Federal Council has put in place a national strategy in 2016 to ensure that Switzerland can benefit from increasing digitization and develop even more dynamically as an innovative national economy (Federal Council, 2016). At the same time, the Swiss government has launched a national "e-Inclusion" action plan for the period of 2016-2020 to promote equal participation and digital opportunities for all (Bundesamt für Kommunikation BAKOM, Biel, 2016). When it comes to the ICT promotion in schools or in adult education, the legislations and the practice vary highly within Switzerland due to the fact that education is in the responsibility of the federal states, the cantons.

The Swiss context indicates a high rate of ICT use. The infrastructure has quite constantly evolved as well as the use of the internet through the Swiss population, which is above the EU average. Still there are some differences in the use of ICT depending on the gender, age, income, educational level, employment and language region (e.g. 10% less in Italian-

speaking part compared to German-speaking part). (Bundesamt für Statistik, Neuchâtel, 2016).
As to the ICT competences[2], 27% of the Swiss population is estimated to have no ICT-experience at all or is beneath OECD level 1 "basic user". A low level of ICT correlates highly with an increased age, a low level of basic skills and a low education level (OECD, 2015). Even if there exist strategies on the national level, the biggest challenges remain the lack of funding to implement these strategies and the political fragmentation due to the federal structure of Switzerland.
When it comes to the use of ICT in schools, the PISA studies have had little impact on a national level. Only few national recommendations were made concerning the integration of ICT-teaching in initial and continuing professional development of teachers and on all school levels in all disciplines as a pedagogical and didactical resource. Also in schools, the use of ICT is higher in German-speaking Switzerland compared to French- and Italian-speaking Switzerland.

Looking to the Future

There is little doubt that technology has the capacity to refine classrooms and encourage new forms of practice (Olive et al., 2010). However the simple addition of technology to a classroom is not enough to instigate educational change. A recent report by the OECD (2015a) determined that students who use computers very frequently at school do "a lot worse" academically than students who use them moderately. This backs up the notion that traditional teaching methodologies and new digital technologies must be incorporated together. Both can certainly benefit from each other's existence. The use of the calculator in the mathematics classroom is one such example. This was evidenced more than thirty years ago when a U.S. study carried out by Hembree and Desert (1986) found that students who use calculators in conjunction with traditional mathematics instruction perform better on paper-and-pencil tests of basic skills, possess better attitudes, and have better self-concepts in mathematics than non-calculator users. The NCTM (2000) also acknowledge that by utilising the graphing and symbol manipulation capabilities of modern day calculators, students are enabled to think differently, not just more quickly. Other recent developments in technology which have been discussed have the potential to do the same. There must be a raised consciousness among mathematics teachers of the potential for improving their teaching by use of digital technologies technology in classrooms. Professional development has a major role to play here, particularly for more experienced teachers. The use of digital technologies can be the most direct way of changing classroom settings for more efficient and effective teaching and learning of mathematics (NCCA, 2005).

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