VIRTUAL MATHS: CONTEXTUALISED LEARNING WITH NEW AND EMERGING TECHNOLOGIES

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The teaching and learning of mathematics continues to be a problem in schools and one which threatens to affect the construction industry. Leading industrialists have noted that if such problems are not addressed during formative years they will emerge and affect the construction industry in the future. To improve learning, government ministers have advocated a need to develop open, universally accessible educational resources that are engaging and stimulating. The intention of the Virtual Maths project was to provide exemplars of interactive web based maths problems and, through an action research methodology, identify the degree that children are interested and engaged in learning through such media. Maths was applied to the real life construction context using Flash technology. Workshops were set up in schools, and students and teachers explored and worked through the tasks, after which feedback was sought. An evaluation of the tools was provided by a maths consultant. Teachers, practitioners and student groups provided suggestions on the maths tools and identified possible ways of improving them. The findings show that maths, set in a real world context, was more interesting and meaningful than unapplied maths.

Keywords: mathematics, teaching and learning, virtual reality, interactive environments.

INTRODUCTION

The QCA (2006) functional maths proposal calls for application of maths to 'real world situations'. While it would be beneficial to take students out of the classroom to experience maths in the 'real world' such activity is resource heavy and time consuming. Equally, the potential dangers of some environments means that considerable effort is required to ensure risks are sufficiently reduced and controlled so that students can enter them. The practicalities of anything other than the occasional out of school trip makes the real world experience too difficult and costly. However, through the use of multimedia technology, maths can be set in a real world context. Using current Flash technology it is now possible to build interactive environments, with layers of visual and audio information, that embed maths in the real world. The working context also adds meaning and purpose to the maths. As students navigate their way through the activities they can easily be exposed to aspects of life that they would not normally encounter. Working through the interactive work-based problems requires the students and teachers to take in information about the environment within which the maths is set. Although such interactive environments can be developed it is essential that data is collected on how they are received by

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students and teachers, and ultimately what affect they have on the learning experience and outcomes. Learning materials are being released on the web with little real consideration for how and if the material is being used. It is essential that as materials are developed research is undertaken to collect observations, opinions and experiences. Development of online learning materials that are visually engaging is expensive. To ensure time is not wasted and the learning experience is improved, development should be iterative and materials systematically improved to suit those engage in learning. The iterative development of 'real life' learning tools will help to progress the link between theory and function, and could be used to lead learners through more complex problems.

Integrated learning and unravelling complexity

QCA (2006) have advocated the need to take students through contextual problems, which can be complex. Using web technology it is now possible to demonstrate and explain theories in multiple ways. The use of different deliveries supported by audio, video, text and various other graphics makes it easier to unravel and explain problems. Different delivery formats and styles can increase the potential of achieving understanding.

By integrating maths with vocational information, the benefits go beyond the immediate educational experience. Such aspects of integrated learning have already been identified as an important benefit of e-learning (BECTA 2008a). As well as being exposed to the general and vocational knowledge, students also acquire ICT skills. Learning by doing has been found to be the most common method of developing ICT skills (National Statistics Office 2007); it is also considered that the learning-by-doing rule can be applied to the maths. Skills required in industry can be replicated in school and the connection to professional practice can be made clear through multimedia resources.

Online vocational maths resources

There is a clear need to develop support material that ensures teachers have a range of options at their disposal to accommodate different learning styles and capture student interests (Clausen-May 2005). While there is debate over teaching and learning styles and their impact (Bose and Bahr 2008), it is obvious that if teachers have a range of resources at their disposal they are more likely to be able to accommodate the needs of students. Although the use of ICT in the classroom has increased, the potential to assist maths teaching and learning has not been harnessed. The web is world wide, yet there are few sites that offer open access interactive maths resources for use in the teaching of maths. While other developed countries are also experiencing problems in the standard of maths education there is little evidence of open access resources support being provided on the internet. The National Centre for Excellence in the Teaching of Mathematics (2009), Centre for Innovation in Mathematics Teaching (2009) and Proskills (2009) provide functional maths resources that can be downloaded and printed, similarly the Cre8ate maths (2009) project at Sheffield has downloadable resources. The Bowland Maths (2008) project is one of the few sites that offer open access interactive web material. Currently, the development of maths resources is sparse and sporadic. On line maths materials fail to provide a comprehensive coverage of curriculum and would seem woefully insufficient to address current concerns.

Raising the standard of maths and making it relevant

The issue of standards in mathematics and science is not just a UK problem. Kuenzi (2008) reporting to USA Congress stated that, "There is growing concern that the United States is not preparing a sufficient number of students, teachers, and practitioners in the areas of science, technology, engineering and mathematics (STEM). A large majority of secondary school students fail to reach proficiency in math and science, and many are taught by teachers lacking adequate subject matter knowledge." While in this study the UK ranked slightly higher than the USA, concern regarding the standard of maths education is just as evident in the UK. Lowry (2009), Chairman of the Institute of Civil Engineers stated that, "…employers have noted that there have been many years of decline in the standards of maths and science knowledge. If children are unable to understand maths at primary school it will be much harder for them to progress to diplomas and university courses in order to become qualified and knowledgeable engineers."

Speaking at the start of National Science and Engineering Week, Lord Drayson said, "As we enter tough economic times and look to boost British expertise in areas such as high tech manufacturing, the foundation for which is Science, Technology, Engineering and Maths skills, it is more crucial than ever that employers join the drive to inspire young people about the possibilities of studying and pursuing a career in these areas" (STEMNET 2009). The need to improve the standard of maths education and experience and the push to engage with industry is evident.

While government ministers have advocated a need to develop open, universally accessible, educational resources that are engaging and stimulating (BECTA 2008a), the task still seems to evade educators. Coupled with the problem of lowering standards (Lowry 2009), the challenges seem to be greatest in the areas of science, technology and mathematics.

RESEARCH METHOD: ITERATIVE DEVELOPMENT AND EVALUATION

The Virtual Maths project has used Flash technology to create functional contexts for maths learning tools. Virtual environments were created from panoramic photos of real locations. The project has created maths problems set in a virtual construction environment. The technology has enabled maths problems to be set in construction contexts created using photography and videos of real situations. Each maths problem was created sequentially and immediately made live enabling the designer to work with feedback from users as the next learning object was developed. The iterative development enabled the designers to experiment with different tools and environments. The overall aim of the project was to work with school students and teachers to develop maths web resources set within the context of construction and assess the potential of the tools to engage and capture the interest of students. The use of the Virtual Site and Virtual Maths project is not exclusive to Leeds Metropolitan University. The site is open access and can be used by all education and training establishments. The Virtual Maths site can be found in the 'Classroom' area of the following web site: http://www.leedsmet.ac.uk/teaching/vsite

The development and research has been undertaken using action research methods. Action research is interpretative research where the researcher is involved in the research setting and, to some extent, the experience itself (Nunes and McPherson, 2002). The cyclic approach to action research is often described as plan, act, observe

and reflect. Action research involves learning through action and reflection, while work is taking place, and it is often conducted in educational contexts (McNiff and Whitehead, 2002). Initially, examples of a contextualised maths project were developed by a team of academics, web designers, construction professionals and maths specialists. The team put forward their ideas to create a scenario that would capture the interests of students. Once developed, the ideas were presented at schools and feedback was sought. At the same time as showcasing the tool, school children and teachers were asked for their ideas of situations within the built environment that could be used to develop interesting maths problems. A number of children suggested situations within their own school which could be used as a context for maths problems that could be developed. Four exercises set in the schools have been created.

Once the ideas suggested by the schools were developed, further feedback was sought on their potential effectiveness as maths tools for self-study, teaching aids or potential learning packages. The tools were also presented at four workshops in secondary schools. Sessions were also held with pupils to see how they navigated their way through the tools, worked with them and used them as study aids.

VALUATION: CHILDREN FROM THE NET GENERATION

The way children learn and the methods of accruing knowledge has changed; it is the norm for children to grow up with the technology and computers. By 2009, 18.5 million households will have access to broadband (BECTA 2008b). All schools in the UK have computers, but over 1.4 million children don't have access to the internet at home (BESA 2007). Although initiatives are underway to develop access in libraries, schools and through mobile technologies, it was considered important for the Virtual Maths project to identify interim measures ensuring students can take away resources and learn without a computer.

Initially, all of the information was focused around the interactive web environment; however, feedback from teachers suggested there was a need for some breakaway activities that allowed students to come away from the computer and work through problems on worksheets. Students could still return to the computer for information, guidance and prompts, but it was clearly thought that engagement with their peers and working on paper was a good thing. It was obvious that computer work does not need to be an isolated learning process but can easily be used to foster and stimulate group activity and in-depth engagement with the problem. It was also considered that this type of computer – non computer interaction was more realistic of real world problem solving.

Creating resources that have the potential for parental involvement

Following the recent BECTA (2009) and Byron (2009) reports that showed 82% of parents felt excluded from their children's school day, initial feedback suggested that the Virtual Maths worksheets would also provide links for parents to school activity. While the worksheets have a practical use in the classroom, they can also be used to encourage parent-student learning at home. The online resources coupled with the worksheets used as homework provide a supportive framework for parents to assist and take part in the technology based learning activity. The Virtual Maths site has been shown to adult groups. As the delivery of the maths is set within a familiar vocational context there is interest in the resources. The site has potential for parent engagement and life long learning. Parents are much more likely to assist with their children if suitable activities and support systems are provided (NCETM 2009).

Practical applications

Virtual Maths has been used by teachers in schools, and although it does not form a key component of curriculum activity, it is used to demonstrate where and how maths is used in industry. Currently, the tool offers an interesting snapshot of maths problems, but more activities need to be developed. To be fully effective as a teaching resource a more comprehensive range of teaching and learning tools are needed. Feedback from the teachers suggests that the maths tools have applications in schools; however, to be used as teaching resources, it was considered necessary to have a broader range of problems and examples in each maths topic. To accommodate students that quickly grasp the task there was a need for challenging problems. Teachers felt that the top end of the class could quickly lose interest. Capable students need more advanced problems for them to work through. At the other end of the scale, the way some of the formulae were presented was considered too taxing for weaker students. To cater for the needs of the less able students and to maintain the interest of those who process maths problems quickly the range of problems needs to be quite broad.

There has been some evidence that students can quickly find their way through tasks, but do not necessarily understand the basis of the maths problems. To aid students who find the tasks difficult, lower level problems need to be provided and, to ensure that the learning takes students through key concepts, the theory needs to be explained. The advantage of multi media is that explanation and support materials can be delivered in multiple formats increasing the potential for understanding. Much of the maths theory lends itself to illustration using animation and video.

Dealing with differences in student ability can be more challenging in maths. Boston (2006) suggested that the range of difference in mathematics is greater than in the vast majority of other subjects; and this poses particular challenges for the teaching of mathematics. At the same time he voiced concern that, "… curriculum, teaching and assessment regimes should extend so the most mathematically able young people… as well as stretch the less capable and build a universally numerate society." Through development of multiple resources, e-learning has a great potential to challenge the advanced learner and support those that need more guidance. To ensure that the tool receives greater use, more supportive material needs to be developed so that packages of work can sustain whole classroom activity. Set around the interactive examples of web media, multiple tasks and worksheets can be developed to ensure students can work at different levels and develop understanding.

The link to the real construction contexts and situations is something that has captured the interest of students. Jagger and Ross (2003) considered the sense of realism to be an important factor when designing effective web based teaching resources. Tools have been used in the classroom to demonstrate where maths problems are applied. The tools set around the construction context, utilising plant and equipment on the construction site tend to stimulate interest. The sites with more interactive features tend to generate greater interest. The dynamic 360 degree photographs with embedded learning objects have also proved more successful than still images. However, to make the tools an effective part of the curriculum, more and varied examples of problems are needed. The material and features need to be matched to curriculum and student needs. A teacher commented that there are a few similar web sites available, but currently there are insufficient resources on the sites for them to be used as full teaching and learning activities. Teachers were surprised that the Virtual Maths site was freely accessible. Teachers were under the impression that such sites need

passwords, which is not the case with the Virtual Maths site. Feedback from the teachers would suggest that sites which do have passwords or require user information to gain entry are establishing a significant barrier to their potential use.

Working in pairs and small groups
A few teachers and maths consultants suggested that the students often work better on functional maths tasks when working in pairs or small groups. It was suggested that additional activities based around the interactive environment could promote discussion and deeper understanding of the problems. Ideas were proposed similar to the Bowland Maths project (Bowland 2008). It is believed that games and activities based around the interactive environment, supported by video, animation and audio clips could assist paired and group activity, making them more stimulating.

Pace and recap
Each exercise is supported with controls that take the students step-by-step through the exercise. The interactive tools, with forward and backward controls, allow students to learn at their own pace. However, it was noted that when students sit close together they are aware of their neighbour's progression. In some instances it was noted that students would skip sections to catch up with their peers. If students had noticed an image or scene on another person's computer that they found more interesting some students were inclined to move to that section. The interesting aspects of the site can both engage the students and cause distraction. Some teachers used their classroom management to limit potential distraction. In one case students were encouraged to play with the tools for a couple of minutes, allowing them to skim over all of the interactive features, before undertaking the maths problem. Children chatted about the tasks and were quick to note any peculiarities and interesting aspects of the site. After a few minutes of exploring, students were asked to complete one of the maths tasks; this helped focus their concentration on the exercise. When students worked in pairs on computers there seemed to be improved engagement and interest.

Students learning, revising and refreshing on their own
Some older college students had noted that with maths problems they had often been embarrassed to admit to their tutor that they were struggling with maths. These students suggested that such resources were useful for catching up and revision, especially since they could be used outside the classroom when studying alone. The step-by-step approach allows students to unravel complex problems. Backwards and forwards controls enable students to retrace steps, allowing for greater comprehension and understanding. Students were keen to suggest that more and similar tools should be developed. The level of interest and enthusiasm for the development of highly interactive web resources was clear.

External review: Mathematics Education Consultant

The following extract is taken from a report produced by a mathematics education consultant written in response to questions posed in relation to the Virtual Site. The comments are based upon the utility of the site to those teaching and learning Mathematics in secondary schools and colleges.

Which aspects of the site are interesting?
Reviews by academics and maths consultants found that the most interesting aspects of the Virtual Site Classroom were the use of dynamic and static images, the mathematical problems set in context and the ICT functionality.

The maths consultant noted that:

A review of the most recent publications on school and college Mathematics promises much. The Virtual Site Classroom is certainly the kind of learning opportunity envisaged by those responsible for developing the new Mathematics curriculum:

"The curriculum should provide opportunities for students to:

- develop confidence in an increasing range of methods and techniques
- work on sequences of tasks that involve using the same mathematics in increasingly difficult or unfamiliar contexts, or increasingly demanding mathematics in similar contexts
- work on open and closed tasks in a variety of real and abstract contexts that allow them to select the mathematics to use
- work on problems that arise in other subjects and in contexts beyond the school
- work on tasks that bring together different aspects of concepts, processes and mathematical content
- work collaboratively as well as independently in a range of contexts
- become familiar with a range of resources, including ICT, so that they can select appropriately." (QCA 2008a)

Furthermore, the requirement for Functional Mathematics to be a part of this curriculum is an extra impetus for schools and colleges to use resources like the Virtual Site Classroom. It offers access to realistic, challenging Mathematics in engaging work-based situations, but can be assimilated into teaching without venturing out of the classroom. The Functional Mathematics guidance for teachers talks explicitly of such learning:

"The key stage 3 programme of study lays the groundwork for pupils to apply their mathematics to real contexts in key stage 4. In addition, it requires that pupils be introduced to a range of real-life uses of mathematics, including its role in the modern workplace. When planning opportunities for pupils to develop and understand functional skills you should consider if you have:

- provided opportunities for different skills you are focusing on in representing, analysing and interpreting to be developed in combination
- ensured that pupils understand that they are learning skills that they will use and apply in a variety of contexts
- given pupils the chance to select the skills and tools (including ICT) they need for a particular task
- provided opportunities for pupils to apply these skills for real purposes and contexts beyond the classroom." (QCA 2008b)

The most recent subject report on Mathematics was based upon evidence from lesson observation in 192 schools. Its key findings include a judgement about the ICT and cross-curricular opportunities that are generally offered to learners. This further highlights the potential value of resources like the Virtual Site Classroom:

"The content of the mathematics curriculum in most of the schools surveyed was age-appropriate. However, the majority of pupils had too few opportunities to use and apply mathematics, to make connections across different areas of the subject, to extend their reasoning or to use information and communication technology (ICT). Higher-attaining pupils were not always challenged enough in lessons. Links with other subjects were insufficient." (Ofsted 2008)

Critical comments and areas of development

When discussing the tool at a regional university forum, one maths lecturer suggested that such tools were potentially a cause of the lowering in standards of maths. The view presented was that maths should be taught from a theoretical base and, at least in the initial stages of learning, the theories should not be contextualised. The main concern raised was that contextual learning coached students through problems and narrowed students' understanding of maths. It was thought that students who were coached through problems would only be able to copy the formula for assessment purposes and not apply it to other contexts. The view put forward here is similar to that recently suggested by du Sautoy (2008) who claimed that making learning relevant reduces the rigor and makes maths less interesting.

Although the regional university forum was attended by over twenty lecturers and skills teachers, none of the other members of the group voiced the same level of concern about applying maths to a context. Indeed there were plenty of points put forward for contextual and functional maths, some members suggested that it was the only way they had managed to find to engage students. One tutor noted that without altering the way maths is taught many students just miss out on a maths education altogether.

The e-learning environments can be developed so that the maths tools that are applied to a construction context can also be produced without a context, in their pure form. Vocational learning, especially when it is built in an interactive web context, does not have to preclude other methods of maths delivery. It is proposed that the pure theory could sit alongside the contextual information. As the aim of this project was to capture interest and accommodate as many different learning styles as possible, this dual approach may be beneficial. There is a need to clearly explain fundamental principles of maths to support functional delivery.

CONCLUSIONS

The project has proved effective in capturing the interest of students and teachers. The potential of web tools to contextualise learning materials making them functional has been realised. Students are inquisitive of the environments they explore and spend time looking at the problems in their context. Adding functionality to maths makes the subject more relevant, interesting and meaningful.

While many still argue the virtues of face-to-face learning, web based resources are becoming increasingly popular as teaching aids, revision and self-study packages. Some staff are resistant to use of web based resources, but for many students, internet use is the norm. Most students are e-mature and quickly find their way around the web pages. Those students that are most capable explore the options at speed and work through the problems. Allowing students to work at their own pace is a considerable advantage; however, to maintain interest the options and activities available need to be extensive. For those students that need more guidance to understand the maths, help can be provided in a number of different ways in an interactive environment. Text, drawings, animation, audio and video can be drawn on to provide supporting information to help students to understand.

It is clear that contextual learning does capture the interest of many, but there may also be a need to keep theoretical information clear and in some cases separate from contexts that may confuse or stifle an open mind. Designing open access web sites that accommodate all users is difficult, but such challenges should not prevent web

developers pushing the boundaries so that abilities and disabilities are considered in the design. In this situation interactive tools, set in an industrial context, do have the ability to capture interest and assist the teaching and learning of core maths skills.

The use of computers to help understand maths does not need to be one which removes human interaction. The research has indicated that the use of interactive computer tools can capture interest and foster deeper learning and engagement in problem solving through peer and group activity.

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