Re-imagining STEM: Peer scaffolding ICT in Initial Teacher Education

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Abstract: *In this paper, we report on how peer scaffolding was used to effect change in tertiary teaching practice and academic disposition in the use of Information and Communication Technology (ICT) in Science teaching and learning. We present a small-scale case study investigating the practice of one of this paper's authors. It is told through two salient episodes which narratively describe the scaffolding used to support a teaching experiment. This was made possible through the national Teaching Teachers for the Future Project (2011-2012) which aimed to enhance the technological pedagogical capability of pre-service teachers across Australia. The outcome was a demonstrable shift in the academic's disposition towards the use and benefits of ICT in teaching science and an increase in skills and confidence for both the academic and his students. This study and its outcomes fit within the contemporary push to "re-imagine" the teaching of Science, and more broadly of STEM, in schools.*

Keywords: STEM, Science education, ICT, teacher education, Alternate Reality Games

1. Introduction

The Melbourne Declaration (MCEETYA, 2008), outlining the national goals for education in Australia, alluded to issues relating to STEM (Science, Technology, Engineering, Mathematics) education in its preamble. It offered that:

Complex environmental, social and economic pressures … that extend beyond national borders pose unprecedented challenges… . To meet these challenges, Australians must be able to engage with scientific concepts and principles, and approach problem-solving in new and creative ways. … Rapid and continuing advances in information and communication technologies (ICT) are changing the ways people share, use, develop and process information and technology. In this digital age, young people need to be highly skilled in the use of ICT. While schools already employ these technologies in learning, there is a need to increase their effectiveness significantly over the next decade. (pp. 4-5)

To impact on schools in the future, these issues need to be addressed in current teacher education practice. This paper will report on one University's response to the dual concerns of enlivening the teaching and learning Science and making the use of ICT in schools more effective. We took advantage of the national *Teaching Teachers to the Future* Project (TTF) (see Romeo, Lloyd & Downes, 2012) to experiment, through the practice of one teacher educator (one of the authors of this paper), with how Science curriculum might be alternatively taught in a pre-service teaching degree.

The TTF project allowed the release of two academics, also authors of this paper, to develop the ICT pedagogical skills of pre-service teachers in the curriculum area of Science. The adopted philosophy was not to deliver a top-down approach, imposing interventions or staff development, but rather to use peer scaffolding and to collaborate with Science education academics. The connection was a simple one - a different approach in teacher education would engender different skill sets and dispositions in future teachers of Science thus satisfying the national demands for authentic engaging Science teaching along with the more meaningful use of ICT. This paper will report on this peer scaffolding process through two salient episodes which narratively and respectively describe (a) the adoption of a blog to support a Science simulation game; and, (b) the use of an Alternate Reality Game to support problem-solving.

2. Background to the study

The following firstly discuss ICT in teaching and learning and then outline the current push to 're-imagine' Science in school curricula. This section includes a brief introduction to the peer scaffolding we adopted throughout the study.

2.1. ICT in teaching and learning

As is clear from the Melbourne Declaration (MCEETYA, 2008), mastery of ICT is a critical 21st Century skill. The Declaration, in Goal 2, notes that "successful learners … are creative and productive users of technology, especially ICT, as a foundation for success in all learning areas" (p. 8). In support of this, the Australian Curriculum (http://www.australiancurriculum.edu.au) has included ICT as one its General Capabilities. This means, in short, that ICT is to be integrated in all learning areas at all levels of schooling in Australia. For Science, this means, students develop and demonstrate their ICT capability when they:

… research science concepts and applications, investigate scientific phenomena, and communicate their scientific understandings. In particular, they employ their ICT capability to access information; collect, analyse and represent data; model and interpret concepts and relationships; and communicate science ideas, processes and information.

(ACARA, n.d., para. 9)

The Australian Curriculum also encourages the use of animations and simulations to represent scientific phenomena, namely, concepts, information and processes that are otherwise not possible to view or experience.

Australian teachers are expected to make active and meaningful use of ICT to support students' learning. Cox and Graham (2009) explained that teachers need "knowledge of the technologies that may be used in a generic pedagogical context, including the affordances and constraints of those technologies, and how those technologies influence or are influenced by the teacher's pedagogical strategies and student learning" (p. 76). From this, we acknowledge that it is not enough to know how to use ICT but that they must also understand their accompanying pedagogical strategies. It is, as Mishra and Koehler (2006) described in their TPACK model, a complex interplay between technological, pedagogical and content knowledge. The authors of this paper have attempted to reduce the isolating of the knowledge of technology from pedagogical and discipline expertise (Lloyd & Albion, 2009) through the technologies addressed in the episodes to be described, namely: (a) blogs, (b) simulation, and (c) Alternate Reality Games (ARG).

Blogs: A blog (web log) is a diary that differs from its paper alternative by being made public and encouraging interaction between reader and author. Blogging is used widely to achieve differing learning outcomes in education (see Churchill, 2009; Dumova & Fiordo, 2011).

Simulation Games: The 2012 K-12 Horizon Report (NMC, 2012) noted that gaming, as part of the Serious Games movement, is an "ideal method of assessing student knowledge comprehension, … [providing] immediate performance feedback to the players" (p. 19). Motivation to succeed or "win" is coupled with the "productive role of play" namely, experimentation, exploration of identities, and even failure.

Alternate Reality Games (ARG): Learners actively investigate scenarios (McGonigal, 2008) through games which typically invite them into a potential future determined by present actions or circumstances. Kim, Lee, Thomas and Dombrowski (2009) explained that an ARG represents an "emerging collective story" whose purpose is to encourage particular behaviours and help form social groups. An ARG may also be used as an analytical tool allowing focus on differing parts of a problem to be investigated through various media.

What is of interest in this study, and in keeping with advice from the literature (Cox & Graham, 2009; Figg & Jaimal, 2011; Mishra & Koehler, 2006), is that the selected technologies were not used independently or for their "own sake." Each had a particular and clearly defined pedagogical purpose best achieved through digital means.

2.2. Re-imagining Science education

Lyons' (2005) meta-analysis of the experiences of high school science students in Australia, UK and Sweden revealed three major themes: (a) the transmissive pedagogy that characterised school science; (b) the personal irrelevance of much of the curriculum content; and, (c) the perceived difficulty of school science. These somewhat explain the growing disenchantment with "school" science evidenced by the decline in numbers of students choosing further study and careers in science. The 2006 OECD Programme for International Student Assessment (PISA) report found that only 37% of 15 year old students worldwide were choosing to pursue careers in science despite 92% believing that science and technology improves people's living conditions (OECD, 2007). PISA also noted that students with a higher self-reported enjoyment of learning science were more likely to have higher levels of science performance.

To counter this decline and disenchantment, Tytler (2007) argued for the "re-imagining" of science. He proposed that school science should be about discovery rather than prescription; that it should challenge students with open-ended and relevant tasks; and that it should enable students to make rational decisions on important issues. He also claimed that teacher confidence and professional development are just as important as the students' learning materials.

Aligned to this is the *Personal and Social Capability* strand in the Australian Curriculum for Science in which students are encouraged to apply their scientific knowledge to make informed choices about issues that impact their lives (ACARA, n.d.). Therefore, pre-service teachers need to have the technological, pedagogical and content knowledge to allow their future students to connect these socio-scientific issues to their lives and feel a sense of ownership and empowerment. This can be a difficult goal to achieve through the traditional pedagogy of reading texts and responding to pre-prepared questions. However, using ICT in more innovative ways, it is possible that models of practice that match new and re-imagined approaches in the teaching of science can be implemented.

2.3. Peer scaffolding

As noted, the study described in this paper was part of the larger Teaching Teachers for the Future (TTF) project. At the University where this study was located, we opted to scaffold, that is support and work "with," our Science education academics rather than establish a deficit master: apprentice role or to deliver formal professional development sessions. We were wary of "fixing" a problem that no one thought they had or to impose change that no one thought was needed.

The concept of scaffolding quickly permeated our relationship with the academics. We dubbed this "peer scaffolding" to distinguish it from the more usual relationship between teacher and student. Yelland and Masters (2007) identified three characteristics of scaffolding which informed our approach. First, scaffolding must be collaborative with the "learner's own intentions being the aim of the process" (p. 364). In the case described in this paper, the *learner* was the Science education lecturer, Alberto. His "intentions" were related to improving his own teaching practice and providing appropriate opportunities for his students to use ICT meaningfully in the teaching of Science. A further shared goal was that his students would, in turn, make use of these approaches in their own future teaching practice.

Second, Yelland and Masters (2007) noted that scaffolding must operate within the learner's zone of proximal development (ZPD). The "scaffolder" must ascertain learners' initial understandings and then them beyond that. In this case, the scaffolder, Michelle, began with a 1:1 interview and examination of teaching materials before offering alternative approaches. The third critical characteristic of scaffolding is that it is gradually withdrawn as learners become more competent and confident. This can be likened to the adjustable and temporary scaffolding used in construction that is progressively removed as the building becomes able to stand on its own. Here, the peer scaffolds were removed once the "learner" had taken control of the teaching environment and was sufficiently confident with the technology and pedagogy to model and integrate the use of ICT in the teaching of Science.

3. Method

The small-scale study in this paper is based on narrative inquiry. This qualitative method was chosen because we wanted to recount particular episodes we believed had a clear link to pressing issues in STEM, most particularly, in Science education. Further, and in accordance with Connelly and Clandinin (1990), we believed that "humans are storytelling organisms who, individually and socially, lead storied lives" (p. 2). Similarly, Riley and Hawe (2004) offered that narrative analysis contextualises the sense-making process by focusing on the person rather than a set of themes. The *sense-making* described in this paper is presented through our interpretation of the emergent narratives and the focus is quite specifically on Alberto and his teaching.

3.1. Research design

The research setting, as noted, is a Faculty of Education in an Australian metropolitan university. Its Learning Management System, *Blackboard*, provided a range of collaboration media, including wiki and blogging spaces, as well as a content repository for lecturers. Wireless Internet access was available for each student and, as will be noted in the Episode narratives, class sets of MacBook laptops were available for use.

The key participants in the study are the authors of the paper. Alberto is an early career academic. Prior to becoming a teacher educator, he taught Science, particularly senior chemistry, in state secondary schools in north Queensland for eight years. The other authors, Margaret Lloyd and Michelle Mukherjee were managing the TTF project for the Faculty. The pre-service teachers indirectly involved in this study were in two different cohorts enrolled in Science curriculum units in Semester 1 and 2 in 2011 respectively. Their studies included: curriculum design; design and planning of assessment, inquiry based activities and inclusive pedagogies in science teaching.

In heeding advice that narrative inquiry needs to be based in multiple sources of empirical data (Connelly & Clandinin, 1990), the data sources used include field notes, interviews with the academic and selected students, documents such as task and instruction sheets, and records of blog entries. While narrative analysis is interpretivist and subjective, every effort has been made to “tell” the stories without bias.

4. Findings and discussion

The following describes two episodes, from the first and second semesters of 2011 respectively, which demonstrate how Alberto’s curiosity about the authentic application of ICT in science teaching was ignited and developed. They also show how and where peer scaffolding was introduced and make inferences as to the impact it had in each instance. In the first episode, Alberto uses simulation software and investigates how this can be extended to encourage collaboration between class members. In the second, Alberto becomes interested in the concept of Alternate Reality Games and considers how they can be used to raise awareness of socio-scientific issues.

At the start of the 2011 academic year, Alberto was a confident user of ICT. He had studied ICT during his own pre-service studies where he created web pages using HTML and gained familiarity with productivity software, namely, word processing, spreadsheets, and presentation packages. However, the only technology that he was using in his tertiary teaching were (a) spreadsheets for data analysis and graphing, and (b) simulation software. Early conversations revealed that he was interested in using ICT in his teaching, but only where he saw a clear benefit to the teaching and learning of science content: novelty alone, for him, was an insufficient reason. At the beginning of the academic year, he explained how he had seen spreadsheet software used in a Year 8 science class: *... [the teachers] were giving up a lesson a week ... to teach Excel completely de-contextualised from anything they [teachers and students] were doing in the other three lessons a week in Science.*

Episode 1 (Semester 1): Alberto wanted his pre-service science teachers to understand that a “dry lab” (using simulation software to obtain data rather than conducting physical experiments) could be used for the Extended Experimental Investigation (EEI) (Hennessy et al., 2007). EEI, a major part of senior secondary school science, ask students to identify a topic, design and perform experiments, gather and analyse data, and to form conclusions. He had chosen *Catchment Detox* [http://www.abc.net.au/science/catchmentdetox] a simulation that challenges players to manage a river catchment over a number of years to achieve successful ecological and economic outcomes.

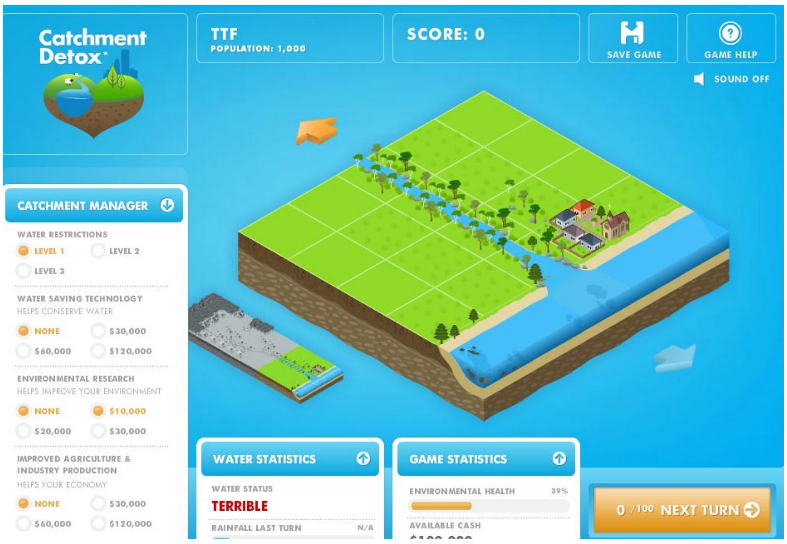

Figure 1. Screen shot from Catchment Detox [http://www.abc.net.au/science/catchmentdetox]

To record students' input parameters and subsequent outcomes, Alberto thought that they should capture screenshots from the game (as shown in Figure 1) and paste these as images into a Word document. Michelle suggested that the students could alternatively post their screenshots along with their decisions (management strategies) to a blog. This then could be viewed, commented upon or adopted/adapted by their peers, thus encouraging collaboration.

Alberto was interested in this but had limited time to develop it. As an overt peer scaffold, Michelle experimented with using the collaboration media available in the University's Blackboard management system. She also created a "How To…" sheet that gave explicit instructions, described the differences between a wiki and a blog, and explained the appropriateness of selection of one over another. The focus was on both scaffolding the task at hand and also setting in place processes that could be transferred to the students' future classrooms and their roles as teachers. It also embedded the notion that particular technologies should be adopted to suit particular needs.

Alberto introduced the amended task, that is, to use the Catchment Detox simulation and the blog, to his students. He asked who had previously used a blog or wiki. A show of hands revealed that only 7 of the 20 students (35%) had posted to a blog while no one had used a wiki. Alberto then led a discussion in which the differences were outlined. The students then "played" the simulation. From field notes, we noticed that they were relatively comfortable with the application. Where problems were experienced, they were technical. For example, most students were unfamiliar with taking screenshots on the Apple laptops they were using. Overall, and despite the technical difficulties with the unfamiliar platform, the students appeared to enjoy the session and completed the task in the allotted time.

When interviewed after the lesson, Alberto said, "To me, that was a legitimate use of technology to achieve a purpose. It wasn't, 'And here's what a blog is', and that's it! It's 'Here's how you use a blog for doing a science inquiry activity'." As noted, Alberto had begun the academic year unconvinced that technology had an authentic role in the learning and teaching of science. This episode demonstrated how his willingness to experiment along with purposive peer scaffolding led to a demonstrable change in his attitude. It also allowed collaboration and sharing amongst the students, a learning opportunity not possible through the initial plan of pasting captured images into a static document. Most importantly, the selected technologies and processes allowed the cognitive aspects of the Extended Experimental Investigation (EEI), that is, the hypothesising and justification of conclusions, to be made visible.

Episode 2 (Semester 2): Alberto's interest in using ICT with his students had been ignited. He independently developed the idea of using games as a medium for students to engage with socio-scientific issues (SSI). He became aware of the Alternate Reality Game (ARG) *World Without Oil* through a television documentary and discovered that it was a web-based game based on the premise that the world was about to run out of oil. The game simulated the first 32 days of a global oil crisis and players could post strategies and solutions by blog, email or telephone. The players did not assume characters or avatars but played themselves voluntarily imagining themselves into this scenario by nominating ways of reducing travel, growing their food and making other daily changes to conserve energy consumption. So powerful was the game that many of the players began to modify their behaviour in the real world.

Alberto was excited by the possibilities of affecting student thinking and behaviour through an ARG. One Saturday afternoon before the semester began, he taught himself iWeb, an Apple application formerly part of the iLife suite, which allows users to create web pages and blogs through templates, that is, without needing to know HTML coding. It is an appropriate tool for ARG development as it allows the inclusion of multiple media. Peer scaffolding here was limited to simple encouragement. These newly developed skills were used to create a few pages of an ARG story concerned with the STEM (Science, Technology, Engineering and Mathematics) crisis, that is, a potential future in which students had stopped studying STEM subjects and where societies had become ill-equipped to adjust to changing world climatic conditions. Alberto began the ARG with a video he had shot in "mockumentary" (mock documentary) style, in which he, the presenter, stood before a failed tomato crop and lamented the lack of scientists and engineers who could tackle a hypothetical food crisis. The students could then follow a link to where they were given the task of reading the "Re-Imagining Science" report (Tytler, 2007) which emphasised the need for a change in the school science curriculum in order to engage more students followed by participation in an online discussion. The next part of the ARG asked them to "run" to the library to photograph resources about the STEM crisis, and to then post these to a wiki.

Alberto also showed his students how to use iWeb and then invited them to create their own Alternate Reality Game (ARG). The observed atmosphere was positive with several commenting aloud how this technique could be used in their future classrooms. Unfortunately, for some, the technology caused confusion. For example, after having entered text, some clicked on the *Home* link without saving and lost their contributions. At this point, one said, "*These are the problems we have in this classroom, but imagine what it would be like with 30 children! That's why I like Powerpoint.*" This is a not uncommon response from teachers reluctant to experiment with unfamiliar technology. It is of interest that Alberto, despite the problems his students were having, was not deterred. He talked about the pedagogy, making his intentions explicit. In this, he was modelling the practice the students would adopt with their future students. For him, mastery of the technology was less important than the learning outcomes being addressed.

Later interviews with students (n=3) revealed their belief that Alternate Reality Games had the potential to engage school students, particularly in socio-scientific issues. Those who were more confident in their ICT skills were able to immediately consider the translation and broader benefits to classroom teaching. Those for whom the technology was unfamiliar or confronting reported that, during the tutorial, they were focused on keeping up with the tasks and working out how to perform the tasks. It was only later that they were able to consider the potential advantages.

5. Conclusion

This paper– through two narratives - has sought to report on a particular instance in teacher education made possible through the support of a major national project. While its findings may not be generalisable to other settings because of this particular context, our abiding sense is of the success of peer scaffolding in changing practice.

It has addressed three interdependent areas: (a) ICT in teaching and learning, (b) re-imagining science education, and (c) peer scaffolding. In regard to the first, we promoted authentic uses of ICT in teaching and learning using social media and Web 2.0 tools that were part of the students' everyday lives. Further, we encouraged a departure from the use of productivity tools, such as the spreadsheet analysis of numerical data. This was evidenced by the use of a blog to enhance a simulation activity and to authentically represent what was expected of an EEI in terms of investigation and collaboration; while the ARG gave an alternate and engaging way of addressing SSI.

This, in turn, supported our interest in "reimagining science." We tried to look at science in a way that its impact on everyday life was paramount and where reaching students' thoughts, feelings, and emotions was valued along with the detached, content-based data collection and manipulation which was traditional science teaching.

Finally, the third area, peer scaffolding, was addressed as an intensive model of one-to-one support professional development. The academic at the heart of this study began with scepticism about the potential value of ICT in teaching Science. He maintained this view and reiterated it in a final interview by saying that: *It's got to serve a purpose. It's got to enhance learning or the human condition in some way. Can I enhance interaction between students? Can I improve interest and engagement through something creative like an Alternate Reality Game?* But, encouragingly, the evidence of his pedagogical experiments supported by peer scaffolding convinced him and he is planning to develop these ideas further. With appropriate scaffolding, he has discovered the clear impact of using the "right" technology to achieve specific learning outcomes. The technology simply provided the context in which the pedagogy became visible.

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