It is paradoxical that on the one hand the adoption of e-learning at higher education institutions is limited, basically due to the resistance of universities that are wary of undermining the brand equity of their degrees, and of faculty who see it as a threat to their jobs and to their Departments (The Economist, 2015). But on the other hand there has been significant progress in its research, as will be appreciated in the selection of papers in this issue of EJEL. So the same stakeholders who are investing their time, money, intellect and effort in researching it, are resisting its implementation. And what makes this paradox even more peculiar is that the findings of that research do not necessarily point towards the demise of universities or faculty. E-learning is not a narrow or linear application of digital technology to assist in delivering knowledge and engaging the learner. It is well established that success comes from optimal and customized combinations of face-to-face and digital to fulfil the needs of groups or even individual learners. This issue of EJEL attempts to go a step further and challenge the reader to think about the many different dimensions and approaches for applying digital technology to e-learning.

In the first paper Barber, King and Buchanan move far beyond the mere delivery of traditional learning methods through a digital platform, to turn around the whole learning process by exploring the relationship between problem based learning, authentic assessment and the role of community in fostering learning in digital contexts. The authors propose that one of the most significant outcomes of this combination of tools is its transformational effect on the nature of learning, on the role of the instructor, and the learners’ attitude towards learning. Highly relevant in the authors’ approach is the use of Digital Moments to develop the students’ confidence in their social communities and to express their ideas in a multimodal form that the authors claim unleashes creativity well beyond that enabled by traditional text-based communication. As the authors themselves admit this derives in a non-tradition approach to learning that may be very difficult to implement by current institutions and systems. The questions that come to mind while reading this paper is if this highly inductive approach to teaching is suitable to students of all learning styles, and if it is not too extreme in going purely digital - would the approach not benefit from some degree of combination with face-to-face learning?

Basitere and Ivala carry out a study on a sample of first year Chemical Engineering students to identify their knowledge gap in mathematics on entry, and design a programme to overcome the gap. They indeed confirm that the students in the study have a significant knowledge gap on entry, and design an “autumn course” based on face –to-face teaching complemented with a closed Facebook group to help in learning beyond lecture room time. Through a pre-test and post-test the researchers confirm that the “autumn course” had a significant impact on improving the minimum required mathematics skills, but they found no significant effect of the Facebook group usage in achieving that improvement despite considerable activity through this social networking tool in issues related to the course. The authors do not give any explanations for this apparent lack of effect of using Facebook. Should one infer from this that social networks do not contribute to learning? In other cultures it has been found that young individuals believe social networks are for personal use and tend to refuse using them for professional or educational purposes, but this does not seem to be the case in this study group as the authors present that there was significant use of Facebook on study-related issues. It could be that Facebook does not have a positive effect, but that other forms of social networking that the authors did not apply, such as blogs or wikis, might have had. Or it could be that the teaching method applied by the tutor was not designed to effectively synergise with Facebook or other forms of social networks.

Charbonneau-Gowdy carries out a piece of action research on a sample of ten pre-service English teachers (i.e., teachers in the third and last year of their undergraduate EFL degree course) to determine whether a guided reading programme using e-readers could positively influence the reading rates of the participants. This is a longitudinal study performed by the author who is a tutor of the programme on which the ten participants are enrolled. The author claims this is groundbreaking research because, although there are some studies on determining the implications of the use of mobile technologies on teaching (Gee, 2003; Baron, 2009) there are no known cases of having evaluated the effects of e-reader devices. The significance of the study, according to the researcher, is that the use of technology in the form of e-readers helped reverse the cultural capital shortage made evident in the participants’ prior studies, and that its effect is sustainable in time after the initial intervention. This is valuable research carried out with rigour, but the reader is left wondering whether the effects would have been even more pronounced if Facebook had been used to augment the programme.
wondering if the effect is actually caused by the use of the e-reading devices, or was simply the result of putting the participants through the guided reading programme independently of the technology (the author does not appear to have controlled for this.).

With their paper on the role of Open Access and Open Educational Resources Hatzipanagos and Gregson bring to question the whole business model of present higher education. The research is a case study on the University of London International Programmes (UoLIP) that is aimed at raising awareness and understanding on what can be achieved in higher education by embracing the Open Access movement; at proposing actions that could be taken to improve institutional use of Open Access materials including Open Educational Resources (OER); and, finally, at examining the implications of such actions for Open Distance Learning and higher education in general. From this research emerges a synergy between Open Access and OERs because both have to address the issues of ease of search, quality and visibility. However the authors indicate that despite there being some commitment to adopting these initiatives there are no systematic institutional or cross-institutional approaches to draw together repositories. The paper does not tackle the issue of what the new business model will look like to overcome the resistance of universities that naturally want to overcome the risk of undermining the value of their degrees.

The issue of how to generate the changes required to move onto a student-centred learning environment by flipping around the lecture room is tackled by Hutchins and Quinney who place themselves firmly in the domain of blended learning. The paper explores the intersections between three strands, namely, research orientations, education strategies and technology enabled learning. The authors propose a framework that intertwines these three concepts into a ‘triple helix’ through which they believe it is possible to initiate the ‘optimum disruption’ towards transforming both the student learning experience and the institutional culture. It is an original and compelling piece of work that indicates a feasible way forward but that leaves the reader wondering how this scheme can be transferred from the highly controlled case described to a broader and more general application.

Yet another completely different angle to the question of incorporating technology into learning is that of 3D as described in the study by Salajan, Mount and Prakki. Building on the combination of the Cognitive theory of multimedia learning (CTML) and Constructivist learning this study researches into how First Year Dental Anatomy (FYDA), a web-based 3D interactive application has been incorporated into the curriculum of a major Canadian university and assesses the perception of learning experience by the students that actually used it. CTML favours, enables and even promotes critical thinking which the authors reminds us leads to knowledge construction rather than just memorizing and putting “knowledge into learners’ heads.” This paper has many illuminating aspects to it, but one thing that strikes the reader is why usage of FYDA is so low for preparation for courses and for reviewing after lectures, and of relatively low usage during lectures. Its most intensive use is for studying for exams. This appears to reveal that the courses have not been designed to incorporate 3D into the essence of the learning process.

In their descriptive paper, Tan, Chang and Kinshuk address an even more innovative application of digital technology to learning, by researching into augmented reality (AR). The argument here is that meaningful knowledge is constructed primarily when the learning process integrates with social culture and life-context. More specifically, this study employs mobile devices to interact with real-life learning objects in a content-awareness mobile learning environment that is underpinned by the 5R adaptation concept for location-based mobile learning, which is stated as: at the right time, in the right location, through the right device, providing the right contents to the right learner. The mobile application identifies the real life object captured by the camera of the mobile device through comparison with a database of objects, and displays upon the image of the object the learning content which is aligned with the learner’s “Personal Learning Status” (i.e., current course, current unit, content level.) This makes compelling reading, but it strikes the reader as if the application of this approach is limited to learning about tangible things but it is hard to see how it could be applied to learning about more abstract concepts.

I hope this set of thought provoking papers sheds light on the fact that achieving the holy grail of effective blended learning is not simple. Its high complexity is founded on that it is not just about combining face-to-face with digital, but actually combining it with many different technologies and approaches to their application. This complexity is what makes the field so interesting and what might explain the paradox of seeing much research but little adoption.
Problem Based Learning and Authentic Assessment in Digital Pedagogy: Embracing the Role of Collaborative Communities

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Abstract: The purpose of this paper is to qualitatively examine the relationship between problem based learning, authentic assessment and the role of community in fostering learning in digital contexts. The authors used “Digital Moments” to create a meaningful learning environment and build the online class community. They then collaboratively developed assessment strategies and tools with students following problem-based learning methodologies. Given that the pace of information is rapid and changing, the authors argue that online learning must occur in a context that embraces these three concepts: 1. Students must be empowered through PBL to choose real world tasks to demonstrate their knowledge, 2. Students are allowed to choose the modality to represent that knowledge and participate in designing the tools for assessing that knowledge and 3. They do so in a supportive online community built through the sharing of Digital Moments. The paper chronicles the interconnection between problem based learning, authentic real world assessment tasks and a supportive online community. This resulted in developing learner autonomy, improving student engagement and motivation, greater use of meaningful self and peer assessments and shared development of collective knowledge. Further to this, it builds a foundation from which authentic assessment, student ownership of learning and peer support can occur in an ongoing way as learners make the important shifts in power to owning their learning and becoming problem-based inquirers in future courses. As a result, in order to fully embrace the online learning environment, we cannot limit ourselves to simple text based measures of student achievement. Stepping into this brave new world requires innovation, creativity and tenacity, and the courage to accept that as the nature of knowledge has evolved in the digital landscape, so must our means of assessing it.

Keywords: Authentic assessment, problem-based-learning, digital communities

1. Introduction

This paper is grounded in the theoretical framework of several authors who identify the parameters for three key components of this paper: 1. problem based learning, 2. authentic assessment tasks and 3. productive and meaningful online communities. This work will contextualize these elements with reference to particular synchronous online environments. (Reeves, Herrington & Oliver, 2002; McCarthy, 2013; Rosemartin, 2013; Herrington & Herrington, 1998; Bozalek, Gachago, Alexander, Watters, Wood, Ivala & Herrington, 2013).

Savin-Baden (2007), Watts (1991) and others discuss the important key features of a problem based learning environment. Savin Baden reveals that there are significant advantages and some disadvantages to PBL. In this framework, there is no rote learning of facts and figures, students brainstorm problems, arrange possible solutions, decide collectively on their learning objectives, do individual work to seek out necessary information, then report back to synthesize and apply their new knowledge collectively to the problem at hand. These features parallel the important factors that are necessary for authentic learning environments and for creating authentic real world tasks used in assessment. Watts concurs that “learning is active, not passive, learning is about ownership of skills, learning is for life. While perhaps too many can remember dull and boring lessons in school, the central theme here is that effective learning is active learning” (Watts, 1991, p. 5).

Literature reveals a general consensus about some of the key elements of an authentic learning environment. These include...
authentic context, authentic tasks, access to expert thinking and modelling of process, provision of multiple roles and perspectives, collaborative construction of knowledge, reflection, articulation to enable tacit knowledge to be made explicit, coaching and scaffolding, and authentic assessment of learning within the tasks. (Bozalek, et al, 2013, p. 631)

Reeves et al (2002) add that tasks must have

real world relevance, be ill defined, comprise tasks to be investigated over time, examine the task from different perspectives, provide opportunity to collaborate, reflect, be integrated and applied beyond domain specific outcomes, are seamlessly integrated with assessment, create polished products and allow diversity of outcomes. (p. 564)

The use of Digital Moments is a robust and valid method of creating meaningful communities through recording digital stories that emerge through these authentic contexts. Connelly and Clandinin (1990) refer to the use of narrative inquiry by stating that “the main claim for the use of narrative in educational research is that humans are storytelling organisms who, individually and socially, lead storied lives” (p. 2). Bulloch and Pinnegar (2001) concur that this “may be best expressed in the story form where linearity gives way to a different sense of time, where emotion drives action” (p. 18). Eisner (1997) states that “stories instruct, they reveal, they inform in special ways” (p. 5). Although Digital moments represent an alternative form of data representation and storytelling, they present a new means to do qualitative research in online environments. The validity of such artistic research is supported by Eisner (1997) as he also refers to the importance of paying attention to the aesthetic and artistic elements of qualitative analysis. He states:

Concerns for verification, truth and precision have led us away from an experiential conception of understanding and toward a verificationist conception of knowledge – something that can be tested, packaged, imparted and sent like bricks across the country to build knowledge structures that are said to accumulate. (p. 7)

In later work Eisner refers to the term “educational connoisseurship” (1998, p. 63) to describe a new way of knowing and forming knowledge. This knowledge is considered valid when it demonstrates “structural corroboration” (1998, p. 110) (such as multiple sources of data including videos, words, photos, drawings, social media) and “internal coherence” (1998, p. 113) (such as reflections, peer sharing, peer teaching). This paper reports on the use of Digital Moments not only as a strategy to create a professional learning community, but as a format for students to use problem based learning strategies and to authentically assess their learning. Implementing Digital Moments as a pedagogical tool encourages the development of trust, motivation, creativity and growth in learning. As an instructional strategy, it allows for many of the parameters in authentic learning environments to exist. Students learn in authentic contexts, do tasks of their choosing, collaborate with others, and have access to peers who share expertise in the particular technology they wish to learn. This creates collaborative construction of knowledge, coaching and scaffolding, and embeds assessment within the learning process. The sharing of each student’s and instructor’s Digital Moment creates a natural log of the individual and collective learning process, and the weekly sharing of stories allows verbal articulation of the learning; it enables the tacit knowledge to emerge as explicit. From this foundation, a natural evolution occurs to allow students to develop and design tasks through which they, along with their instructor and colleagues, would use to assess their learning.

Table 1: Common Characteristics of PBL, Authentic Assessment and Digital Communities

<table>
<thead>
<tr>
<th>Problem Based Learning</th>
<th>Authentic Assessment</th>
<th>Digital Communities</th>
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<tbody>
<tr>
<td>Real world situations</td>
<td>Real world tasks</td>
<td>Real world student narratives</td>
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<tr>
<td>Collaborative Work</td>
<td>Collaborative assessment</td>
<td>Collaboration sharing Digital Moments</td>
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<td>Co-constructed solutions</td>
<td>Co-constructed assessment</td>
<td>Community based learning</td>
</tr>
<tr>
<td>Multiple outcomes</td>
<td>Multiple products and artefacts</td>
<td>Multiple stories and relationships in community</td>
</tr>
<tr>
<td>Digital tools vary</td>
<td>Digital modes of assessment</td>
<td>Digital Moments to narrate learning and share stories</td>
</tr>
</tbody>
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2. Rationale

Problem-based learning has evolved significantly over the past several years. There are many different modalities and there is much diversity in the field. One of the origins of PBL was in the McMaster medical school, which brought leading edge PBL to the forefront of learning environments for medical students. Barrows (1980) had found that students could learn content and skill, but they were not able to apply that knowledge in a new situation. This is also what Schon (1987) refers to as “reflection-in-action”. Bereiter and Scardamalia (1980) also acknowledge this idea of demonstrating new abilities and skills in unique situations as the development of expertise, or “how experts become experts”. The difference between novices at any task and experts is that experts continue to push the edges of their knowledge, and can react and problem solve in new and uncertain situations. Novices merely repeat patterns that they already know, and this is often not enough to deal with new, complex and elaborate situations. Professionals must learn to apply their knowledge in new and varied situations, where the parameters are uncertain and they must combine what they, and their colleagues collectively know in new ways. This is particularly important in a digital world, where individuals can “google” any subject to find out about it. Collective knowledge is built with peers, colleagues and the internet. This final partner, access to the world wide web, demands that we learn how to learn differently, as content is rapidly at our fingertips, yet learning how to critically contextualize that content means we need to assess the problem from all sides. According to Savin-Baden (2007) there are significant characteristics of PBL that include:

- Complex real world situations that have no one ‘right’ answer are the organizing focus for learning.
- Students work in teams to confront the problem, to identify learning gaps, and to develop viable solutions.
- Students gain new information through self-directed learning.
- Staff act as facilitators
- Problems lead to the development of clinical problem-solving capabilities. (Savin-Badin, 2007)

It is clear that learners in the 21C exist in a world that continually redefines itself. The development of new knowledge outpaces our ability to keep up with content, thus many authors have re-defined the essential skills required of the 21C learner. Several authors concur that these skills include the development of creativity, self-motivation, innovation, problem-solving and collaboration skills (McNeill, Gosper & Xu, 2012; Voogt, Erstad, Dede & Mishra, 2013; Kaufman, 2013). These are also skills that are developed by students in a problem based learning context.

Within the digital world, we have a myriad of opportunities to invite students to develop these skills, if the instructor has the courage and tenacity to relinquish some authority, and level the playing field. Expertise no longer resides in one individual in a professional learning community, and so the roles of teacher and learner meld. It is in the development of this safe and trusting environment, envisaged here through the creative implementation of Digital Moments as a teaching and learning tool, that growth occurs. This is what Flavin (2012) refers to as “disruptive technologies” (p. 103). He states that “when digital technologies are brought into the classroom setting, the lecturer may have to relinquish some of their authority, thus impacting on the ‘rules’ and ‘division of labour’ nodes in order to enable enhanced learning” (Flavin, 2012, p. 104). This sharing of ownership in the learning environment has been identified by Cochrane (2012) as one of the critical success factors in mobile learning. He states that features of a successful virtual learning environment include

*pedagogical integration of technology into the course and assessment, lecturer modelling of the pedagogical use of the tools, creating a supportive learning community, and creating sustained interaction that explicitly scaffolds the development of ontological shifts, that is the reconceptualization of what it means to teach and learn within social constructivist paradigms, both for the lecturers and the students. (Cochrane, 2012, p. 125)*

The sustained interaction of the individuals’ Digital Moments within the professional learning community is a foundational element within which problem-based learning and authentic assessment of that learning can emerge. The varied sources of data collected as Digital Moments (youtube, tweets, photos, poems, drawings) tell the story of the class as it evolves. Definitions of online communities vary, but Lin and Lee (2006) state “the online community can be defined as a social relationship aggregation, facilitated by internet-based technology, in which users communicate and build personal relationships” (p. 480) Wenger and Synder (2000) believe that “online communities facilitate virtual collaboration among community members with the
potential of transforming the activities of off-line into an online context” (in Lin & Lee, 2000, p. 480). While this social element of online learning remains a predominant challenge to educators, effective online pedagogy relies on how skilled the instructor is at developing and sustaining a sense of belonging to the digital community. By combining problem based learning, authentic assessment tasks and a strong sense of community, educators can become adept at helping students become independent autonomous learners who are capable of solving the complex problems facing 21C learners.

3. Methodology

This research occurred in three phases and was used to analyse the effectiveness of using the pedagogical documentation strategy of “Digital Moments” as an assessment tool.

Phase 1: This involved using Digital Moments as an opening activity in online synchronous and asynchronous undergraduate courses as a way to create a professional learning community. Students in each phase took a course entitled “Psychological Foundations and Digital Technology” and there were 35 participants from a variety of backgrounds including education, nursing and health care, gaming, and business. The instructor was an Assistant Professor in the Faculty of Education. Classes watched 3 hours of podcasts per week on their own, then met once a week for one hour over a 12 week period in the winter term. The purpose of using “Digital Moments” was to simulate the social and community building network that evolves naturally during the first minutes of a face to face class environment. Each week, 35 pods were created in Adobe connect, and students entered the virtual room ahead of class time to post their Digital Moment. Students were given some exemplars as to what a Digital Moment might look like, (words, phrases, pictures, colours, musical links) but were not limited in their creativity. Anecdotal reflections from students recorded in Blackboard chat rooms, audio recordings of Adobe connect classes and field notes from the professor were collected.

Phase 2: Students in this phase began to facilitate others’ use of new technologies in order to submit their assignments in different formats. Having gained confidence and trust, two important elements of a virtual professional learning community, they began to ask the instructor if they could submit their final assignments using alternate means to text-based artefacts. While traditional teaching at the undergraduate level involved a final examination, or submitting text based essays and final papers, students were allowed to fulfil their requirements by using alternative modes (youtube, video, audio, photo journal) as long as the work demonstrated evidence of competence, critical thinking, and was clearly grounded in the literature. Students participated in the development of assessment criteria and along with the assignment they handed in an assessment document that they had negotiated and collaboratively developed with the instructor.

Phase 3: Students began to use a variety of assessment tools they had developed collaboratively by which they were able to assess their own work and the work of others. They were able to provide feedback and comments to each other on how valid and reliable the assessment tools they developed were, and used that feedback to make changes or adjustments. Collectively the group agreed to try each of the tools when assessing their own and their peer’s work. These included rubrics, but also included portfolios of their course work, journals and comments by their peers who had witnessed, and often aided in the learning process. These tools were built in social and constructivist ways to ensure that the learning was both meaningful to the learner and relevant to their own professional contexts.

4. Data Collection

Ethical review was passed and informed consent of participants was obtained. Data were collected via recordings of classes in Adobe connect, including both formal and informal chat rooms for review. Anecdotal information from external professional learning communities created by the students in Linked In and Facebook was obtained. Recordings of classes were kept on a secure server located at the university. Audio and text data were used to analyze how well the strategy worked in terms of students’ perceptions of their online community. Students were asked to maintain weekly comments in Blackboard chat rooms and use this as a journal format to record their observations about their online community. Copies of assessment tools and the links to multi-modal assignments were stored at the university website. It is also worthwhile to note that after the experiment had completed, several of the graduate students, themselves employed as teachers, have
continued to journal with the professor and began to use the “Digital Moments” strategy in their own work environments.

5. Findings and Key Themes

The Process of PBL: It is important to note that these students had graduated from a more traditional educational system wherein the teacher holds the power and students are asked to produce a graded product. Often they had not participated in the decision-making process whereby this product was defined, and almost always they had not participated in collaboratively taking ownership of the assessment process. While some students may have had experience with self and peer assessment, it is critical to acknowledge that these are skills that students must be taught. Learning how to give and receive feedback is an important piece of the PBL environment, and meaningful feedback that stretches beyond “great job” is essential for the process to move forward. This lack of learner experience in having autonomy creates resistance at first, as students want to be fed criteria, rubrics and want exemplars of what constitutes a graded product. Instructors as well, may initially resist PBL as it means that they have to examine how relevant their grading practices actually are, and step outside of what are often institutional or systemic methods of grading students. In addition, instructors need to be able to accept a wide variety of products, understand and be able to explain why they are allowing this lack of “sameness” to superiors in the university and to be comfortable with the fact that they are using fair and accurate assessment practices. This can be a challenge, and might be helped by instructors collaboratively meeting in their own PBL professional development sessions to discuss the process and to learn how others are using PBL, while simultaneously meeting the university requirements.

Student Perceptions of PBL: It is interesting to note that the first course students take using PBL is often a difficult one for them, as they do not exhibit the required independence and autonomy. Most students expect to take an exam at the end of a university course, and this model did not have a summative examination. Two populations of students emerged, those taking the course as an elective and others taking it as part of their undergraduate degree. Students taking the course as their second or third on in a series of PBL courses embraced the concept, after some initial difficulty which was an important part of their “un-learning” what it means to be a student. Students generated lists of what they perceived to be the advantages and disadvantages of PBL as a learning strategy. Among the advantages they listed being the meaning-makers and constructivist learning, less rote learning of facts and content easily found online, more student choice and autonomy, greater flexibility and creativity in the final product, and getting to work collaboratively with peers. Disadvantages were primarily the initial discomfort, struggle and lack of specific criteria given by the instructor as to the end product. They also referenced that PBL might be easier in a digital context as they could use Adobe connect to work with colleagues anywhere in the world in different times and places, which enriched their projects considerably.

6. Creativity

Kaufman (2013) reveals that “school is not simply about tests and ‘checking boxes’ of topics and assignments. Rather, schools today should have a mission of developing students as individuals and igniting their creativity” (p. 79). Students in this project began to unleash the bonds of traditional online courses they had taken, and began to flourish in the freedom of creative practice. At the same time, ironically, they began to take more responsibility for their own learning. Being allowed to choose empowered them to discover the intimate bond between real freedom, self-responsibility and creativity. While many stated they had been indoctrinated by a culture of marks and grades, many revelled in the return to a natural state of learning, one that allowed freedom, innovation and a deeper level of responsibility than many had taken in some time. In previous online courses, the keeper of knowledge had been the instructor. It took courage on the parts of both instructor and learners, but once out of their educational cage they embraced the wide open fields of knowledge the digital world provided. One student referred to his favourite quote that “wild elephants walk softly in open fields” as a metaphor for feeling free, calm and in his natural learning environment.

6.1 Extended relationships

The use of Digital Moments began to take on a life of its own beyond the scheduled class time. Some students created their own learning communities on Facebook and LinkedIn in order to stay in touch once the course
had ended. In addition, Twitter feeds were used to follow each other and sustain friendships and learning experiences. These extended connections through technology became a web within which students connected on a personal level, a professional level, both emotionally and digitally. This is evidence that “learners are responding to the new technical and social opportunities with little help from the formal education system” and there is “evidence of deep networking and knowledge building in learners’ informal practices” (Littlejohn, Beetham & McGill, 2012, p. 551). Learning that is situated in digital worlds must also have a social component to be effective. Kearney, Shuck, Burden and Aubusson (2012) concur that learning is a social endeavour. They identify three distinct features of mobile or virtual learning that include “authenticity, collaborations and personalisation” (p. 2). They refer to a socio-cultural model for virtual learning and the importance of “enhanced collaboration, access to information and deeper contextualisation of learning” (2012, p. 2).

6.2 Teacher-Learner-Teacher Role Shifts

During the course, the roles in this professional learning community became almost indecipherable. While still within the university context, the instructor fulfilled the responsibility to assign grades to students. But in the learning environment, the power differential became almost invisible. The students with expertise in particular technologies took on the role of instructor, the teacher became the learner, thus empowering learners with the confidence to take risks, make mistakes, and ask for help. This supports the notion that 21C learners must be able to think critically, be problem-solvers and work collaboratively. In particular, for 21C learners in a virtual classroom, they must be able to go beyond the class and use their digital literacy within the context where they work and live. “It is obvious that not only learners, but also teachers need to acquire 21st century competencies as well as become competent in supporting 21st century learning” (Voogt, Erstad, Dede & Mishra, 2013, p. 408). In order to create authentic learning and assessment tools, teachers need to learn how to design such tasks. McNeill, Gosper and Xu (2012) surveyed academics and found that many continued to target lower order learning outcomes. They state that

universities increasingly value the skills such as problem-solving, critical thinking and creativity, yet the curriculum needs to be designed to support and scaffold development of these skills, and integrating them into assessment strategies has proven a challenge. While new technologies have sometimes been heralded as having the potential to address an apparent gap between the rhetoric of curriculum alignment and assessment practice in universities, academic practice is slow to change, and the uptake of new tools to support the development of higher order skills remains relatively low. (McNeill, Gosper & Xu, 2012, p. 283)

This research argues that if Digital Moments can be used to create learning environments that support academics to learn new skills, then they may create more relevant 21C learning outcomes for their own students. In the digital world, it is imperative that teachers, regardless of academic standing, continually redefine themselves as life-long learners and model this for their students.

6.3 De-valuing and Re-valuing

The implementation and acceptance of arts-based and creative assessment tools meant a significant ‘unlearning’ and ‘revaluing’ what it meant to demonstrate one’s knowledge. It became important to unpack how each learner had developed their values about the importance or lack of importance of marks and grades versus the value of the learning process itself. Students began to see how the development of friendships and simple human qualities like trust, caring and compassion were the real foundation for creating meaningful learning experiences. It also helped them to begin to trust themselves; they began to believe there was an authentic self in each learner who could choose which direction to go, which tasks were personally and professionally relevant, and which were best left to others. The level of passion and interest became more important than the grade, and this represented a significant shift in values. As Kaufman states “development of these skills is purposefully integrated within core content areas in ways that help students find relevancy in their work, a characteristic central to motivation and learning” (2013, p. 79). Contrary to traditional educational frameworks, wherein the power is centred in the instructor or the institution, this model required a re-valuing of where the fundamental responsibility for learning resides - within the learner.
7. Discussion

The three factors of problem based learning, authentic assessment and meaningful community are a powerful combination of tools that online instructors can use to provide students with effective digital pedagogy. Perhaps most significant is its transformational effect on the nature of learning itself, the instructors’ role, and on the learner’s attitude towards learning. Far from reforming students, who may then revert to past methods of learning, these three elements combine to shape a student’s way of perceiving the learning. Students who had taken several courses in this modality became accustomed to their autonomy and independence. They embraced the flexibility and creativity that came alongside of the greater responsibility for their own learning. From the instructors’ perspective, this was a fundamental learning outcome. Students began to exhibit greater competence and confidence in using open source digital resources, needed less direction from the instructor and enjoyed taking the reins of their own learning.

The human story remains at the essence of every great learning experience. Using Digital Moments to tell individual stories and create learning communities proved an invaluable teaching strategy to create meaningful learning experiences for students. This sharing of stories, allows for learners to develop empathy, compassion and deeper understanding of each other. As the 21C learning landscape becomes increasingly impersonal, isolated and digital, it is imperative that we continue to use pedagogical strategies such as Digital Moments to preserve the richness of our online learning environments. As Cousins and Bissar affirm, 

*What stories can be told about the fast-changing world of higher education, and what can we learn from them? Adapting to new situations, conquering fears and overcoming obstacles are familiar storylines, with particular relevance for university lecturers having to introduce new technologies in their working practices.* (2012, p. 1)

Digital Moments are personal, and help us to create connections in a world where being wired to technology 24-7 often makes us feel disconnected from those around us. This is the great paradigm of the digital 21C world. Educators need to find ways to reconnect learning in a very human, empathetic and meaningful way. Without this, we cannot ground our problem-solving in a human context, and we cannot solve the issues we face alone. Rolfe (2012) states the importance of identifying individual pioneers and “understanding the motivations and characteristics of potential users in order to establish strong and sustainable practices” (p. 16).

We know that student engagement in online courses is challenging as instructors face a huge inundation of competition from text, you-tube, Facebook, Twitter and more. Students are wired in, and our instructional strategies need to acknowledge that keeping their attention requires us to use some of the same engagement strategies that are used so successfully by social media, video games and digital environments. Badge, Saunders and Cann (2012) acknowledge that students’ online attention is focused on these other sites with high activity rates, and that “engagement is more than participation, it requires emotion and sense-making as well as activity, these social networks are rapidly moving beyond their original purpose and are inevitably becoming part of the learner experience” (p. 2). Thus, to engage students in authentic learning environments, capture their attention and imagination, we need to use social strategies that appeal to students. Based on this captive audience, we can move them towards authentically assessing their learning, using modalities that are not text-based, but which permeate their world on a moment by moment basis.

8. Conclusion

Our digital stories can be effectively used as a strategy to create authentic online learning environments, and to assess student work authentically. This requires us to revisit several of the themes that emerged in this project. First, we need to celebrate and encourage the development of creativity by allowing students to use original and artistic ways to express knowledge; further, they need to be able to create the means to authentically assess that knowledge and the learning of self and peers. Second, we need to acknowledge that the successful creation of the parent professional learning community is often insufficient, and readily gets supplemented by digital communities of practice developed by students. This is evidence of the power of extended relationships among learners, and it also allows for the shift in power from the university instructor to the real world of the student. Using Digital Moments can be a precursor to this shift. Third, the roles of teacher and learner must be interchangeable and fluid. The degree to which the instructor is willing to empower students, risk making mistakes and put themselves in the context of ‘beginner’s mind’ will parallel
the trust and empathy in the learning environment. If we are to make it safe for students, we must model a certain degree of vulnerability ourselves, relinquish our post as ‘expert’ despite our academic qualifications, and quite probably re-learn to have fun with the simple process of learning. Finally, there is a significant de-valuing and re-valuing that occurs in authentic learning contexts. 21C learning environments do not require students to leave behind text-based measures of knowledge completely. Rather, they acknowledge that text-based measures of achievement are insufficient to capture or measure things in a digital world.

Ultimately, both learners and instructors must discern what remains ‘real’ in any authentic learning context. Digital worlds provide us with a plethora of options beyond text; we need to become responsible and free users of these alternative means to demonstrate knowledge. Our assessment methods must catch up to the reality of learning in the 21C. Our tool box must expand to include, but move beyond text to celebrate multimodal measures of knowledge.

The experience of becoming ‘real’ online was a journey fraught with highs and lows, like any good adventure. It is clear that digital classrooms can provide uniquely human learning experiences. The gaps that were anticipated in getting to know students, creating relationships between students online and designing a safe environment for taking personal risks in learning were not as scary as previously thought. Prior to teaching in this environment, the authors believed that “authenticity in teaching” would be more difficult online. In some respects, it is, but in our unfolding digital world, perhaps we need to use this venue for reaching out to learners more globally. Technology was a powerful tool, but the humanity in the classroom remained untouched as the real driver of the learning experience. It is important to remember that the teacher-learner relationship cannot be replaced, nor does it need to be replaced by high tech solutions. In order to have successful online pedagogy, we must venture into the connections between problem-based learning, authentic assessment and the importance of community. These three elements are interwoven. Despite our traditional training in wanting to know the “right” answer, we should embrace a variety of solutions and let students take ownership of the problems they wish to study within the context of our courses. Instead of running from difficulty and challenge, we need to embrace our stuckness, trust in the collective nature of knowledge, use our peers, our instructors and our digital tools to find new and creative solutions. As Robert Pirsig stated in his book “Zen and the Art of Motorcycle Maintenance”(1975):

“Stuckness shouldn’t be avoided. It’s the physic predecessor of all real understanding. Stuckness isn’t the worst of all possible solutions, but the best possible situation you could be in. Your mind is empty; you have a hollow-flexible beginner’s mind. Consider for a change, that this is a moment to be not feared but cultivated. If your mind is truly and profoundly stuck, then you may be much better off than when it was loaded with ideas. “ (1975, p. 257)

The nature of knowledge has shifted; the nature of assessment lags far behind. Problem based learning helps shape students’ knowledge, and helps them acquire the key attitudes necessary for success in a digital world. Digital access to knowledge will continue to move faster than we can keep pace. Our job as instructors is not to carefully box our students’ knowledge in text based measures, label it securely in a container we feel is safe, and move on. If we limit ourselves to this academic prescription pad, serving our students a traditional dose of only text based assignments, we will remain far behind the digital divide. While not abandoning our history of essays and academic writing, we need to expand this learning and assessment tool box. We need to let students explore problem based learning, in the same way they will experience problems in their future work and careers. They should be assessed authentically to demonstrate their knowledge in a variety of artistic and creative ways that best fit their digital skills and knowledge, and should develop the confidence and competence to participate in meaningful online communities. These are the characteristics required to succeed in an internet-based world. While institutions and systems may balk at this non-traditional approach to learning and assessment, we must move forward and embrace all that the digital world has to offer, relinquish institutional power, and place the reins squarely where they belong, in the hands of our students.

References


Mitigating the Mathematical Knowledge gap Between High School and First Year University Chemical Engineering Mathematics Course

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Abstract: This paper reports on a study carried out at a University of Technology, South Africa, aimed at identifying the existence of the mathematical knowledge gap and evaluating the intervention designed to bridge the knowledge gap amongst students studying first year mathematics at the Chemical Engineering Extended Curriculum Program (ECP). In this study, a pre-test was used as a diagnostic test to test incoming Chemical Engineering students, with the aim of identifying the mathematical knowledge gap, and to provide students with support in their starting level of mathematical knowledge and skills. After the diagnostic test, an intervention called the autumn school was organized to provide support to bridge the mathematical knowledge gap identified. A closed Facebook group served as a platform for providing student support after school hours. After the autumn school, a post-test was administered to measure whether there was an improvement in the knowledge gap. Both quantitative and qualitative methods of collecting data were used in this study. A pre-test was used to identify the mathematical knowledge gap, while a post-test was employed to measure whether there was a decrease in the knowledge gap after the intervention. Focus group interviews were carried out with the students to elicit their opinions on whether the intervention was of any help for them. Students’ participation on Facebook in terms of student post, post comments and likes and an evaluation of students’ academic performance in comparison to their Facebook individual participation was also conducted. Quantitative data was analysed using descriptive statistics, while qualitative data was analysed using inductive strategy. Results showed that all the students in this study had the mathematical knowledge gap as no student in the class scored 50% on the overall pre-test. Findings further revealed that the intervention played a major role in alleviating the mathematical knowledge gap from some of the students (with 1/3 of the students scoring 50% and above in the post-test) and no positive correlation between students’ academic performance on the post-test and students’ participation in the Facebook group was noted. We hope that insights generated in this study will be of help to other institutions looking into designing interventions for bridging the knowledge gap. Reasons for lack of improvement in the knowledge gap of 2/3 of the students in this class will be highlighted.

Keywords: knowledge gap, extended curriculum program, descriptive statistics, inductive strategy, diagnostic test, autumn school, Facebook closed group

1. Introduction

In South Africa, Engineering programs require at least two years of university mathematics. The student selection into these courses is based on one’s marks achieved in the final school leaving examination – the National Senior Certificate (NSC) (Van der Flier, Thijs & Zaaiman 2003). Over the years, students entering university engineering courses struggle to succeed in the first year mathematics (Moyo 2013; Wolmarans et al. 2010). As a result, the South African higher education (HE) sector is faced with the challenge of the mathematical knowledge gap. Mathematical knowledge gap is defined as the lack of smooth transition from high school mathematics to university first year mathematics for students majoring in science, mathematics and engineering due to the shortcoming of both the high school and the first year university mathematics programs between the knowledge possessed by school leavers and the knowledge required for first year entry into mathematics courses (Wolmarans et al. 2010). Research shows that some institutions have taken steps to bridge this knowledge gap, while others have continued to ignore the problem leading to high dropout rates (Moyo 2013). This paper reports on a study carried out at a University of Technology, South Africa, aimed at identifying the existence of the mathematical knowledge gap and evaluating the intervention designed to bridge the knowledge gap amongst students studying first year mathematics at the Chemical Engineering Extended Curriculum Program (ECP). The Extended Curriculum Program gives access to higher education to students from disadvantaged backgrounds who have only met the minimum requirements for entry to university and assists them in developing academic foundations by offering instructions in small classes over an extended period of time, and with more dedicated support.) In this study, a pre-test was used as a diagnostic test to test incoming Chemical Engineering students, with the aim of identifying the mathematical knowledge gap and to provide students with support in their starting level of mathematical

Reference this paper as Basitere M and Ivala E “Problem Based Learning and Authentic Assessment in Digital Pedagogy: Embracing the Role of Collaborative Communities” The Electronic Journal of e-Learning Volume 13 Issue 2 2015, (pp68-83) available online at www.ejel.org
knowledge and skills. After the diagnostic test, an intervention called the autumn school was organized to provide support on the knowledge gap identified. A closed Facebook group served as a platform for providing student support after school hours. After the autumn school, a post-test was administered to measure whether there was an improvement in the knowledge gap. Students’ participation on Facebook in terms of student posts, post comments and likes and an evaluation of students’ academic performance in comparison to their Facebook individual participation was also conducted.

Using both quantitative and qualitative methods of collecting data, findings of the study showed that all the students in this study had the mathematical knowledge gap as no student in the class scored 50% on the overall pre-test. Findings further revealed that the intervention played a major role in alleviating the knowledge gap from some of the students (with 1/3 of the students scoring 50% and above in the post-test) and no positive correlation between students’ academic performance on the post-test and students’ participation in the Facebook group was noted. We hope that insights generated in this study will be of help to other institutions looking into designing interventions for bridging the knowledge gap. To investigate the matter under study, the researchers were guided by the following objectives:

- To investigate the existence of the mathematical knowledge gap
- To evaluate the impact of the intervention designed (the autumn school and the closed Facebook group) to bridge the knowledge gap

2. Literature

2.1 The transition between schooling and first year entry into mathematics courses

According to 2005 HEMIS (The Higher Education Management and Information System), the “pool” from which suitable science and engineering students are selected is small. For instance, 20 percent of the 2008 National Senior Certificate (NSC) candidates achieved a pass that allowed them access to admission to degree studies at higher education institutions, and only 7.9 percent of the candidates achieved more than 60 percent in the 2008 NSC mathematics examination – a requirement to enter Engineering programs (Department of Education 2008). Research suggests that many students in the South African schooling system are underprepared for success in higher education (HE), and especially in mathematics and science disciplines (Badat 2010). Research shows that students entering university engineering courses struggle to succeed in the first year mathematics (Moyo 2013; Wolmarans et al. 2010). This is partly attributed to the mathematical knowledge gap possessed by school leavers and the knowledge required for first year entry into mathematics courses (Wolmarans et al. 2010).

The knowledge gap includes: a serious lack of essential technical facility – the ability to undertake numerical and algebraic calculations with efficiency and accuracy; a marked decline in analytical powers when faced with simple problems requiring more than one step; and most students entering HE no longer understand that mathematics is a precise discipline in which exact, reliable calculations, logical exposition and proof play an essential role (Clark & Lovric 2009). The matric topics that are said to be problematic and not taught in a way that minds the gap are: functions, sequences and series, differential calculus, euclidean geometry, analytical geometry, vectors, complex numbers and statistics. This mathematical knowledge gap encountered by first year engineering students in mathematics courses is not unique to the South African context (Moyo 2013; Wolmarans et al. 2010). These authors indicate that similar patterns have emerged in the United States, amongst others. However, the situation in South Africa in respect of mathematics is regarded as being more pronounced than elsewhere (Wolmarans et al. 2010). The effects of the knowledge gap in South Africa are that students drop out affecting the throughput rates and some students are discouraged from taking mathematics and physical sciences because they are perceived as cognitively difficult. This may have a long-term impact on the skills available in these areas in the country. As a result, it is imperative that institutions of higher education find educational strategies that would impact student success (Scott et al. 2007). Hence, many universities in South Africa in response to the fact that schools do not adequately prepare students for what is expected of them when they enter first year mathematics are designing interventions aimed at helping address this deficit (Human et al. 2010). Thus, this paper reports on a study carried out at a University of Technology in South Africa, aimed at identifying the existence of the mathematical knowledge gap and evaluating the intervention designed to bridge the knowledge gap amongst students studying first year
mathematics at the Chemical Engineering Extended Curriculum Program. Facebook, a social media application, was used as part of the intervention.

2.2 Facebook for teaching and learning

Social media can be defined as a group of internet-based applications built on the ideology and technology of Web 2.0, which allows for the creation and exchange of user generated content (Kaplan & Haenlein 2010). Social media emphasizes active participation, connectivity, collaboration, community and sharing of knowledge and ideas amongst users (Correa 2013). This technology exists in different forms such as internet forums, weblogs, social-blogs, micro-blogging, wikis, podcasting, social bookmarking and social networks (Mazer, Murphy & Simonds 2007). The case for use of social media for teaching and learning is quite convincing (Badge et al. 2012; Ivala & Gachago 2012; Leece & Campbell 2011; Muñoz & Strotmeyer 2010). Badge et al. (2012) contend that by encouraging engagement with social media, students develop connections with peers, establish a virtual community of learners and ultimately increase their overall learning. By participating in a community of learners, students become more engaged with the course content, which increases the achievement of popular learning outcomes such as critical thinking. Similarly Junco (2012) reports a positive relationship between the use of social networking websites and student engagement adding that frequent users of social networking websites participated more often and spend more time in campus organisations than less frequent users. Mazur et al. (2007) also indicated that social networks offer opportunities to cultivate the student-teacher relationship, which creates a positive learning experience for both parties. Hence social networking services such as Facebook, Twitter and MySpace have gained huge popularity and widespread use in HE globally over the past few years.

The reasons for using Facebook in this study was because Facebook is ranked the top social networking site (SNS) in the world with an estimated 1 billion monthly active users and 552 million daily active users on average (Facebook newsroom statistics 2012). Studies by Hargittai (2008), Jones and Fox (2009) and Junco (2012), also indicated that Facebook is the most popular social media website for college students. Given that Facebook continues to be popular amongst college students, and that universities are interested in engaging and retaining students, Junco (2012) advises that those working in HE need to familiarize themselves with Facebook (and other such technologies) and to design and support interventions that meet students where they are in order to help them get to where they are going. Reporting on an experiment with Facebook as a teaching and learning tool, Esteves (2012: 6) revealed that: students asked questions related to the course topics by posting on the group’s wall and received answers through “comments” from other members of the class; students shared new media like videos, websites, comic strips, podcast related to web design and publishing, distance education and Facebook as used for learning; and students used the “Chat” feature to discuss class-rated topics or simply chat casually with their classmates and faculty-in-charge. Facebook offers educators an additional venue for connecting with diverse cohorts of students, as well as a different forum for exchange with students in a less hierarchically structured manner. By “meeting students where they are” (e.g. Facebook) educators can capitalize on the existing incentive of participation in personal networks much like the commercial interests take advantage of their potential clients’ presence in those spaces. In terms of creating a “community of learners”, the use of a tool that students embrace in their daily lives, may improve discussion thread postings on course material, while supporting interactivity with students in these informal spaces.

However, caution needs to be exercised as literature shows that social network services might also negatively affect learning. For example, Welch and Bonnan-White (2012) found that many students had difficulty with the technology due to lack of familiarity and that some students were reluctant to adapt to unfamiliar technology and classroom expectations. Social media can also cause miscommunications, often because of the limited context available in digital communication and “since the lack of face-to-face contact involved in using social technologies leads to limited context, it is incredibly easy, and takes very little ego investment to propagate rumors and harassing content quickly and easily across the Internet”. Other disadvantages of using Facebook for teaching are privacy concerns and issues of self-disclosure and identity management (Correa 2013).

2.3 The context of the study

The study was conducted in the 2013 academic year at the Department of Chemical Engineering at a University of Technology, in South Africa. The participants of the study were 41 ECP Chemical Engineering students. The
ECP programme has been designed to support students who are enrolled in a Chemical Engineering course with a minimum of 50 percent pass rate in mathematics and physical sciences. As part of the support system, the ECP students take half a workload compared to mainstream students (mainstream students are those whose matric marks are above 50 percent and who take six subjects per semester). The ECP programme takes two years in which students are provided with the necessary support to acquire the necessary skills and competences they need to succeed in their studies. The ECP programme is supposed to play a role in filling in the mathematical knowledge gap but in practice that does not happen often.

Therefore, in this university, the lecturer responsible for teaching mathematics with support from the department decided to administer a diagnostic test to incoming Chemical Engineering students to measure the mathematical competence of students upon arrival at university and to provide prompt and effective support to students on mathematical knowledge gap. The approach of diagnosing and providing support is based on the trust that incoming students are in principle quite capable of overcoming the initial difficulties and can attain the desired level in a rather short term. The lecturer's administration of the diagnostic test and designing of the intervention was driven by the concern that students may lack certain conceptual understanding as well as dispositions that are essential in the practice of mathematics and applied mathematics and the fact that the possibilities for genuine education depend on the knowledge and experience already existing within students (level of development) as well as on the students' potential to learn (Vygotsky 1986). The diagnostic pre-test consisted of open-ended questions, while the post-test consisted of open-ended questions with a few multiple-choice questions. The areas covered by both the pre-test and post-test were: trigonometry; analytical geometry, fractions and simplifying exponents and calculus.

On establishing the existence of the mathematical knowledge gap, the lecturer designed an autumn school, with a closed Facebook group (the intervention) being used to extend learning out of the classroom. The intervention was run for one week and it was aimed at: filling gaps in mathematical knowledge and skills, reviewing essential facts and brushing up on calculations and developing appropriate attitudes. The reason for this lecturer’s caring about the knowledge gap was to improve student learning; to increase and/or maintain their motivation to study mathematics and to consider a career in a mathematics related field and to use resources effectively. Additionally, the lecturer cared about the transition because he has a responsibility towards his students, as they strive to achieve their university goals, to offer resources that are most effective for students’ success so that students who fail in their studies will then know that it was not due to poorly designed transition and initial university offerings (Clark & Lovric 2009). On the social economic level, there is a tendency for greater proportions of the population to become engineers and scientists. As a result, engineering and science study programs are needed to take students who may in the past not have been considered as suitable for such studies, and then need to educate them to the right level. Secondly, the school system in South Africa is currently struggling to produce a sufficient number of students who are well prepared for engineering and sciences course. As a result, university courses need to adapt, and many engineering and science undergraduate programs in South Africa are already presenting support subjects in addition to “core” mathematics, science and engineering subjects (Human et al. 2010). In the next sections, the methodology and the results of this study will be presented.

3. Methodology

Both quantitative and qualitative methods of collecting data were used in this study in order to ensure triangulation of data and to enhance the significance of the findings by integrating different ways of knowing (Caracelli & Greene 1997).

3.1 Context and participants

The study was carried out at the faculty of engineering, Department of Chemical Engineering at a University of Technology in South Africa. The participants of the study were 41 students enrolled for ECP Chemical Engineering in 2013 and working towards a national diploma. A purposive sampling was used to select the participants in this study (Patton 1990). The students were selected because it was felt that they had rich information gained through their experiences in the intervention (Patton 1990).
3.2 Data collection

Both quantitative and qualitative methods of collecting data were used and the data consisted of recordings of three focus group interviews with the students, which were carried out to draw out their perceptions of the benefit of the intervention (autumn school and the use of the Facebook group). Quantitative data was gathered through the use of a diagnostic test as pre-test, used to identify whether students had the mathematical knowledge gap and a post-test was administered after the intervention to measure whether the intervention had any impact on addressing the mathematical knowledge gap students possessed. The pre-test question paper consisted of open-ended questions, while the post-test question paper comprised of open-ended and multiple-choice questions. An analysis of Students’ participation on Facebook in terms of student post, post comments and likes and an evaluation of students’ academic performance in comparison to their Facebook individual participation was also conducted.

3.3 Data analysis

Quantitative data was analysed using descriptive and inferential statistics, while qualitative data was analysed using inductive strategy. Frequencies were calculated to determine whether the students had mathematical knowledge gap and to measure whether the intervention had any impact in addressing the mathematical knowledge gap. A paired sample one tailed $P$-test was executed to test for significant differences in the pre- and post-tests marks. Facebook data was extracted using a PHP script (which makes use of the Facebook application interface (API) written and self-hosted by Mr Nzumbuluwani Mmbara (IT specialist) of Musuku Africa Pty (Ltd), South Africa. Focus group interview data was recorded on tape and transcribed verbatim. The interviews were analysed focusing on the identification of conceptual themes and issues emerging from the data, using techniques such as clustering, and making contrast and comparisons (Miles & Huberman 1994). The researchers were especially interested in moments in the project that could be construed as the focal points for the benefits of the intervention.

The participants’ consent to participate in the study was sought and the purpose of the study was explained to the students. Interview transcripts and student scripts were available for the students to scrutinize. Anonymity and confidentiality were adhered to as promised to the students. The faculty of engineering ethics committee gave ethical clearance.

4. Findings and discussion

The study aimed at identifying the existence of the mathematical knowledge gap and evaluating the impact of the intervention designed to bridge the knowledge gap amongst students studying first year mathematics at the Chemical Engineering Extended Curriculum Program (ECP), at a University of Technology in South Africa. Findings are presented under the following categories:

- Identification of the existence of the mathematical knowledge gap
- Impact of the intervention in addressing the mathematical knowledge gap

4.1 Identification of the existence of the mathematical knowledge gap

Findings of the study showed that students had the mathematical knowledge gap in the four areas assessed (that is, trigonometry; analytical geometry, fractions and simplifying exponents and calculus), as no student in the class scored 50% on the overall pre-test (see figure 1).
The above results confirm the existence of the mathematical knowledge gap amongst the incoming first year Chemical Engineering students. These results are in agreement with findings by Wolmarans et al. (2010) and Moyo (2013) who reported that the mathematical knowledge gap existed amongst first year engineering students in mathematics courses in South Africa and elsewhere in the world.

4.2 Impact of the intervention in addressing the mathematical knowledge gap

After establishing that the incoming first year engineering students had the mathematical knowledge gap, the lecturer designed and implemented an autumn school to teach the four areas tested in the pre-test. A closed Facebook group was opened to extend learning beyond the classroom. After the autumn school, a post-test was administered on the first day of the new university term, which commenced after the autumn school. Findings of the post-test showed that the intervention played a major role in alleviating the mathematical knowledge gap from some of the students (with 1/3 of the students scoring 50% and above in the post-test and 2/3 scoring less than 50) (see figure 2), with Facebook playing a crucial role of extending learning beyond the classroom time. Further, the pre-test results showed a zero pass rate, with average results of 23%, which indicates that students lacked understanding of some of the basic mathematical concepts needed to be mastered before they start their first year engineering mathematics. The results of the post-test indicated an improvement on student performance with a pass rate of 39%, with an average student mark of 48% (see table 1). To determine whether the pre- and post-test marks were comparable, a p-test was performed on the pairs of pre-test and post-test data. A p-value smaller and equal to 0.05 (p ≤ 0.05) is interpreted as significant as it indicates a probability of 5% or less difference between the pre-test and post-test data sets. The p-test showed a p-value of 2.22E-11, which is less than 0.05 indicating significant difference between pre-test and post-test (see table 1).
Even though 2/3 of the students did not score 50 percent and above, results show that there was increased understanding in knowledge as their marks had improved compared to what they had scored in the pre-test (see figures 2 and 3). However, it is disconcerting that only a third of the student population entering Chemical Engineering ECP reached a desirable level of mathematical competence (scoring>50%).

Table 1: Comparison of students’ pre-test and post-test marks

<table>
<thead>
<tr>
<th></th>
<th>Pre-test</th>
<th>Post-test</th>
<th>End term results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>41</td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td>No of passes</td>
<td>0</td>
<td>16</td>
<td>31</td>
</tr>
<tr>
<td>Pass rate</td>
<td>0</td>
<td>39</td>
<td>76</td>
</tr>
<tr>
<td>Mean</td>
<td>23</td>
<td>48</td>
<td>54</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>13</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>57</td>
<td>33</td>
<td>9</td>
</tr>
<tr>
<td>P-test</td>
<td>2.22E-11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Furthermore, figure 4 below shows a time series graph indicating student academic participation on the closed Facebook group. Facebook participation in this study was defined by the number of academic posts posted by individual students, students’ post comments on the academic posts posted by the lecturer or other students and the number of students who liked the posts. Students’ posts in this study were in terms of asking questions, which encouraged interaction and told the other students that their opinions on the subject of the post matters. Some students responded to the academic posts by use of post comments, which are comments generated in response to the academic post. Other students liked the post, which is a way of letting the student who posted the post knows that they engaged with the content and enjoyed it. In this study, the total number of academic posts were 96 (see table 2), 171 post comments (see table 3) and 41 likes as shown on Table 4 below;
### Table 2: Individual and total students’ posts on the Facebook group

<table>
<thead>
<tr>
<th>Year</th>
<th>Students</th>
<th>2013 Posts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abongile Ta Levi Nomfombo</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Avela Manqina</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Dale Lethling</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Dimph Matshiya</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Easton Chad Carolissen</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Grant Marthinus</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Kamva Mbalentle Dolz Landzela</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Leigh Boo-thang Kruczynsky</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Litha Martin Dyani</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Lloyd Talmarkes</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Malema Rendie Rendie</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Matodzi Thalitha Makhado</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Meagan Saul</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Noxolo Shabangu</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Nqobile Mamogobo</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Pohotona Matome Thabang</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Prudence Qhamisa Shuba</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Sihle Isipho Samazima Kratshana</td>
<td>2</td>
</tr>
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<td></td>
<td>Sihle Ntsikelelo Zenani</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Simbongile Kopana</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sinazo Nkuku</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Siphokazi Favour Tomela</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Thami Tha King</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Themb-Eliehle Sopazi</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Yonelisa OlwAm Sitshinga</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Zingisa Fani</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Zulfah Samuels</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td><strong>Grand Total</strong></td>
<td><strong>96</strong></td>
</tr>
</tbody>
</table>
Table 3: Individual and total students’ posts comments on the Facebook group

<table>
<thead>
<tr>
<th>Year</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month</td>
<td>(Multiple Items)</td>
</tr>
<tr>
<td>Students</td>
<td>Comment</td>
</tr>
<tr>
<td>Abongile Ta-Levie Nomfombo</td>
<td>1</td>
</tr>
<tr>
<td>Aphelele Piriri Mxabanisi</td>
<td>1</td>
</tr>
<tr>
<td>Aphiwe Mhlonyane</td>
<td>9</td>
</tr>
<tr>
<td>Avela Manqina</td>
<td>2</td>
</tr>
<tr>
<td>Dale Lethling</td>
<td>1</td>
</tr>
<tr>
<td>Dimph Matshiya</td>
<td>6</td>
</tr>
<tr>
<td>Easton Chad Carolissen</td>
<td>2</td>
</tr>
<tr>
<td>Grant Marthinus</td>
<td>1</td>
</tr>
<tr>
<td>Kamva Mbalentle Dolz Landzela</td>
<td>7</td>
</tr>
<tr>
<td>Leigh Boo-thang Kruczynsky</td>
<td>19</td>
</tr>
<tr>
<td>Litha Martin Dyani</td>
<td>7</td>
</tr>
<tr>
<td>Lloyd Talmarkes</td>
<td>4</td>
</tr>
<tr>
<td>Lulo Asa Kazi</td>
<td>3</td>
</tr>
<tr>
<td>Malema Rendie Rendie</td>
<td>4</td>
</tr>
<tr>
<td>Matodzi Thalitha Makhado</td>
<td>3</td>
</tr>
<tr>
<td>Meagan Saul</td>
<td>4</td>
</tr>
<tr>
<td>Noxolo Shabangu</td>
<td>4</td>
</tr>
<tr>
<td>Nqobile Mamogobo</td>
<td>10</td>
</tr>
<tr>
<td>Prudence Qhamisa Shuba</td>
<td>12</td>
</tr>
<tr>
<td>Rabs Vhafuwi</td>
<td>1</td>
</tr>
<tr>
<td>Sihle Isipho Samazima Kratshana</td>
<td>3</td>
</tr>
<tr>
<td>Sihle Ntsikelelo Zenani</td>
<td>4</td>
</tr>
<tr>
<td>Simbongile Kopana</td>
<td>3</td>
</tr>
<tr>
<td>Sinazo Nkuku</td>
<td>1</td>
</tr>
<tr>
<td>Siphokazi Favour Tomela</td>
<td>10</td>
</tr>
<tr>
<td>Thami Tha King</td>
<td>9</td>
</tr>
<tr>
<td>Thanyani Pandelani</td>
<td>3</td>
</tr>
<tr>
<td>Themba-Elihle Sopazi</td>
<td>22</td>
</tr>
</tbody>
</table>
Table 4: Individual and total students’ likes of the posts on the Facebook group

<table>
<thead>
<tr>
<th>Students</th>
<th>Likes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avela Manqina</td>
<td>2</td>
</tr>
<tr>
<td>Dale Lethling</td>
<td>3</td>
</tr>
<tr>
<td>Easton Chad Carolissen</td>
<td>1</td>
</tr>
<tr>
<td>Kamva Mbalentle Dolz Landzela</td>
<td>2</td>
</tr>
<tr>
<td>Leigh Boo-thang Kruczynsky</td>
<td>1</td>
</tr>
<tr>
<td>Litha Martin Dyani</td>
<td>2</td>
</tr>
<tr>
<td>Lulo Asa Kazi</td>
<td>3</td>
</tr>
<tr>
<td>Matodzi Thalitha Makhado</td>
<td>4</td>
</tr>
<tr>
<td>Moloto Maleka</td>
<td>3</td>
</tr>
<tr>
<td>Pohotona Matome Thabang</td>
<td>2</td>
</tr>
<tr>
<td>Prudence Qhamisa Shuba</td>
<td>4</td>
</tr>
<tr>
<td>Sihle Ntsikelelo Zenani</td>
<td>4</td>
</tr>
<tr>
<td>Simbongile Kopana</td>
<td>1</td>
</tr>
<tr>
<td>Thanyani Pandelani</td>
<td>1</td>
</tr>
<tr>
<td>Themb-Elihle Sopazi</td>
<td>5</td>
</tr>
<tr>
<td>Zulfah Samuels</td>
<td>3</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>41</strong></td>
</tr>
</tbody>
</table>

According to results presented in figure 4, the highest number of post was in the month of May during FISA examination with 38 academic posts, 70 post comments and 19 likes. The most post comments or discussion took place during the month of February, whereby more than 100 post comments were posted. Mathematics Autumn School was conducted between the months of March and April and a slight increase (8%) in the number of academic posts was visible with a 23% drop in post comments and a 64% drop in the number of likes. The drop in students’ participation on the Facebook group between the months of May and June was due to the end of the term and the mathematics FISA was written at the end of May when students were no longer participating on the Facebook group.
The above post engagements (likes, post comments, share, etc.) show that the Facebook group allowed students to engage more with the subject matter outside the classroom, which may have led to deeper understanding of the subject matter. The figure 5 below shows an example of how students engaged on the Facebook group.

Figure 5: A screenshot showing an example of how students participated in the Facebook group

Moreover, the relationship between students’ participation in the Facebook group and their academic performance in autumn post-test was analysed. A correlation coefficient (this was only calculated for the students who participated in the Facebook group) for academic posting (0.17558) (see figure 6), post
comments (0.03) (see figure 7) and likes (0.083) (see figure 8) were obtained and showed no association between academic student performance in the autumn school post-test with Facebook participation.

**Figure 6:** Correlation between student’s post-test marks against Facebook academic post

**Figure 7:** Correlation between student’s post-test marks against students’ post comment
Figure 8: Correlation between students’ post-test marks against students’ likes of the Facebook posts

This finding indicates that academic performance in the autumn school post-test was not only as a result of the number of academic post students posted, post comments or likes, but could have been as a result of many other factors such as the autumn school. However, these results demonstrate that by students participating and collaborating in learning in the Facebook group, they collectively contributed to intelligence/knowledge creation] and drew upon and contributed to distributed expertise and mentorship (Lankshear & Knobel 2011) which enhanced the understanding of the subject matter.

Quantitative data does not provide the reasons why two thirds of the students did not score 50 percent in the pre-test. But reasons are important in order to make informed decisions regarding the impact of the intervention. Therefore, three focus group interviews, each comprising of ten students, were carried out with the students to elicit further comments on the impact of the intervention. Analysis from the focus group interviews showed that all the students found the autumn school of benefit to them as it introduced them to things they did not learn in high school, helped them revise high school work and gave them the basic competences and skills needed to cope with university work, as exemplified in the following quotes:

**Student C:** I think it helped a lot with some of the things we did in school, …we did not do in school.. like we did not cover most of the things like trigonometry in NCS…So his intervention actually help when it comes to trigonometry.[sic]

**Student E:** It was fine… because at first we didn’t know the basics of things we were introduced to like here at university. So the bridging the gap thing gave us the basics so that we can cope well on like doing… the university work.[sic]

The teaching methods of the lecturer and the use of a closed Facebook group were given by the majority of the students as some of the aspects of the intervention, which enhanced its usefulness. On the lecturers’ teaching methods, students said:

**Student D:** It was his teaching method during that time. He had patience...we could bring like any queries that we had to him, especially the difficulties we had during matric...so we had an understanding to that, which helped us step up to be introduced into the university work. [sic]

The Facebook closed group was said to have been helpful in extended learning outside of the class. For example, students indicated that they used Facebook to:
**Student F**: I use Facebook to get notes, my notes, like most of the notes I get it from Facebook and if I want to know what is happening here [on campus] like if we are about to write a test and I am not sure about a thing...then that’s when I use Facebook...[sic]

Facebook was also used extensively by students to post questions and get answers from their peers and the lecturer, which enhanced their learning as evidenced in the following:

**Student A**: When you do tutorials like Mr Moses gave us or things on the book then you go and ask question on the page and then you get answers and then they also show you steps on how you do it and then you get more understanding like that. You don’t have to wait on something until the following day you just ask on Facebook and then they help you out, then you’ll understand it, then you can do it... Mr Moses can help us and also the tutors and also my classmates. [sic]

**Student B**: It definitely improved my academic life because as I said, if you study a day before the test you can post like in the group a question and they help you with that question and if the question... comes in the test and then you score marks with that question. [sic]

Some of the students indicated that Facebook enabled shy students who would hardly ask questions in class to post questions on the Facebook group:

**Student G**: You know sometimes its difficult when you’re sitting in class and you want to ask a question but you are ashamed to ask it because you know ...maybe they’re going to laugh at you. But the Facebook is giving you a platform where you ask a question then there’s no one who’s going to laugh at you but you are going to ask a question which you’re going to help the second person who was going to ask that question and if they answer that question everyone is gaining not only you who’s is gaining...which is good. [sic]

The above results show that students felt that Facebook was of benefit to them because they learned from each other’s posts. This is vital because participating in someone else’s learning contributes to the growth of that person, one’s experience as peers’ tutor becomes a significant component of his/her education process and the best way to test whether we have learnt something is to teach it to someone else (Clark & Lovric 2009). Despite the above benefits of the intervention, 2/3 of the students scored less than 50 percent in the post-test. Students gave varied reasons for their failure. Some of the reasons given were: forgetting what they learned, being lazy to study, lack of time management; being nervous during exams and struggling with university work. Some of the students echoed the following student’s sentiment:

**Student E**: It is not the lecturers problem... he is doing his job and he is giving extra, but we also have like reach out like put more effort in, the time ...we have the responsibility like she says, like we do the certain work, Thursday, we have to go and revise it that day...[sic]

The above results show that students appreciate the effort the lecturer was putting into teaching them and acknowledged that they needed to take responsibility for their studies. The researchers suggest that balance has to be struck between being too helpful, a short-term fix, and encouraging students to overcome their own deficiencies and problems (Clark & Lovric 2008), as a well-intended initiative at helping students, if lecturers go too far (babying students), can certainly disempower students as learners. Another reason given for failure was that students did not have time to study as they had to travel home and at home they had to do household chores or for some the environment was not conducive:

**Student B**: ...Like me I get up at home 8 o’clock, [leave] from here about 4:30 pm because I am using the train from Belville to here [home] from here [Campus] to Kuils River, from Kuils River I take another train. So I don’t have enough time to study...[sic]

**Student C**: ... like most of the people here are staying in Res [residence] and you have to cook when you get home...you have to do like a lot of things when you get into your home before you study. So some of the things that we do like cooking, washing dishes and everything actually consumes our time of studying...[sic]
Student D: Where I live I’m surrounded by taverns ... So it is always noisy all the time and I’m living with too many people...there are a lot of disturbances...the environment is not conducive for me to study.[sic]

The above results highlight issues, which were not elicited by the diagnostic test but are crucial in impacting student success. The researchers suggest that student background information, their attitude towards mathematics and their learning styles should be included in the diagnostic test in order to enable the lecturer to design a relevant intervention for the students.

5. Conclusion and recommendations

Findings of this study showed that the incoming first year Chemical Engineering Extended Curriculum Program (ECP) students at a University of Technology in South Africa had the mathematical knowledge gap and hence the need for this University to come up with effective strategies for strengthening incoming students’ level of mathematics knowledge and skills in order to enable them to cope and succeed in their university studies. The intervention designed by the lecturer in this study was perceived by all the students as beneficial for their studies. In particular, the lecturer teaching methods and the use of a Facebook group was applauded by the students, although there was no association shown between students’ participation in the Facebook group and their performance in the post-test. The researchers argue that the lack of association between students’ participation in the Facebook group and their performance in the pre-test indicates that alleviating the mathematical knowledge gap should not only be attributed to students’ participation in the Facebook group, but that other factors may have contributed (e.g. the autumn school).

However, due to 2/3 of the students not scoring 50 percent in the post-test, the researchers agree with Clark and Lovric (2009) in suggesting that an effective diagnostics tool must inquire besides obvious information on mathematics background knowledge and skills, students’ attitudes towards mathematics and learning mathematics, their motivation, intelligence, learning styles, and their social development in order to enable lecturers to design a relevant and effective intervention. The researchers further suggest that the university needs to find ways of assisting students living out of residence in order to enable them to have enough time for their studies. Further research will be conducted to establish exactly what aspects of the mathematical topics students found cognitively difficult to understand and ways of enhancing their understanding will be devised.

Acknowledgement

The researchers would like to acknowledge the Research in Innovation in Teaching and Learning grant that funded this study, the students who took part in this project and Mr Nzumbuluwani Mmbara, from Musuku Africa Pty (Ltd) for analysing the Facebook posts. This paper was first presented at the 9th International Conference on e-Learning, Chile June 2014. Feedback from the audience and the reviewers helped to reshape this paper for publication in this journal.

References


Telling Tales: Towards a new Model of Literacy Development Using e-Readers in Teacher Education in Chile

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Abstract: Current debates on quality standards in education often look to the levels of an increasingly diverse array of literacies as a measure of that standard. At the same time, while mobile technologies are profoundly changing the way we live, communicate and learn in our everyday lives, relatively little seems to be known about their potential to influence basic literacy in formal education sites. Examining the use of practical and affordable emerging technologies in many countries worldwide where literacy rates are an issue, seems as yet to have been overlooked. Considering the implication of multiple literacy and communication skills to economic and cultural development and stability in evolving countries and increasingly in developed ones as well, finding immediate answers to challenges in this area is critical. This paper reports on a longitudinal study that examined the power of e-readers to support change in the literacy habits and ultimately the learning cultures of a group of English as a foreign language (EFL) teachers-in-training in Chile. The aim of the study was to determine if access to low-cost mobile readers and a social-learning driven, technology-supported, guided reading program, could reverse their literacy challenges. The study is based on social-cultural theory in which learner agency, access to funds of knowledge and social interaction are imperative ingredients for developing engaged, life-long learners and readers. Participatory Action Research (PAR) is used to conduct the inquiry. Working within a qualitative research paradigm, ethnographic tools and numerical data from pre- and post-test results, helped to uncover how the use of technology influenced both the literacy practices and identities of the teachers-in-training. The findings have led to the proposal of a new 21st century model for literacy education for such challenging contexts. This model could have important implications for Chile as well as learners, educators and policy makers elsewhere.

Keywords: education in Chile, multi-literacies, teacher education, mobile learning, e-books, literacy in challenging contexts

1. Introduction

I have never considered myself as a good reader, because I hate reading my whole life. (Reflective Essay, Marie Jesus, January 2014)

When I started this new step in my life [university studies] and I read the program I knew that I had to adopt new habits. At the beginning it was terrible because I had to read books that were wrote in English. I never read something in Spanish and now I will have to learn to read in English. (Reflective Essay Karina, January 2014)

As the new century progresses, the volume and tone of the conversations around 21st century skills being developed in educational institutions, at least in the developed world, seems to be rising to a fever pitch. Given the tremendous rate at which technology has infiltrated informal and formal learning sites, albeit in the latter sometimes less enthusiastically, it is not surprising that a great deal of this dialogue is debating how technology will help support the development of these so-called essential skills. Paradoxically, along with the recognition that technology will be integrally tied to 21st century skill development is that individuals will need the multi-literacy skills to take advantage of that technology support. In short, taking full advantage of technology for learning and being an effective and productive global citizen in the 21st century go hand in hand.

Many evolving nations, and some developed ones, are left on the sidelines of these dialogues. Most are marginalized from such high-level debates, as they find themselves still struggling with the challenges of promoting the most basic reading and writing literacy skills among their citizens. The comments of Karina and Marie Jesus, two individuals studying English pedagogy in Chile, reflect those literacy challenges. While it is generally known and accepted that economic and cultural development is tied directly to the literacy levels of a country’s citizens (Mingat & Tan, 1996; Matear, 2008; Norton, 2010, ), in many of these countries finding long-term effective strategies to face the enormous challenges of promoting basic reading and writing competencies, has been elusive. And yet, along with English language learning, it is commonly accepted that
these basic skills are critical gateways to developing the much-acclaimed skills of the century on the micro level. On the macro level of a country, these same basic literacy skills, once acquired by the majority of its citizens, can assure a voice in the global dialogue, not to mention support responsible management of one’s national resources in the global market and sustained economic growth.

Chile, a growing economy and recently accepted member to the Organization for Economic Co-operation and Development (OECD), is one such evolving country. While proud of its economic progress over the last ten years, it is also very aware of its deficiencies, especially in education. It has been in the spotlight for several years as students have taken to the streets demanding solutions to these issues (The Economist, April 12, 2012). A high degree of social stratification is partly at the root of these protests and the deficiencies in education they seek to address. Indeed, a 2009 OECD report placed Chile in the bottom quarter of the list of thirty-one nations in terms of literacy. Reports on English language literacy skill rates project an equally dim picture (SIMCE 2012, Dowling, 2007). At the same time, heavy investments in technology in public education by government have made little dent in these statistics (FP.cl, 2014). The first ever ICT Sistema de Medición de Calidad de la Educación/Education Quality Measurement System or SIMCE, conducted in the country in 2011, revealed that 50% of secondary students in this country have basic to intermediate digital literacy skills and only 3.3% use computers for their learning. Interestingly, Chile leads the rest of South America in the numbers of mobile devices. A surprising finding of a 2010 OECD study on the connection between technology use and educational performance revealed that the new digital divide is no longer solely about access, but rather the one existing between those who have the right competencies to benefit from computer use and those who do not.

These findings ring particularly true in my own work in an English teacher education university program in Chile. Most students in the program are not lacking access to technology; almost all carry smart phones, ipads, ipods and tablets. Yet their levels of literacy and English skills confine many to using these tools solely for entertainment or social networking; i.e. listening to music, watching movies and connecting with friends on Facebook. Instructors, and indeed the students, recognize these shortcomings. Under the circumstances, it would be reasonable to expect that pre-service teachers in language should be doing all that is possible to develop the advanced language proficiency and literacy skills that they will need as future teachers of language. Yet in my experience, such is often not the case. Many in the country concerned about education view these pre-service teachers’ literacy skills, or lack thereof, as a litmus test of the hopelessness that pervades the country for the future of educational development in Chile. In an effort to come to terms with this hopelessness, fingers continue to point from within at the multiple roots of its low literacy rates - a stratified, poor quality and economically-driven education system, generally low rates of education in parents, poorly trained teachers and the high cost of reading materials, are cited most often.

And yet, while regular international standardized testing and its results continue to feed this feeling of hopelessness for reversing or even understanding the issues around literacy, little is being done in terms of in-depth educational research in or for this country to re-direct this hopelessness toward well-grounded action and to seek local solutions. As one Dean of an Education Faculty in a large private university in Chile, one of the few that conducts research save for the two elite public universities here, recently reported to me: “There is virtually no research being done in this university in education, let alone in technology and its relationship to literacy development.” (Personal communication, January 2014). And with reportedly few educational researchers in Chile fluent in English, participation in solution-generating dialogues with others from abroad with similar interests in literacy and technology (for example, Warschauer, 2006; 2011; Thorne & Black, 2007; Godwin-Jones, 2010) is limited. It’s a definite catch-22 scenario. Without this dialogue and the kind of research that it fosters, changes in education, including finding effective solutions to the literacy issues it faces, could easily remain elusive in Chile. The research reported here, in part, was an effort to spark dialogue in Chile around seeking literacy solutions through the use of technology.

The aim of the study was to determine whether a guided program using e-readers could influence the low reading rates of a group of pre-service tertiary level teachers. Some headway into understanding the implications of the use of mobile technologies in particular for literacy are being made in the wider research community (Gee, 2003: also see Baron, 2009 for a summary of this area of research). No grounded research in the use of e-readers, in particular, seems to be available. One notable exception is that of Auer (2014) who used tablets to determine the affordances offered by these tools to increase cognitive and metacognitive
reading strategies in seven foreign language learners in Denmark – ironically, a country that generally boasts very high levels of literacy.

The dearth of research in this area is understandable perhaps since the popularity of these mobile devices has only recently taken hold within the general public (Godwin-Jones, 2010). Since 2010, when interest in e-readers first began to soar in the public domain, the affordances of these mobile devices have opened up many questions around learning and literacy practices. The goal in conducting the study was to begin to address some of the questions surrounding the use of these e-readers through evidence generated with individual pre-service teachers. Answers to these questions are crucial, especially given the implications that supporting the development of literacy habits of these future teachers can potentially have on others. For example, it can quite reasonably be assumed that the ten Chilean pre-service teachers in the study, as future teachers of English in this country will teach to multiple, large groups of learners in their classes. They most likely will be responsible for over one thousand learners alone in their first year of teaching. The answers to these questions might also inform the field of education more broadly as the border between formal and informal learning becomes increasingly blurred globally and the use of technology outside the classroom is being recognized as influencing what takes place within. The findings could add further insight for other nations that are searching for context-appropriate technology solutions to the educational issues they face. The New Technology-based Literacy Development Model that the research spawned could act as a roadmap for the practical application of changes in these settings.

2. Addressing literacy challenges with technology

The study was an attempt to respond to the literacy challenges that a group of future language teachers face as they prepared to become teachers of English as a foreign language (EFL). The connection between literacy development in English as a second/foreign language and in one’s own native language has been well supported by research (Norton, 2010). The principal objective of the study was to determine whether shorter (4-month) and longer term (12-month) access to a guided reading program using technology, in this case mobile e-reading devices, would have implications for them as learners and for their literacy skills. In this article, I report on the results of the longitudinal study. The project that was put in place in early October, 2013 involved research on ten EFL pre-service teachers studying in the undergraduate English Pedagogy program in a large private Chilean university. The focus of the study was examining how literacy development, and the participants themselves, were influenced over the 16 months as a result of participating in this guided reading program.

The study was conducted as a means of uncovering many kinds of information about the personal literacy experiences of the individuals who chose to participate in the research project. Three questions guided the first 4-month phase of the research study:

1. What is the nature of the previous literacy experiences of the participants and how do they perceive their competencies at the outset of the research study?

2. How does the reading program influence, if at all, the reading habits of the participant pre-service teachers and their use of language, in this case English?

3. How does the reading program affect their identities as learners, future teachers and as individuals?

3. The Theory: Literacy, Social Identity and Technology

Lipka and Siegal (2011) observe that “strong literacy skills are a prerequisite for success in contemporary society”. (p.1874). They are not alone in their observations. Finding ways that are effective in supporting learners in developing strong literacy practices has been the topic of educational research for several decades. While there is still much conflicting debate on how to foster literacy in formal learning sites, most scholars now agree that literacy development is more than just a cognitive process of phonetic decoding.

Literacy development is being recognized as a complex, social process embedded in relationships “connected to different practices and preferences among social classes” (Myrberg and Rosen, 2009, p. 696). From early childhood, children are socialized into certain cultural practices around language and literacy that define who they are as a person - their social identities. These initial interactions in the early stages of children’s lives
prepare them culturally, socially and cognitively for fundamentally different life roles (Heath, 1983). The practices that they develop through these early experiences can also predict their future scholastic achievement and group membership. In the Chilean context, where the vast majority of higher education students are the first generation to attend university and where parents are generally lacking highly honed literacy skills themselves, little in the way of preparing children for the kinds of higher order thinking that is characteristic in these academic settings can be expected.

Bourdieu’s concept of cultural capital, (2002) offers a theoretical construct to explain how this social stratification occurs. Cultural background, knowledge, preferences, attitudes and behaviours passed down for example by educated or higher classes to their children are rewarded in the school system and thus reproduce societal inequalities. Although there is substantial evidence to support the influence that cultural capital has on students’ literacy practices and scholastic achievement, there is less known about how various mediating factors, such as new programs and the emergence of new learning tools, can affect and/or alter the expected trajectory of these processes.

In order to consider mediating processes that might influence the social stratification that occurs in the development of literacy, we need to understand how literacy, in and of itself, functions. Luke and Freebody’s (1999) model explains that in a postmodern world, literacy involves the reader taking on four distinct roles: Breaker of the language codes; Participator in the meanings of the text; User of text functionally and a Critic, analyzer and transformer of text.

The processes that make up Luke and Freebody’s model are interesting to the present study for several reasons. First of all, they help us to understand where learners are on the continuum in terms of their literacy development – areas where they are able to assume the necessary roles and others where they need guided support. The model also reminds us of the highly contextual nature of literacy. In other words, from a sociocultural perspective, literacy is politically, economically, culturally, historically, pedagogically, linguistically and personally charged, and importantly, embedded in relations of power.

Warschauer has conducted extensive research (2006, 2011) in the use of laptops in schools. His research has provided grounded evidence of the powerful role these personal IT tools can have on literacy development and learning, especially for learners at risk or marked by their SES (socio-economic status). The substantial findings he has uncovered in the area of multi-literacies have also allowed him to raise the alarm bell that “it takes more than handing a child [or in this case, a future teacher] a laptop [or e-reader] to transform education” (p.ix). This warning offers clear signals to educators and policy makers to consider the multiple factors affecting the success of computer technology in influencing learning, but falls short of determining whether e-readers, with their unique digital affordances, can be positive influences in support of literacy development.

Auer’s (2014) studied mobile devices, i.e. tablets, and the extent to which these tablets could provide the cues, normally provided by teachers, to encourage higher order thinking in a group of Foreign Language (FL) learners as they read. Her findings provide insight to the inquiry in the Chilean context as well. She discovered that the participants took advantage of various features of the tablets to engage in metacognitive strategies to enhance their reading comprehension: built-in search features for checking back on what had been read, a glossary available for quick explanation of words and highlighting for identifying central information. These technological features suggest that mobile tools such as e-readers can offer potential literacy support especially for low-level readers, such as those in the Chilean study.

Drawing on the theory of cultural capital and previous studies in literacy and technology, I support the argument that technology, in this case e-reader technology, depending on its use, can offer encouraging signs of influencing learners’ identity and literacy development. I base my support on the emerging findings from this longitudinal study of the literacy experiences of a group of pre-service EFL teachers in Chile. In the next sections, I explain the 4-month study and report on the major findings both from that initial study and those that resulted over the longer term.

3.1 Phase 1 of the Longitudinal Study: Pre-service EFL teachers as readers

Phase 1 of the study ran from late September 2013 to January 2014. The self-selected participants included a group of 10 pre-service teachers in their third year of an undergraduate English pedagogy program in Chile.
Most of the participants had taken part in a course I had taught the previous semester. All of them had failed or scarcely passed previous language courses. They self-selected themselves for what became clear in the data collection process, the realization of their low course marks and fear of their tenuous situation in the Pedagogy Program. The participants were told that the study would involve enhanced opportunities to practice their reading skills using technology. Each participant was given an e-reader and a steady offering of e-books of their own choice in the first 4 months. The offer was then extended to the remainder of the 12 months in the longitudinal study.

Part of the draw for the participants in agreeing to these sessions was the opportunities it afforded for guided linguistic feedback in the weekly individual and/or pair interviews. These interviews along with periodic whole group meetings were a major source of the data collected. In these meetings, the participants discussed the books they were reading at the time and often commented on their evolving literacy experiences. Written journals that these participants submitted as part of their course work, as well as reflective essays in which they wrote about their literacy experiences at the end of Phase 1, also accounted for a substantial amount of the data. Results of two term tests and one final test were consulted and analyzed as a means of looking for trends in the data.

From my background knowledge of the individual participants and their skill levels as well as from remarks many made to me, I understood that all of these individuals had various literacy challenges. Many were quite open about their lack of interest in reading and about their feelings of inadequacies as a result. In an informal survey, all but one reported having read less than one book in English or Spanish in the 18 months prior to the study. I based my research questions on the assumption that they wanted to change their literacy levels and that they lacked strategies to do so. For this reason, a Participatory Action Research (PAR) design was considered particularly appropriate. Both participants and I, as their teacher/researcher, were seeking to make changes to their literacy levels that we saw necessary, not only in terms of their linguistic capabilities in English but also for the potential implications that these changes could have for them as individuals and teachers.

From my perspective as a teacher with over 30 years of pedagogical experience, and from my knowledge of the more recent literature on reading, I also assumed that giving the readers choice and refraining from testing them could have a positive influence on their desire to read. Since the study is connected to the learning of English as well as literacy development, I adopted Spolsky’s (1989) argument that practice and exposure to the target language are essential for making progress in the language and that that exposure can come from the intersection of both formal exposure in the classroom and/or the informal exposure outside, such as reading for pleasure.

4. Methodology

Both phases of the study were conducted within the qualitative research paradigm. Qualitative research is taking on an increasingly more important role in research on the uses of emerging innovative technology tools for learning especially in classroom-based research (Charbonneau-Gowdy 2015). This interest mirrors what has been happening in general education research for the last 25 years. Questions regarding the use of technology, especially those from a sociocultural perspective, are progressively moving away from level 1 assessment, i.e. user satisfaction and usability. Instead, an emphasis is being placed on grounded support for their pedagogical value and influence on learners as complex social beings. Within the qualitative/ethnographic research paradigm there is a capacity to uncover rich data needed for understanding social beings and also to be sensitive to the complex factors that operate in and influence human activity in learning settings (Meskill, 2013).

The data that was generated over the first four-month phase was extensive (see Table 1). The data sources included: research notes from 50 hours of weekly face-to-face and/or Skype interviews which ranged from 30 to 60 minutes each; 260 pages of writing journals; evaluation results from two term tests that were offered as part of their course, as well as pre- and post-standardized tests in the various language skills; participant generated reflective journals and field notes and observations. These data sets were analyzed using standard qualitative methods for themes and patterns. The numerical data generated by the tests was also tabulated and analyzed. In this section, I highlight some of the findings that have been most interesting in Phase 1 of the study with reference to the questions I have posed. I then present and reflect on the long-term findings in Phase 2 followed by some concluding remarks.
4.1 Phase 1: Guided Practice in Reading

In the initial stage of the study, all of the participants expressed with strong conviction that they were motivated to improve their language skills. After all, the majority of these individuals were in the Pedagogy Program to become teachers of language. They had already spent time in classrooms in their teaching practice sessions and they were quite aware that knowledge of the language was critical for survival in their profession. Yet in all but two cases, none of this strong motivation led to reading of any kind in the year and a half prior to the study. At the same time, they willingly chose to participate in the study despite the extra time it would take from their already busy academic, personal, and work schedules, including for many, a 2-4 hour commute to and from university per day. According to the participants, other factors in their motivation were fear of further course failures, the high cost of their education and the burdens that this cost represented for themselves and their families, the tremendous cultural focus on marks and grades, plus the pride of being a first generation family member to attend tertiary education. These factors caused pressure and anxiety to several of the participants, which was evident in their demeanor, especially in class – shy to engage, hesitant about their accuracy when speaking, a reluctance to write and multiple comments and physical signs of anxiety that I witnessed.

5. Findings and Analysis: Cultural Capital, Identity and Investment in Literacy Change

An important theme that surfaced in interacting with the participants and that apparently added to their anxiety was their early and more recent experiences in literacy in their own language. Few had access in their childhood to a parent who read to them regularly or to a wide range of books. Many agreed that literacy development in their early schooling was inconsistent and/or “boring”. Some reported teaching approaches were didactic and consisted often of lack of choice of reading materials or old classics that had little relevance to their lives. These practices were accompanied by frequent testing that reflected an emphasis on copying and/or lifting information from text. Six of the ten participants admitted that they rarely read books in their own language for pleasure while the other four did so irregularly. Reading in English was confined only to what was required in their courses and this requirement in itself was often neglected. All of the participants expressed that they felt weak in the syntactic and morphological use of the language. Their comments seemed to be corroborated by the disparaging remarks concerning their linguistic skills from colleagues who also taught some of the same individuals in other courses. In other words, the literacy identities, both in English and in Spanish, that the participants projected and that was reinforced by the impressions of others, including their teachers was one of being “weak, poorly skilled, mark driven yet resistant to working to improve.” Their deficiencies in cultural capital, using Bourdieu’s (1994) construct, was being reflected in the learning context in their images of themselves as deficient as well as in their anxiety as they considered their chances to succeed in the program. Bourdieu’s observation that “The sense of the value of one’s own linguistic products is a fundamental dimension of the sense of knowing the place which one occupies in the social space.” (p. 82) seems particularly relevant in explaining why many of the participants saw themselves as marginalized in the teacher-training program.

Over the period of this first phase of the study, as I met with the participants each week for them to tell the stories of what they were reading – to tell their tales, I began to observe subtle and more obvious indications of change in the way many of the participants’ viewed themselves and their subjectivities. As Diana remarked midway through the first four months of the study:

I feel more confident with myself when I’m talking because I didn’t used to be like that. I was always afraid of making mistakes. Now I think the book and the reading is like a support to me. (Diana, Group Interview, November 2013)

Diana, in her own words, clearly expresses these changes in her awareness of her increasing confidence to speak in class. Other signs of changes in Diana and many of the others were their increased vocal proactivity in the classroom, despite the presence of ‘more advanced others’ in the group, the visible exhilaration when some in the group received marks that far surpassed what they had achieved previously, increased attendance in class, more regular submission of assignments, as well as expressed enthusiasm for the books they were reading and the prospects of reading the next.

Table 1: Research Design and Phases of the Study
### Phase 1
#### Oct. - Dec. 2013

1. **What is the nature of the previous literacy experiences of the participants and how do they perceive their competencies at the outset of the research study?**

   - Individual face-to-face or Skype interview notes
   - Group interview recordings

2. **How does the reading program influence, if at all, the reading habits of the participant pre-service teachers and their use of language, in this case English?**

   - Participant weekly writing journals

3. **How does the reading program affect their identities as learners, future teachers and as individuals?**

   - Documents
   - Field Notes

4. **What are the long-term affects of the guided e-reader program on their reading habits and identity construction?**

   - Individual interview notes

### Phase 2

4. **What are the long-term affects of the guided e-reader program on their reading habits and identity construction?**

   - Documents

Norton’s (2010) construct of *investment*, which is broader than motivation, helps explain the changes to participants and to their engagement in literacy practices. Partially due to the convenience of the e-readers and the access they provided to a whole range of books and learning features, the participants began *investing* in increased and more regular reading. These literacy opportunities as well as those that came from participating in the guided weekly discussions programs led to the learners beginning to recognize, as
evidenced by their testimonies and my observations, that the value of their “cultural capital” was increasing in the classroom and in the context of the Pedagogy Program. With the increase in their individual cultural capital, there was a corresponding change in their learner identities, or their sense of place in that context. This change in identity was obvious in some of the participants’ willingness to speak more confidently in front of others. Their change in engagement in turn served to help some of the participants view themselves as key players in the classroom and at the same time to further their literacy skills even more. Lave and Wenger’s (1991) theory of a community of practice, in which through a process of legitimate peripheral participation (LPP) individuals move from the margins to the centre of interactive communities by being mentored or “apprenticed” by more powerful others, are further theoretical justification for the changes the participants were experiencing.

Evidence of changes in this first phase of the study was not confined solely to the participants’ construction of more empowered literacy identities, or to their own testimonies. There were also encouraging linguistic changes that were revealed through the data sets:

- evidence of more regular and intensive reading of English, an average of 3 books per participants over 10 weeks;
- increase in level of length and difficulty of books chosen;
- noticeable decline in the number of major errors in weekly journals especially syntactical, although there was a less evident decline in mechanical errors.

With regard to Luke and Freebody’s model of literacy, there was also strong evidence to support that the participants moved through the first 3 stages of the model. Karina’s remark: “During the first pages in the first book that I read, I had to learn what the book was trying to say me... First I read one hour per day with some difficulties, but then I was extending the hour to two hours then three and so on... (Reflective Essay, Karina, January 2014), is just one example. Other examples included the participants who revealed that they regularly spoke to one another in English as a means of practicing. Another participant explained that she was reading regularly to her younger sister. Yet, unsuccessful attempts to encourage a deeper discussion of topics indicated that most of these individuals had not progressed to the stage of critical analyzer.

The numerical data that was collected during this first phase of the study involved the results of two term tests in their Language program that coincided with the outset of the study and at the end of three months. Students in the program are tested in all four literacy skills – reading, writing, listening and speaking. A comparison was made of the changes to the grades of the participants as opposed to those of their classmates who did not participate in the e-reader program. The results of the tests showed little difference when comparing changes in listening and writing. On the other hand, there were interesting differences with regard to speaking and to some extent reading (See Tables 1 & 2). For example, there was a 26 % increase in in the average speaking grade of participants on Term Test 2 in relation to their average speaking grades on Term Test 1. On the other hand, the average increase for their classmates was 16%. These results are especially encouraging for two reasons. Firstly, generally the participants in the study underperformed on tests for all skills, especially speaking compared to the rest of the class. Secondly, given Vygotsky’s theory that learning is dialogic, that is that cognitive change begins with verbal social interaction, the fact that the participants have shown significant progress in their oral skills suggests that changes to their other skills could follow, but in the longer term.

Similar impressive changes to speaking and reading test results were noted for the participants in on pre and post standardized practice tests (Table 2), the Cambridge University based First Certificate of English practice tests. On these tests, the participants improved their average grades by 20% and 15% in speaking and reading respectively

Table 1: Comparative Grades on Term Tests
It is of course difficult to untangle cause and effect for the progress suggested by the numerical data; numbers can be so imprecise when used to understand human behaviour, regardless of the means used to gather them. Yet, if we agree with Krashen (2004) and others who argue that free reading is a major factor in the development of language, and with Vygotsky (1986) that learning is dialogic, then it is clear that the reading strategies in which the participants were engaged, was certainly a factor in the improvement in literacy skills that was recorded.

It is also important to point out as well that the advances that the participants made in their literacy skills could be tied to the affordances of the e-readers themselves. Many of the participants kept lists of new words, used the quick search for looking up meanings of words and were able to flip back to pages and bookmark if they wanted to remember a particular phrase or way of expressing an idea. Indeed, I observed that some would take on the role of “more experienced other” in our story telling sessions. In that role, some would explain to me how to make more use of my own e-reader. It could be argued, quite legitimately I believe, that the combined features of the particular technology used for their reading, was an added source of scaffolding in their literacy development.

5.1 Phase 2: Further Findings and Reflection

After the first 4 months of the study, participants were given the option to continue with the research process, in other words the guided reading program. My pre-decision to prolong the study was made with the intention to address a further question I had with regard to the e-reader reading program initiative:

What are the long-term affects of the guided e-reader program on the participants’ reading habits and identity construction?

The favourable results that were reported in the first phase of the study were encouraging. Yet, before developing a model for promoting literacy in broader contexts, I needed to understand whether the reading habits and identity changes the participants had constructed in the first 4 months of the study were sustained. Along with the participants, I was personally involved in the long-term outcome of the efforts they had applied.
over the 4 months of Phase 1. I also had often witnessed initial enthusiasm with new emerging technologies, ungrounded in long-term practice, leading to costly investments by educational institutions. I sought to ensure that the recommendations for the technology-based learning model I was promoting had the necessary research support.

Over the 12-month follow-up period in Phase 2, four participants dropped out of the research process – two at the beginning and two, midway through. Interestingly, one of those individuals, Mical, related to me that she had decided to leave Chile to pursue her learning of English by working in the US as an ‘au pair’. She spoke excitedly about the fact that she would have access to a whole library of books close to her host family’s home. Further communication has confirmed that she is indeed taking advantage of such opportunities. Her decision to take this initiative may in some contexts appear rather insignificant. Yet, as a young Chilean female, Mical’s decision was very atypical. Not only is it very unusual for young Chilean females to leave their families, the move represented a significant divergence from the extremely shy and reserved identity that she portrayed at the outset of the study in the classroom. There had been evidence of changes to her learner identity during the first phase of the study. The self-directed nature of Mical’s decision, combined with the continuous interest in reading, speak to the empowered identity construction and literacy developments that were reported in Phase 1, as visible signs of influence of the guided reading program on the participants.

Although the remaining seven participants in the study were offered an ongoing supply of access to e-books of their choice during Phase 2, only three books were requested from all seven participants combined. It appeared that the reading habits that these individuals seemed to be establishing in Phase 1 were being abandoned in Phase 2. Yet, careful analysis of the data sets during this phase indicated that there were other positive signs of a continuation of some of the advances they had made as a result of the opportunities they had in the guided reading project. Many of these signs suggested 21st century learning and higher order thinking.

For example, a testimonial provided by Danisa midway through this phase suggested increased metacognitive awareness of her use of language. In attesting to the linguistic progress she was making because of her e-reading, she claimed that she was noticing her own linguistic development for the first time and added: *I’ve noticed these changes every time I speak or write* (Danisa, Testimonial, June 2014). Danisa’s growing language awareness supports what I witnessed from some of the other participants and according to literacy studies, is a clear indication of higher order thinking.

In this period, the remaining participants were required to read extensively in preparation for their undergraduate theses. It was obvious to me that these particular individuals took on that task with a level of responsibility that I had not seen in the period previous to the study in my contact with them in other courses. Indeed, the majority had often displayed a fear of academic articles that demanded higher-level thinking. It appeared that the new learner identities they had assumed and their added comfort with reading had a transformative influence on their capacity to face these academic texts.

When it came time for each of the participants to present their own theses, undertaken in groups, there was a further sign of significant identity and learning changes. The questions they posed and the research they conducted reflected a degree of both critical thinking and innovation that was uncharacteristically superior to that which I saw in many of the other theses I observed. This difference was particularly noteworthy, given their earlier marginalized status as academic learners. One of the participants, Karina, took part in a group that initiated a project where upper students mentored new incoming first year students through a social media platform they constructed. The research received significant notice from faculty and the idea sparked the Pedagogy Program to pilot a similar project in the following semester. Another three participants produced a thesis that offered a critical perspective of the dichotomy between teachers’ professed beliefs and their actual teaching practices. The level of quality of their thesis in terms of the degree of critical analysis it reflected, was indeed remarkable, especially considering the level of literacy that one of the participants, Karina had, as reflected in a comment at the outset of the study: “At the beginning it was terrible because I had to read books that were wrote in English”. (Karina, Reflective Essay, 2014). Karina’s sense of being overwhelmed at the thought of reading English and the words she uses to express that thought elude to her literacy skills at the outset. The evidence from the data sets in Phase 2 reveals a direct contrast to the identity Karina portrayed earlier on. The standard of academic work that she accomplished during the thesis process in this phase is also a testimony to those emerging changes.
It could be argued, of course, that the changes in cognition and identity reported were the result of many influences in the academic lives of these individuals over the period of the longitudinal study. Yet, when I compare the evidence from the analysis of the initial data sets which indicated an insight into their learner identities and literacy levels after more than three years in their university program, with the evidence from data analyzed at the end of the 16-month study, I am left with little doubt that the guided e-reading program had a significant impact on their transformation.

Importantly, the obvious interplay of identity and cognitive transformations that the e-reading program apparently sparked and which continued to take place over the longer term are indicative of the power of the particular model of literacy teaching that supported the guided e-reading program. This emerging model that I believe has the potential to transform literacy education also aligns with what Illeris (2014) argues is the necessity to expand our understanding of transformative learning to include the concept of identity. I would argue that increasingly this expanded view of transformative learning is being played out in technology spaces. I believe that the occasions that the e-reader program allowed to these individuals for building their basic as well as digital literacy skills – their 21st century cultural capital, and at the same time to construct 21st century learner identities, i.e. both critical and innovative thinkers, clearly underlines for me the need for constructing a new model of literacy education.

It is clear that Luke and Peabody’s model with its emphasis primarily on the development of mental capacities falls short of considering identity markers and the role of technology in a more expanded view of literacy development. An emerging model (See Figure 1) that I propose takes into account learner choice, lack of testing and opportunities for sharing reading experiences with others, i.e. Telling tales, that have been shown to be effective drivers of literacy in formal learning. Importantly, the model also includes the co-construction of identity and the technological context as essential factors to consider in the literacy, or more precisely multi-literacy, development process.

![Figure 1: New model Literacy Development](image)

6. Conclusion

The findings of the initial study revealed the literacy development of the 10 pre-service teachers over the course of the 4-month initial phase of the study. The latter findings provide evidence that these trajectories were maintained and indeed continued, despite an obvious decrease in the reading that had taken place in Phase 1. Perhaps one could question the connection of technology to the rather impressive results that were revealed over the course of the study. A critical reader might further suggest that an extensive library would serve the same end in supporting the literacy development of the participants. While of course there is some validity to these observations, the point is that prior to the study most of these individuals had not had such an opportunity to rich sources of literacy tools. For most of these individuals there was a lack of reading materials and occasions to use language to discuss what they were reading, if at all, both at home and at school.
The significance of this study is that it provided clear evidence that technology, in the form of e-readers, was able to offer support for reversing to some extent the shortage of culture capital that the participants in the study had and portrayed in their academic studies. The longitudinal study clearly indicated that many of these changes were sustained. While there was certainly a decrease in requests for e-books and the “telling tales” meetings have become very sporadic, the findings reported here indicate the influence of that initial reading program has been long term and profound. When considering the thesis results alone, there is evidence of those profound changes both in terms of identity and learning. In my view, the quality of the theses that some of the participants produced twelve months after the e-reading program offers strong evidence for this claim. Based on the reaction of other faculty members, the marks that some of the participants received and the follow-up initiative one of the theses sparked, are further proof of a recognition of changes to their cultural capital.

The participants’ accomplishments are substantiated by other research in this area. Guthrie (2004) has shown that students from low income and low education backgrounds, but who are highly engaged readers, will substantially outscore more privileged students. The higher percentage of average increase in test results compared to other classmates, many of whom had cultural backgrounds that supported their academic studies, could be one example of this phenomenon. The confident and active learner roles that the participants assumed both in the classroom and as researchers when conducting their respective studies, is another. Both Guthrie and Cummins (2007) offer convincing support to arguments that the increased reading that the participants chose enthusiastically to do initially and then in the context of their thesis process, their obvious enjoyment in doing so and also in other forms of literacy such as speaking, writing and listening will result in a propensity to pursue literacy activities more actively within the context of their studies and beyond. Mical’s choice to move to the US to enhance her opportunities to develop her English and her excitement at having access to a library nearby is an example of precisely the kind of self-regulation that is so lacking generally in the Chilean education system. Two other participants are making the plans to do the same. The fact that five of the participants have chosen to buy their e-readers and have requested to meet periodically for discussions outside the university despite the fact they are finished with their formal studies, is another example.

The model that has been built from this research study and its findings could be an important part of a pedagogical solution to the literacy woes that this country and others may be seeking. Further in-depth studies of the application of this model for institutional pedagogical practice in teaching literacy, as suggested in this research, are needed at all levels of the education system and in a variety of contexts, both in Chile and internationally, to determine its long-term effectiveness. Although technologies and their tools may change rapidly, when it comes to literacy development, the uses of a technology to support long-term solutions are the only ones that matter.

References


The Role of Open Access and Open Educational Resources: A Distance Learning Perspective

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Abstract: The paper explores the role of Open Access (in licensing, publishing and sharing research data) and Open Educational Resources within Distance Education, with a focus on the context of the University of London International Programmes. We report on a case study where data were gathered from librarians and programme directors relating to existing practice around Open Access; the major constraints in using Open Educational Resources and the main resource implications, when adopting Open Educational Resources, were also investigated. Our aim was to (a) raise awareness and understanding of what is possible to achieve in higher education by embracing the Open Access movement (b) identify next steps and actions that could be taken to improve institutional use of Open Access materials, including Open Educational Resources, (c) examine the implications of such actions for Open Distance Learning and generally the higher education sector. Our investigation highlighted some opportunities and the findings resulted into some clear recommendations that emerged both for practitioners and for students in this area. There seems to be a clear synergy between the different but related movements of Open access and OERs as both have to address issues of ease of access, quality and visibility in order to become accepted in higher education.

Keywords: Open access, open educational resources, open education, open and distance learning, open access publishing and licensing, digital scholarship

1. Introducing Open Access and our investigation

The movement of Open Access is attempting to reach a global audience of students and staff on campus and in open and distance learning environments. Open Access is free, immediate, permanent online access to the full text of research articles and data for anyone, webwide. There are also intellectual property rights and equity issues that are particularly relevant to the context of Open and Distance Learning, where access to resources related to research articles and data is frequently problematic for students and staff.

The paper will report on a case study where data were gathered from librarians (including information specialists) and the University of London International Programmes (UoLIP) programme directors relating to existing practice around Open Access and Open Educational Resources (OERs). The University of London International Academy collaborates with a number of Colleges and Institutes of the University of London to offer flexible and distance learning programmes worldwide. These are delivered through the University of London International Programmes. Our investigation explored (a) the use of Open Access materials, (b) OERs and awareness of Creative Commons licences, (c) perceptions of quality and usefulness of open licensed materials, and (d) collaborative schemes for drawing together on Open Access repositories across institutions. We also investigated what were considered to be the major constraints in using OERs and the main resource implications, when adopting OERs.

The purpose of our investigation was to understand how open licensed approaches are used within the Colleges of the University of London that contribute to the University of London International Programmes and explore any policies that are being applied. The objective was to acquire an understanding of the current situation; in addition, the intention was to share and discuss the results and recommendations at the follow-up workshop that took place two months after the dissemination of the survey and our data collection. This was a necessary component of our methodological approach, as we hoped that this would also lead to some interesting recommendations on how the International Programmes and the sector could benefit from and engage with the Open Access movement.

Reference this paper as Hatzipanagos S and Gregson J “The Role of Open Access and Open Educational Resources: A Distance Learning Perspective” The Electronic Journal of e-Learning Volume 13 Issue 2 2015, (pp97-105) available online at www.ejel.org
2. The Open Access spectrum

In Open Access digital artefacts are freely accessed, with no financial costs to the person that accesses them; in addition an area, which is of great interest, is how resources that are freely accessed can also be reused, with or without modification. This usually includes the conditions under which reuse and modification could be legitimate. Creative Commons (2014) is the major influential licensing framework that has attempted to regulate access and reuse. Table 1 provides a synoptic view of the established areas of Open Access (Table 1):

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<td>‘Green’ open publishing repositories</td>
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Table 1: The Open Access spectrum

- ‘Green’ open publishing repositories, which, for the most part, contain summary data about publications rather than full text or final drafts of publications, which their authors have posted before submitting the text to a journal. The elliptical information in summaries and the inclusion of drafts rather than the definitive final version that is published in the journal can be seen as limitations and are increasingly making the combination of green repositories and subscription publishing an unsatisfactory compromise to the Open Access movement.

- ‘Gold’ open publishing repositories, in which publication costs are paid before publication, allowing the publisher to permit wider distribution without damaging loss of revenue (Swan, 2010; Swan and Houghton, 2012). But the use of term ‘open publishing’ can be misleading, because it has been used to embrace rather different approaches. In some cases, ‘gold’ means up-front payment for limited distribution rights, i.e. a paper may be distributed but not reused in any way, including text or data mining, without further charges.

- Open Data – this is a broad area that allows reuse, revising, remixing and redistributing of data. These data can be freely used, reused and redistributed by anyone – subject only, at most, to the requirement to respect an intellectual property sharing license, i.e. ideally to attribute and share alike. As Rushby (2013) points out data sharing is a natural extension of Open Access, rather than an optional ‘add-on’.

- Open Educational Resources are teaching, learning or research materials that are in the public domain or released with an intellectual property license that allows for free use, adaptation, and distribution. (UNESCO, 2009). They are freely available online for everyone to use or reuse, whether you are an instructor, student or self-learner. Examples of OERs include: full programmes, programme modules, curricula, materials from teaching sessions in different formats, assessment resources: assignments from quizzes to exam papers to e-assessment, lab and classroom activities, pedagogical academic development materials, games and simulations, and many more resources, contained in digital media collections around the world (JISC, 2013).

- Open Development is about making information and data freely available and searchable, encouraging feedback, information sharing, and accountability (Smith, and Reilly, 2014). The World Bank is one of the organisations that have launched such open development initiatives.

- Open Licensing, where the most influential body is Creative Commons, a non-profit organization that enables the sharing and use of creativity and knowledge through free legal tools. Creative Commons Licensing (ibid.) offers a range of licenses to regulate sharing - i.e. a Creative Commons attribution licence (CC-BY) is now the de facto standard for Open Access licensing (free to copy, distribute, display, perform, make derivative works, and make commercial use, however an overall common rule is that the original author must be given credit). Others like UNESCO have adopted an Open Access policy, requiring that their publications be licensed under the Creative Commons Attribution ShareAlike license. This BY-SA license means that users who make adaptations of content released under it must share their resulting creations under the same license (State of Creative Commons report, 2014).
There are a growing number of examples of these forms of Open Access. In the following section we discuss a few that illustrate approaches and initiatives.

3. Examples of Open Access

Many institutional libraries are now building digital repositories to develop capacity to make Open Access research available in this way. Initiatives are emerging to create consortia to run federated repositories with capabilities for supporting discovery of content from across repositories by use of powerful search tools.

The Institute of Development Studies is one of many institutions that now make Open Access materials available through an institutional repository Open Docs (2014), based upon an open sources repository application, the DSpace platform (DSpace, 2015). The concept of knowledge hubs that provide access to open data sets is also emerging strongly, with examples such as the FAO (Food and Agriculture Organisation of the United Nations) which supports the Coherence in Information for Agricultural Research for Development network (CIARD, 2014), a movement dedicated to Open Access knowledge related to a particular discipline, agriculture. The Institute of Development Studies is launching the Open Knowledge Hub (2015), which makes Open Access content related to development research widely available, and encourages contribution, use and innovative reuse by interested partners.

These examples are indicative of a growing range of initiatives that are likely over time to transform the knowledge sharing landscape and the way research is created and made available and accessible. This transformation is also likely to have a big effect on how knowledge can be reused, for example in the design of Open and Distance Learning materials, and in the way students can access resources.

4. Open Access Funding

Open Access publishing funding models work on the assumption that in ‘gold’ standard published the author must pay to cover the loss of journal subscription fees. These are referred to as the Author Processing Costs (APC) and can have a harmful effect on Open Access publishing; consequently recent public funding related initiatives have attempted to address this issue.

Incentivising Open Access publishing has resulted in major policy changes and recommendations in the UK for public funding to cover APCs, but in exchange for a requirement to publish public funded research and knowledge creation. The UK Finch report (Finch, 2012) produced a commitment for £30 million per annum to be allocated to supporting Open Access publishing, and the research Councils UK (RCUK) and the European Union are also now funding APC costs. RCUK is doing this by providing block grants to the Higher Education Funding Council for England (HEFCE, 2014) institutions to cover APCs for gold standard Open Access publications. However, according to the Study of Open Access Publishing (Dallmeier-Tiessen et al, 2011), when researchers publish in fee-based open access journals, the fees are paid by funders (59%) or by universities (24%).

Such newly introduced requirements to publish as Open Access conflict with some of the ways in which researchers are currently incentivised, recognised and rewarded. Both their intellectual property rights and desire to publish in the ‘top’ journals are affected, so compliance is an issue. Organisations like the Welcome trust charity foundation (2015) responds to this by withholding 10% of the grant fees it provides if the author does not comply, and the Department for International Development (2015) policy requires that researchers must comply within six months of finishing their work. It has also recently become a requirement under the Research Evaluation Framework (REF) in the UK that certain forms of publications for academics entered in the REF must be Open Access (HEFCE, 2014).

5. Open Access and the Emergent Metrics in Scholarship

Open Access brings changes to which some researchers are resistant and others question whether the APC model that underpins Open Access publishing is another form of exploitation, which may make it relatively harder for authors in developing countries or non-established authors to publish their materials. A related issue surrounds use of the ‘ISI impact factor’, i.e. the most commonly used metric for impact, a measure reflecting the average number of citations to recent articles published in a particular journal publication, which
is the prevalent measure used to rate the quality of research, which however gives far greater recognition to articles published in peer reviewed journals as opposed for example to academic work published on repositories. In addition, this is seen as fundamentally working against recognition and incentivisation of researchers that are not based in linguistically and culturally dominant countries and new forms of publishing (Gray et al. 2013). Many are now advocating for alternative forms of metrics that relate substantively to use and the value of published research, irrespective of the form of publication (e.g. Altmetric, 2014).

Altmetric collects article level metrics and the online conversations around research on behalf of publishers, institutions and funders, combining a selection of online indicators (both scholarly and non-scholarly) to give a measurement of digital impact and reach. It does this by tracking, collecting and measuring large amounts of data collected from all the places where stakeholders, e.g. scientists, patient advocates, journalists, nurses, engineers and members of the public talk about science online - for example, blogs, Twitter, Facebook, Google+, message boards and mainstream newspapers and magazines.

Overall, technology has an impact on practices such as tenure, publishing and open courses and is transforming academic practice (Weller, 2011). Another area of Open Access that has the potential to change academic practice in the light of the influence of emerging new technologies is OERs.

6. Open Educational Resources: benefits and disadvantages

There are perceived advantages and disadvantages in the use of OERs (D’Antoni, 2007; Lane 2010; Hatzipanagos, 2012; 2013). They are seen to be displaced from proprietary ‘silos’, i.e. the institutional Virtual Learning Environments, hence breaking the authorisation barriers that these impose and they are also copyright ‘free’, as contributions to collective knowledge. However, they most often come against recent improvements in creation of technology enhanced learning content, as they can be didactic in nature, the reason being that interaction is frequently non existent or poorly scripted in OER learning design. They are also often elliptical shells to fill in with context and meaning. Context and wrap around activities are missing as interactive aspects and their learning design are separated from content and are both implicit rather than explicit (ibid.).

Our previous research on engagement with OERs (Hatzipanagos, 2013) identified some trends in use and perceptions of their value:

• There is a preference for ‘useful’ (utilitarian), specific (contextualised) and practical (of an obvious purpose) OERs’.
• The “context often is missing” criticism is prominent, which seems to instigate a preference for reusable/ready to use rather than repurposable/useable subject to customisation OERs.
• The main perceived potential benefit of OERs is “improved learning” and less “saving on academic time to develop appropriate material/content”.

To get a better understanding about these areas, especially in the context of Open and Distance Learning, we conducted a case study. A case study strategy appeared to be the appropriate method to employ, by enabling action and events to be set within context by examining one selected setting (Yin 2003).

7. Methodology

Our investigation comprised:

• An online survey (of a quantitative and qualitative nature), which was distributed to the UOLIP. We addressed a broad target audience of librarians (inc. Information Specialists) and programme managers/course leaders. The two versions of the survey (one for librarians and one for programme leaders) were broadly similar and were adapted to the nature of the participants’ work and the context in which they operated.
• A workshop/focus group during the Research in Distance Education (RIDE) 2013 conference, where we invited the participants of the original survey and other experts in the field to discuss
the outcomes and offer recommendations on how the International Programmes and the sector could benefit from and engage with the Open Access movement.

The survey yielded twenty-one returns; of these, twelve came from librarians and nine came from Programme Managers/Course leaders. The questionnaire responses were analysed and quantitative and qualitative data collected from the questionnaires were analysed to determine common issues, which were considered as fundamental by the respondents. The purpose of the focus group (with 30 participants) was two-fold. Firstly we aimed to present key findings of the analysis to the participants to gauge their perspectives in a relatively unstructured fashion. Secondly, we aimed to expand on key issues emerging from the data analysis through semi-structured questions reprising some of the themes that emerged from the survey data analysis.

8. Our Findings: Open Access

8.1 Institutional policies and Open Access repositories

46% of the participants in this study indicated that their institutions were in the process of developing a collection of recommended Open Access materials while while 54% responded that their institutional libraries had no policies related to Open Access subscriptions. For those institutions that had an in-house open licensed digital repository (73% of the respondents indicated that such a digital repository existed in their institution), librarians were asked how they were promoting these Open Access collections.

8.2 Marketing and creating awareness

Responses indicated that there were local marketing initiatives that created awareness of these Open Access collections. They included dissemination and creating awareness routes using social media, email and RSS (Rich Site Summary) feeds, mailing lists, blogs and creating awareness via face-to-face endeavours, i.e. presence at conferences, and through workshops, faculty committees and departmental meetings. The respondents also mentioned some other promotion methods, namely via informal academic networks inside the institution and working closely with IT services and departmental administrators.

8.3 Open Access journals

Respondents were also asked whether their institutions produced any Open Access journals. The responses were again mixed with a 46% indicating that they produced and promoted open journals. These were often made available through the library by creating a catalogue record and links to full text, or were added to the institutional repositories or on open journal system platforms and archived in repositories; as an example, the ePrints (2014) repository was mentioned.

8.4 Training and support

Another important dissemination and awareness avenue was via staff and student development activities, including training in information skills, in ‘how to publish’ and in ‘how to create’ sets of online resources and guides that would signpost Open Access initiatives.

An area of inquiry was whether libraries provided training or support to staff and/or students on how to find open licensed materials and assess their quality. A low percentage of 27% responded that their libraries provided support for both staff and students. Training and support on how to produce open licensed materials seemed to be staff rather than student oriented with only 18% of the respondents indicating that their institutions provided training or support for students through the library on how to produce open licensed materials.

Respondents of the survey were also asked about modes, channels and devices of delivery of their Open Access materials. 46% responded that they had plans to make Open Access materials available via mobile technologies and tablets.

In addition, programme directors were asked about their opinion on quality and usefulness of open licensed materials. Overall they were positive about the existence of “many good resources”, however they also referred to the challenges of evaluating the quality of such resources before adoption. Representative
comments of this type highlighted a commitment to the Open Access movement, whereas any apprehensions had less to do with infrastructure in place and more with the evaluation of the quality of these materials:

“All books should be available online. I am a strong supporter of Google’s scanning program.”

“Massive Open Online Courses (MOOCs) and open journals (are) generally of very high standard in my experience”.

“Variable (quality). Until there is a way of screening/rating that is robust, difficult to recommend.”

“I think that it is useful to use open licensed materials where possible but aware of them being carefully used in context.”

When asked whether a collaborative scheme for drawing together an Open Access repository across the colleges involved in the UoLIP would be useful, the responses were positive (73%) but cautious, highlighting the complex logistics for such an endeavour.

Overall, there was an optimistic attitude about the future of open access, when participants were asked how significant Open Access materials were likely to become in the next 5-10 years. Respondents agreed that Open Access publishing would become part of the default. As someone commented “…there will be increasing pressure to make research findings available”. The reasons that were given were financial (“shrinking budgets”), and pressure (“growing awareness of Open Access & research council funders’ mandates on Open Access, growth although unevenly across disciplines”). There were significant implications for student learning because “if academics are changing their practice, so too must students be prepared to learn in this new research environment”. Arguments were supported by statistics on current Open Access uptake and projections on increase. As someone commented: “I believe that Open Access content will grow both in importance and size. At the moment stats show that 10-15% of articles are published with ‘gold’ Open Access, I believe that number will reach the 40-50% in the next 10 years”. This was linked, according to someone else, to a “political shift in having more scholarly research publically available”.

9. Findings: Open Educational Resources

9.1 Opportunities

Both librarians and programme directors were asked in the survey questions about OERs. A relatively sizeable percentage (64%) did not make use of Open Access materials (i.e. Open Access journals, and other digital resources including OERs) in their practice. They were also not familiar with the different types of Creative Commons licences.

Respondents saw advantages in OER use. They thought that the almost ‘self-nurturing’ nature OERs might require “less effort to maintain than institutional resources”. They also saw another long-term benefit that of investing in OER development that could yield gains in the future. As someone commented: “like most ‘e’ advancements, the development of OER e-assessment materials is time and resource intensive in the short term, but should result in cost/time savings in the medium/long term.”

There was also a reputational benefit both for the institution and staff involved. Comments of this type were:

“(Can) raise the profile for the institution/materials authors/instructional designer”.

“As a marketing device, enhancing the institution’s reputation for quality educational materials”.

However, the “volatile”, almost “touch and go” (attributes they used to describe OERs) ever changing nature of the key OER repositories made them question whether they represented a reliable source of teaching materials. As someone also commented: “…the world of OER is not static enough to make it meaningful other than a snapshot of that day…”

The overlap between institutional endeavours in a particular discipline was for others an advantage for such a collaborative initiative. A respondent commented: “I expect there may be some overlap between subject
materials of interest to our students and students of computational courses provided by .... and .... (other institutions of the University of London)"

9.2 Constraints

The survey and discussions in the workshop investigated the constraints and barriers in using OERs. A key constraint according to the respondents of the survey was a limited understanding of their value. They also alluded to a cultural resistance whose facets were – a “new thing”, “not developed here”, “can we trust it?” etc.

However, the main, often repeated perceived barrier in discussions was a lack of staff development to familiarise academics with the nature and opportunities of OERs and time to search and explore repositories of OERs for suitable learning and teaching resources.

This seemed to echo similar investigations (UKOER/SCORE, 2014), where lack of digital literacies does feature highly as a barrier too, although follow-up interviews that were carried out suggested that finding/evaluating quality OER is a time issue not a skill issue and likewise many staff avoid releasing OER due to the time involved in making them sufficiently polished (a reputational concern) and fully compliant (a legal concern).

10. Discussion: The emergent landscape in Open Access and OER use in UOLIP

Our findings indicated that there seemed to be clear advantages of Open Access for open and distance learning environments that included:

1. Many students (inc. in developing countries) becoming more digitally literate, and libraries ‘serving’ effectively people who are not physically present;
2. Promoting digital resource access, availability and usage;
3. Gaining more feedback and engagement with learners, who can collaborate on ongoing development of ideas and resources;
4. Establishing and recognising new ways to measure impact;
5. Supporting more effective exploration of resources and data (where purchase is not needed);
6. Enabling data mining by allowing simultaneous access to articles/digital resources.

Regarding Open Access, there seemed to be a momentum to recognise, support and reward Open Access initiatives and systems. This could be done by:

1) Librarians, IT departments, programme leaders and researchers working closely together as there are some non-obvious linkages between digital repositories, standards, and quality of resources that need to be explored further;
2) Building awareness of students, and making resources available as Open Access, including associated data sets for Open and Distance Learning students to work on.
3) Authoring open licensed Open and Distance Learning materials with references to open licensed research.

Regarding OERs, based on the survey responses and workshop discussions, ‘searchability’ and ‘discoverability’ of OERs seemed to be an overall issue and programme directors referred to a limited number of OERs in certain disciplines; however the data we collected did not provide sufficient information on the relationship between disciplinarity and OERs, which seemed to represent a rather complex landscape.

Finally, another dominant trait in the responses was that practitioners were commonly not familiar with OERs and Open Access initiatives; therefore there should be a strong academic development aspect in any engagement activity.
11. Conclusion: the Open Access debate and this Investigation

The Open Access agenda itself has instigated some important global debates, as it is changing the model of access, including associated business models, for research and education. Whilst promoting free access and affecting the forms in which knowledge is made available, it is also impacting the incentives surrounding knowledge creation. In this regard we should not immediately assume that by its very nature, Open Access wholly responds to values that promote access to public funded knowledge as a human right.

There seems to be a current debate and on-going initiatives about reaching a global audience in higher education; this affects staff (academics, teaching practitioners and librarians) that are directly or indirectly linked to learning and teaching. It also seems to affect increasingly both in the context of global education on and off campus and Open and Distance Learning students. Other current initiatives are helping to create awareness of Open Access issues, e.g. Massive Open Online Courses (MOOCs) have become a driver for many higher education institutions. Many institutions have responded to the MOOCs call, embracing some of the principles of the Open Access and Open Educational Resources movement, at least the ones that help to institute policies and regulate practice in this context.

Our investigation explored the use of Open Access materials in a specific open and distance learning context, that of the University of London International Programmes, where there is an increasing awareness amongst librarians and programme directors about opportunities and challenges. The intention to commit is there in combination with optimistic ‘aphorisms’ about the inevitability of doing so in the future; however there are no systematic institutional or cross-institutional approaches in embracing Open Access or other collaborative schemes to draw together repositories across institutions. There is relatively limited awareness of OERs and associated licensing especially among academics and tutors combined with perceptions of benefits and some fair apprehensions about resource implications and related quality assurance, when adopting OERs. In addition, ‘searchability’ and ‘discoverability’ of resources and promotion and awareness is considered an important prerequisite for success both for Open Access and OERs.

Our investigation highlighted some opportunities that resulted into some clear recommendations that emerged from our data both for practitioners, learning support staff and for students in this area. There also seems to be a synergy between Open access and OERs, not only because of their unquestionable status as ‘facilitators’ of immediate, permanent online access to the full text of research articles and data for anyone and shared learning and teaching digital resources, webwide; more significantly they both have to address issues of ease of access (inc. cost and an accepted place within the publishing spectrum), quality and visibility in order to become accepted in higher education.

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The Flipped Classroom, Disruptive Pedagogies, Enabling Technologies and Wicked Problems: Responding to ‘the Bomb in the Basement’

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Abstract: The adoption of enabling technologies by universities provides unprecedented opportunities for flipping the classroom to achieve student-centred learning. While higher education policies focus on placing students at the heart of the education process, the propensity for student identities to shift from partners in learning to consumers of education provides challenges for negotiating the learning experience. Higher education institutions (HEIs) are grappling with the disruptive potential of technology-enabled solutions to enhance education provision in cost-effective ways without placing the student experience at risk. These challenges impact on both academics and their institutions demanding agility and resilience as crucial capabilities for universities endeavouring to keep up with the pace of change, role transitions, and pedagogical imperatives for student-centred learning. The paper explores strategies for effective change management which can minimise risk factors in adopting the disruptive pedagogies and enabling technologies associated with ‘flipping the classroom’ for transformative learning. It recognises the significance of individual, cultural and strategic shifts as prerequisites and processes for generating and sustaining change. The analysis is informed by the development of a collaborative lifeworld-led, transprofessional curriculum for health and social work disciplines, which harnesses technology to connect learners to humanising practices and evidence based approaches. Rich data from student questionnaires and staff focus groups is drawn on to highlight individual and organisational benefits and barriers, including student reactions to new and challenging ways of learning; cultural resistance recognised in staff scepticism and uncertainty; and organisational resistance, recognised in lack of timely and responsive provision of technical infrastructure and support. Intersections between research orientations, education strategies and technology affordances will be explored as triggers for transformation in a ‘triple helix’ model of change, through examining their capacity for initiating ‘optimum disruption’ to facilitate student-centred learning, role transitions, and organisational change. We share the findings of ‘our story’ of change to harness the positive utility of these triggers for transformation through deploying strategies for negotiating complexity, including the requirement for a shared vision, a robust team approach, the need for ongoing horizon scanning and application of soft skills (e.g. active listening, timely communication) necessary in order to build student confidence, academic partnerships, and facilitate organisational dexterity and resilience in the face of barriers to change.

Keywords: Transformative learning; change management; flipped classroom, technology-enabled learning; role transitions; organizational change

1. Introduction

The challenges for universities to survive and prosper in the early 21st century are highlighted by Shore’s argument (2010, p.15) that ‘a new set of discourses has emerged around universities and their role that draws together different, often contradictory, agendas’ heralding ‘a shift towards a new, multi-layered conception in which universities are expected to fulfil a plethora of different functions’. Echoing Dolence and Norris’s (1995) manifesto for transforming higher education, to redesign, refine and realign, within this complex and competitive climate, HEIs must engage in innovative strategies to advance research, education and professional practice while continuing to place students at the heart of the education process. These demands impact on individuals and organisations, necessitating both agility and resilience in strategic, business and cultural domains (Mukerjee 2014). If the university is to respond effectively to the pace of change it must reshape and reinvent its core business model while also seeking new future-oriented business. This entails
managing, role transitions, and pedagogical imperatives which offer value propositions to shift to more student-centred, immersive learning experiences, deep faculty/student relationships and the development of critical thinking capacities which remain risk-free for the student experience (Mukerjee 2014; Norris et al 2012).

Norris et al. (2012 p.19), referring back to Dolence and Norris (1995) argued that ‘global society was undergoing a fundamental transition from the Industrial Age to the Information Age and that ‘For higher education, this translated into using Information or Knowledge Age tools – pervasive information and communications technology – to meet the needs of this New Age: universal learning throughout life, personalized and suited to current needs.’ Universities are embracing technologies to facilitate teaching and learning, simultaneous with the growing use of mobile and digital technologies in students’ everyday lives. Lea and Jones (2011, p.378) suggest ‘the potential of social networking, digital and mobile technologies are permeating the academy, not only through student practice but in terms of dominant institutional drivers and government-led funding to harness technologies and applications for supporting teaching and learning’.

Enabling technologies offer potential for enhancing student learning within the complexity and demands of HE provision by crossing boundaries between research and practice, creating opportunities for co-construction of knowledge, and releasing academic staff potential to engage with a rebalanced workload in research, education, and professional practice. But while change in higher education is endemic, technology-enabled initiatives can contribute to the complexity and pace of these changes. Mukerjee (2014, p.56) argues “the digital world is driving innovation and continuous change at such a rapid and random rate that universities are struggling to keep up with demand”. These developments require detailed organisational planning, co-ordination and resourcing (Breen et al 2001) to assure effective change management and minimise risks. This is not to suggest that change can be managed scientifically in a rational, ordered and linear fashion with appropriate planning tools and resources in place. The reality of change may be experienced by different stakeholders as an amalgam of more disjointed and disruptive processes. Initiators of innovative technology enabled strategies, offering new mixes of tutor-facilitated and student-managed learning, can encounter resistance to change manifested at individual and organizational levels where these developments challenge deeply held beliefs and pedagogic practices (Greener 2009, 2010a. p.188).

2. Theoretical framework

While universities have been engaging with digital technologies to support education provision since the development of virtual learning environments (VLEs) in the 1990s, the rapid growth and widespread uptake of mobile devices and potential for ubiquitous connectivity, as ubiquitous mobile moves towards ubiquitous broadband (International Telecommunications Union 2013), offer unprecedented opportunities for using the time and space available for teaching and learning differently. ‘Flipping’ the classroom is one such phenomenon which captures this potential (Baepler et al 2014; Kim et al 2014; Moffett and Mill 2014; Strayer 2012; Westermann 2014). The ‘flipped’ classroom is usually associated with providing course materials, frequently in the form of videoed lectures, for students to engage with outside the classroom, enabling in-class time to be repurposed for student-centred collaborative learning activities that build on the learning resources provided. It has been argued that the flipped classroom enables a shift away from traditional information-transmission, teacher-led lectures where students sit and listen as passive learners, to offer an active and collaborative learning environment, where students assimilate knowledge through application and evaluation, more conducive to facilitating deeper approaches to learning through encouraging higher order critical thinking and creativity (Mazur 2009; Wallace et al 2014; Westermann 2014).

Rather than interpreting the ‘flipped classroom’ narrowly and simply as a process of inversion, where content is delivered outside the class and learning activities within the class, we have adopted a broader, more inclusive definition, which sees the phenomenon of ‘flipping the classroom’ as a powerful threshold concept and catalyst for change within the tradition of hybrid or blended learning approaches, which combine the strength of face-to-face and technology enhanced learning (Picciano 2014). Following Strayer’s argument (2012), what distinguishes ‘flipping the classroom’ from the normal practices of teachers who support their classes with readings and resources is where the technology affordances are being used regularly and systematically to provide and support a disruptive pedagogy. Kim et al (2014, p.38) highlight the value of considering ‘unique interpretations’ of flipping the class and investigating their respective strategies to assist the design of “better learning environments in which students can be more engaged, active, and responsible for their learning”.

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But research on enabling technologies for education tends to concentrate on benefits and outcomes rather than examining evidence of processes and people at work in the disjuncture, flux and movement within education initiatives. Pennington (2003, p.4) highlights the tensions between outcomes and process orientations:

Structures, procedures, attitudes and behaviours underpinning the status quo have often taken years to lay down and are not susceptible to overnight transformations. For this reason the introduction and management of change should be conceived as a rolling process requiring subtle and persistent choreography rather than a defined event occurring at a particular moment.

We believe the notion of the positive utility of resistance to change should not be overlooked and can be explored and better understood in order to implement change successfully. Understanding transformative learning at individual and organizational levels, and acknowledging and working with resistance, reluctance and pedagogic diversity is at the heart of negotiating change creatively and sensitively. This position acknowledges the importance of context and situated learning (Argyris & Schön 1978, Lave & Wenger 1991) and builds on social-constructivist (Mayes & Freitas 2007) and experiential learning theory (Dewey 1933, 1938). The utility of generating purposeful disruptions as tensions and challenges to stimulate transformative learning has been considered elsewhere (Hutchings, Scammell & Quinney 2013). While recognising the value of education initiatives as levers for transformation and organisational change, we also recognise the challenges for change agents in attempting to achieve ‘optimum disruption’ where initiatives are experienced as too uncomfortable, too difficult or simply too unwelcome and therefore resisted or rejected (Hutchings, Quinney & Scammell 2010a).

This paper shares ‘our story’ of negotiating change in the development of a collaborative lifeworld-led transprofessional curriculum for health and social work disciplines. Our purpose is to explore the intersections between three strands, (1) research orientations, (2) education strategies, and (3) technology enabled learning, described as the ‘triple helix’, through their capacity for initiating ‘optimum disruption’ towards both transforming the student learning experience and academic and organisational cultures (See Figure 1). We will examine strategies deployed for negotiating complexity, including the requirement for a shared vision, a robust team approach, the need for ongoing horizon scanning and application of soft skills (e.g. active listening, timely communication) necessary in order to build student confidence, academic partnerships, and facilitate organisational dexterity in the face of barriers to change.

Figure 1: Triple helix model of change: research process and findings (Hutchings, Quinney & Galvin 2014)
3. Case Study: flipping the classroom and its implications

Exploring Evidence to Guide Practice (EE2GP) is an undergraduate intermediate (Level I, Year 2) unit/module designed for large student cohorts. Technology is used to connect learners to humanising practices through engagement with distinct kinds of evidence; conventional evidence, technical knowledge or knowledge for the ‘head’ in the form of qualitative and quantitative research papers and policy and practice guidelines and protocols, together with evidence of people’s experiences of a situation or condition, knowledge for the ‘heart’, represented through stories, narratives, poetry and drama, and facilitated by rich, multimedia enabling technologies. What is unique about this blended learning approach is that it is informed and underpinned by a lifeworld-led humanising philosophy in which students are encouraged to gain personal insights that come from imagining ‘what it is like’ for the person experiencing human services, to make connections to their own personal and professional experiences, knowledge for the ‘hand’, and to integrate understandings about these different kinds of complex knowledge, the head, heart and hand to inform and guide their practice (Galvin & Todres 2013).

The student learning experience of a flipped classroom is facilitated over five weeks with eight learning days and two assessment days (See Figure 2). The learning days each week consist of one contact day and one day for student managed guided learning. The contact day includes lectures and group work designed to initiate student inquiry and collaborative learning based on student viewing, listening and reading of learning resources through online case studies designed for each of the different professional groups participating. Students, allocated to groups of 6-8, are guided through student managed guided learning (SMGL) activities, using a detailed guide with tasks and questions to structure and scaffold their learning, both for the group work in class and for self-managed SMGL activities on the student managed day out of class in preparation for critical reflection and individual blogs each week posted in the group blog.

Figure 2: ‘Flipped classroom’ student experience (adapted from Hutchings et al 2013a)

Key drivers for this major development were informed by the University’s and Faculty’s strategic priorities to:

- Expose undergraduate students to research undertaken in the Faculty of Health and Social Sciences (HSS) and bringing research and teaching cultures closer together;
- Pioneer the application of innovative teaching, learning and assessment strategies
- Increase usage of technology enabled learning;
- Release staff potential; by achieving economies of scale through replacing face-to-face teaching across all the professional programmes with one common blended learning module.

The scale of transformational change effected by this initiative was considerable with anticipated and unanticipated outcomes. Key challenges associated with changing cultures, managing the scale of technology infrastructure, support required, and raised expectations for learning technology provision, were highlighted at individual, Faculty and organization levels. Since the curriculum was introduced in 2010, 11 professional groups have been involved with over 600 undergraduate students each year from nursing (adult, child health, learning disabilities and mental health), midwifery, occupational therapy, physiotherapy, operating
department practice, paramedic science, community development and social work. The initiative impacted directly on working practices, within HSS and the wider University. Key stakeholders included, academics, programme leaders, the Faculty management team, and professional staff in advisory and support roles, based in the Faculty and centrally, including a web developer/educational technologist, learning technologist, IT project manager, academic staff developer, quality and enhancement officer, and examinations coordinator. Approximately 40 academic staff have contributed to the module as developers, champions and facilitators. Introducing this module as a large change management initiative necessitated the negotiation of barriers and risks associated with resistance to change and some scepticism in our Faculty, not dissimilar to the ‘resentment and ambiguity’ identified by Browne (2005, p.57).

4. Methodology

‘Our story’ of negotiating change is told through the voices of those experiencing it, to enable us to explore strategies for effective change management through three major levers for change (the ‘triple helix’, of research, education and technology) towards transformations recognised in impacts on student learning, academic roles and organisational development. The methodological approach adopted was to build a multi-authored narrative for our story of negotiating change (See Figure 1). This approach is informed by the concept of ‘organizational becoming’ (Thomas et al 2011, p.22), where organizations are recognised ‘not as fixed entities, but as unfolding enactments’ in flux and ‘constituted by and shaped from micro-interactions among actors, situated in their every-day work’. Our own position is that levers for optimum disruption towards achieving transformative learning can be recognised in action at individual and organizational levels through student and staff descriptions of their experiences. We draw on qualitative data collected in 2010-11 and 2011-12, captured through questionnaires and focus groups, to highlight individual and organisational benefits and barriers in deploying the triple helix (See Table 1).

Table 1: Demographic profile of participants (Hutchings, Quinney & Galvin 2014)

<table>
<thead>
<tr>
<th>Data collection method</th>
<th>2011.1 Block 1</th>
<th>2011.2 Block 2</th>
<th>2012.1 Block 1</th>
<th>2012.2 Block 2</th>
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<td>n = 219</td>
<td>n = 302</td>
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<td>n = 243</td>
<td>n = 188</td>
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<td>• What challenged learning</td>
<td>Student 8, 13, 18, 20</td>
<td>Student 4, 6</td>
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<tr>
<td>• What you enjoyed most</td>
<td>Student 3, 7, 14</td>
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<tr>
<td>• What you enjoyed least</td>
<td>Student 12, 15, 17</td>
<td>Student 5, 19</td>
<td>Student 11</td>
<td>Student 16</td>
</tr>
<tr>
<td>Response rate</td>
<td>98%</td>
<td>94%</td>
<td>86%</td>
<td>94%</td>
</tr>
<tr>
<td>Staff</td>
<td></td>
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<tr>
<td>Focus group (SFG)</td>
<td>n = 12</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>• Horizon scanning tool</td>
<td></td>
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The student experience was monitored and evaluated through weekly deployment of questions using the ARS (audience response system) voting pads or clickers and an end of module online evaluation completed following their online exam. A staff focus group (n=12) was conducted with academic champions and developers interested in contributing to the module, using an horizon scanning tool to stimulate discussions. Further staff comments were captured during a launch event and through ongoing feedback from programme teams. The core project team also shared their experiences of developing the module, considering what it meant for them, and how they engaged with the ups and downs of the process. The analysis of this data informs this paper. Ethical processes were followed to ensure informed consent and data confidentiality in compliance with institutional protocols for undertaking educational research with students and staff.

5. Analysis of findings

The intersections between research, education strategies and technology with their capacity for initiating ‘optimum disruption’, when flipping a classroom, are examined in relation to achieving student-centred learning, academic role transitions, and organisational change. These complex interrelationships forced us to consider issues of interdependency, tensions and, at times, conflicting agendas in respect of changing cultures, organizational priorities and our core team goals.

5.1 Research orientations for practice

A key driver for the initiative was to expose undergraduate students to research undertaken in the Faculty, drawing on research expertise informed by a lifeworld-led humanising philosophy (Galvin & Todres 2013). The 17 web-based case studies developed, provided diverse evidence of people’s experiences of specific conditions and situations, such as stroke, dementia, back pain, birth, and social isolation. Students were facilitated to explore a range of rich, multimedia evidence from the arts and humanities including narratives and poems, informed by citizen and service user perspectives, in association with qualitative and quantitative research papers, and policy documents, to guide practice for humanly sensitive care (Pulman et al 2012).

5.1.1 Student experiences

Students appreciated the relevance of different kinds of research evidence to guide their practice and the value of engaging with service user and carers’ stories:

*Watching the clips relating to my case study, discovering what people went through and it having an impact on my way of thinking and how I can use this within my practice.* (Student 1)

*The qualitative evidence stood out for me as I began to empathise with the patients. I was able to understand their thoughts and feelings, and began thinking of how this can be applied to practice.* (Student 2)

Students demonstrated developing awareness and confidence to assess different kinds of research evidence and apply critical judgement in professional practice:

*It made me realise that not all evidence is reliable and encouraged me to make my own decision about what evidence to take into account and how to apply it into practice.* (Student 3)

However some students experienced difficulties understanding research methodologies and terminology and seeing the application to professional practice. They described varying degrees of disruption from feeling challenged to experiencing the tipping point beyond optimum disruption:

*Getting to understand all of the research terms that I had never heard of before and relating these to practice challenged my learning and has given me a deeper interest into the subject of using evidence to guide practice.* (Student 4)

*The amount of reading you were expected to do, and learning all the research processes was incredibly difficult as this topic was totally alien to me.* (Student 5)

5.1.2 Staff experiences

This initiative offered opportunities to develop greater integration between research interests and teaching in the Faculty. Academic staff feedback welcomed the integration of lifeworld-led theoretical perspectives for guiding practice:
I just really loved the idea that the evidence comes from the arts and humanities as well as the sort of traditional research evidence. (SFG)

Academic staff also appreciated how the module demonstrated success in bringing the research and teaching cultures closer together:

Students have often said to me they think that research is done by those people who are very academic and very senior, so I think it’s really good that those people are actually teaching at an undergraduate level and making it applicable to practice in a really exciting way. (SFG)

However staff also realised the disruptive nature of this approach for their own roles.

The model of the unit challenges the traditional way in which we have viewed how we carve out our time as academics and teachers. I’d quite like to develop a case study so how does that fit with my role in the rest of the world of my work, it’s not a case of contact hours, but it’s about what role do I play? (SFG)

5.2 Education strategies for transformative learning

Another driver was to pioneer the application of innovative teaching, learning and assessment strategies to alter the typical mix of face-to-face lectures and seminars linked to essays or group presentations and encourage more active co-construction of knowledge over information transmission (Hutchings 2008) by flipping the classroom. Students were allocated an online case study on a particular condition or situation relevant to their professional practice, research process and methods information, podcasts, keynote lectures, and individual and group work activities shared through group blogs. The development of new assessment strategies, including assessment of group blogs, with formative assessment of weekly individual blog contributions culminating in a final group blog assessment and delivery of a multiple choice computer assisted assessment, with weekly practice questions in class, using the ARS voting pads, to prepare students for the online examination, has been discussed elsewhere (Hutchings et al 2013a).

5.2.1 Student experiences

Students had to read, prepare weekly blogs and work in groups to produce their group coursework summary. They recognised the student centred learning approach as different and some enjoyed the active and collaborative learning opportunities:

It is the first time that we have really had to manage our own learning rather being 'fed' the information in a lecture. (Student 6)

I enjoyed working in my group to produce the final blog. We worked well together and were able to bounce ideas off each other. (Student 7)

The degree of scaffolding necessary to support student learning varied with different students. The challenges were viewed positively by some and they were able to learn progressively using the online resources and guidance:

Having to read, understand and submit a blog weekly challenged me and was good for me to take in what I had learned and read and think about it. (Student 8)

The case studies and podcasts have been a new way of learning for me and it has encouraged me to do work on a weekly basis. This is something I usually struggle to do, but knowing that a weekly piece of work needs to be submitted has aided my learning. (Student 9)

Each week it became easier to understand what was required of us to do. It all came together like a jigsaw bit by bit. I felt at the end I had learnt a lot more than I had thought. (Student 10)

Other students were more reliant on face-to-face contact with a tutor and peers:

I would have preferred normal group seminars where we are being taught information and we can freely ask questions. (Student 11)

The normal pattern of engagement in lectures and seminars appeared to be disrupted by this more independent student managed learning approach, which relied on student engagement and learning with the online materials and guidance provided. The tipping point in optimum disruption, the transition to a more independent learning approach, proved too much for some students.
Not being told the information that was necessary to pass the unit, having lecturers believe that "it's on MyBU" or "listen to the podcast" is a suitable response or solution to a student’s enquiry. (Student 12)

5.2.2 Staff experiences

Implications for academic staff were also manifested through the introduction of these different education strategies. Staff who assisted in the development of the web-based case studies vocalised how it can change how they interact with students. One described how she felt distanced from the body of knowledge she had created and concerned the facilitators would do justice to her work:

I feel slightly detached now which has been quite difficult. It’s like giving birth...! Well there you go and look after it and make sure that you get across what I want you to get across. (SFG)

5.3 Technology affordances and logistical impacts

The University and Faculty’s strategic priorities included increasing usage of technology mediated learning to enable the student learning experience to be enhanced and provide opportunities for academic staff to engage more fully in learning technology enhancement through championing, developing and facilitating curricular initiatives. It was anticipated the introduction of the module would bring economies of scale in staff facilitation realized through the changing balance between face-to-face teaching and online learning in this model of the flipped classroom. The large cohorts of students each year were facilitated in two blocks of 300 students using a blend of enabling technologies to provide rich, multimedia online case study resources, group blogs, online frequently asked questions, and a fast feedback forum, all focused on enabling collaborative learning activities, in class and out of class, supplemented by in class lectures supported by ARS voting pads used to gather opinions and gauge knowledge, and student drop-in sessions. Resourcing requirements also included use of a 300 capacity lecture theatre complex including flexible learning spaces that could accommodate group work for student contact days necessitating timetabling the in class contact days at a different campus, booking of computer labs for the computer based assessment, technical support for facilitation of the ARS voting pads, and provision of a robust and secure online assessment platform for delivery of the online exam.

5.3.1 Student experiences

Students recognised the technology mediated approaches adopted as distinct from previous learning experiences and they welcomed the flexibility they afforded:

It was so different from any other module we had done before and was highly computer based. (Student 13)

I enjoyed the self-managed learning days as I was able to complete the required work in my own time and at my own pace. (Student 14)

While some students struggled initially they managed the optimum disruption initiated by these approaches and their readiness for engaging with them improved:

I found blogging very difficult as I’m not very brilliant on the computer but that in itself was a learning process! (Student 15)

I think if I was asked to do blogs now I would feel more comfortable with them. (Student 16)

5.3.2 Staff experiences

The introduction of technology mediated learning within the module affected the roles of academics as developers, champions, and facilitators. It demonstrated role transitions, from module teachers and research staff to resource developers, from uni-professional programme leads to transprofessional champions, and from research-focused professoriate to module facilitators. Academic staff identified how the technology could impact on their working practices and changing roles:

It does radically change how I interact with the students ...... the technology is starting to take us into new areas and there is an element of being de-skilled and wondering how I am going to cope in this brave new world. (SFG)
6. Discussion: responding to ‘the bomb in the basement’

We have shared our story and outcomes of working with the complexities of change at individual, professional and organisational levels and identified the connectivity and flux between these levers in securing effective change management. While individual narratives may have focused on the nature of the technology or the education strategies adopted, or the ways the module engaged with research, these findings demonstrate the complexity and intersections of factors at work in successfully managing a major curriculum innovation and the adoption of a flipped classroom approach. They highlight the importance of deploying strategies for change management that can negotiate through the ‘wicked’ problems (Rittel & Webber 1973), not only logistical but also significantly cultural, and seemingly intractable, which underpin this initiative.

An academic colleague from another faculty, who attended one of the launch events, described the potential impacts of this innovation as ‘a bomb going off in the basement’. Our analysis has revealed factors identified are as much cultural as logistical. For example, one student says:

I would have preferred more lectures and less ‘computerised’ study as I don’t feel this aided my learning at all. (Student 17)

How are we to interpret this comment? Is this about the use of technology mediated approaches per se or could it be more deeply embedded in the degree of disruption caused by the move away from the normality of educational strategies established in the first year of the programmes and focused on the familiar structure of lecture and seminars? Could the innovation, facilitated through technology enabled learning, have strayed too far from the established culture and personalisation enabled in small face-to-face groups within uni-professional programmes?

I feel this unit has used far too much ICT. I agree it is important in our future disciplines, however, this unit has been completely impersonal. (Student 18)

Studying in such a large group. It lost the personal touch. (Student 19)

On the one hand, organisational level logistical problems in managing complexity, dealing with risks, and achieving integration could be presented as resolvable with careful planning:

There’s a lot of quite complex background issues to get resolved and sorted to be able to deliver something that’s slick and successful because it requires pulling together an awful lot of different teams. (SFG)

The core planning team acknowledged the need ‘to have confidence the technology works’ with ‘Plans and processes for systems failure and managing organisational pitfalls’. (SFG)

But on the other hand, there was a lot of change impacting on stakeholders at individual and organisational levels. Some staff felt an ‘element of being deskilled’ with:

So many different techniques and technologies for people who have maybe not engaged in it before. (SFG)

Some students felt overwhelmed by the amount of disruption generated by this initiative:

Having it on a different campus, was all out of our comfort zone, different lecturers, different style of learning, different online style of accessing information. (Student 20)

6.1 Strategies for effective change management

Enabling technologies offer unprecedented opportunities for flipping the classroom to achieve student-centred learning. While the concept of the flipped classroom provides a powerful catalyst for changing education practice, it can hide the immense amount of time and effort required to support and sustain student-centred learning for large cohorts of students. Strategies for ensuring reliability and sustainability of resources and tools, changing people and cultures, and embedding processes into education practice, are needed to assure ownership and transferability of the processes and sustainability of the initiative so that:’It
doesn’t sit outside, it sits within’... (SFG) the programmes, framework teams, Faculty, and University. Strategies for success focus on:

6.1.1 Creating a shared vision through a holistic model for education innovation

The success of this initiative is based on a ‘triple helix’ model for education innovation with three major and interconnected strands, informing, grounding and aligning the processes of change management, previously discussed by Hutchings, Quinney & Galvin (2014) and represented in Figure 3.

- Strand 1: Research orientation for practice - Embedding a lifeworld-led theoretical perspective as a model of transprofessional and transformative learning

The theory of lifeworld led care and education, bringing art and science together, is underpinned and informed by research expertise in the Faculty. Learners are connected to humanising evidence based on the head, heart and hand for guiding and developing professional practice for critical judgement and ethical sensitivity.

Through flipping the classroom, we have demonstrated what Wallace et al (2014) described as a commitment to strategically designed learning opportunities which can guide our students towards deeper learning through engagement in immersive real life stories for nurturing knowledge for the heart as well as knowledge for the head. What informs this approach is the goal of preparing students for professional practice by developing their “capacity to think like an expert” (Wallace 2014, p 269).

- Strand 2: Education strategies for transformation - Realising a social-constructivist pedagogy for informing student-centred collaborative learning

Student effort is rewarded through reading, imagining and integrating evidence, capitalising on the significance of others through innovative arts and humanities materials as well as traditional research evidence, peer group learning, and tutors. The key message is that research is embedded in practice and not a technical toolkit. Learning is assessed formatively by means of weekly individual blogs and summatively through group coursework blog summaries and an online multiple choice exam.

The importance of realising a social-constructivist pedagogy, is reinforced by Mazur (2009) who challenged assumptions that as academics we know what education is, arguing how it is much more than just information transfer. For successful learning to take place, we need to use strategies for engaging students dynamically because students need to work with new information to make sense of it and to make connections to their pre-existing knowledge and experiences. Mazur (2009) explained how his teaching had evolved from “teaching by telling” to “teaching by questioning”, using multiple choice questions for students to answer with clickers to promote thinking about challenging topics. Further recognition of the value of achieving ‘optimum disruption’ for successful learning is reflected in Strayer (2012 p.192) where he stated: “The disequilibrium or unsettledness that students face in an inverted classroom is not necessarily at cross purposes with successful learning” but he also recognises the need for scaffolding with “support structures built into the course so that the teacher and students alike can monitor student learning as they complete tasks”.

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Strand 3: Technology affordances - Harnessing the potential of a range of technologies to enhance student learning

The learning processes are mediated by a virtual learning environment with rich multimedia web-based case studies and collaborative group work facilitated through blogs, online assessment and ARS. The technologies can also deliver cost-effective solutions for managing large student numbers and releasing staff time.

Strayer (2012 p.172) highlighted how “interactive technologies make it possible for educators to qualitatively reconceptualise the teaching and learning dynamic” but he also acknowledges how students “could be frustrated when they encounter learning tasks that aren’t clearly defined” (2012 p. 191). For success, the potential distancing experienced through technology affordances needs to be carefully balanced by social presence, focused on discourses among students and their teachers, and teaching presence, through appropriate orchestration of the learning environment (Kim et al 2014).

This triple helix model for education innovation is dynamic, interactive, and integrative. It has enabled us to forge ahead with managing the complexities and uncertainties wrought by change, working with systemic challenges beyond our control but not beyond the powers of a cohesive and committed team to negotiate and influence.

6.1.2 Building a robust and dedicated core team for managing change

We have described our approach to change management as ‘middle-grounded’ to signify the benefits of actively promoting and building on open, flexible, morphing teams, grounded in a humanising philosophy and a shared vision and values for developing innovative pedagogical practices endorsed by our Faculty (Hutchings et al 2011). The shared vision, commitment and complementary team roles helped manage the integration and risks associated with changing cultures, and negotiating institutional processes, technology infrastructure, and raised expectations. Team members drew on the experience, enthusiasm and commitment of colleagues to deal effectively with challenges, constraints and uncertainties associated with the development of this complex project.

6.1.3 Managing organisational challenges through partnership, listening and regular communication

Harnessing technology for enhancing student learning highlighted organisational and individual challenges in managing the changes associated with the scale of technology infrastructure, support required, and emergent expectations for learning technology provision for all. Organisational challenges included managing timetabling...
logistics, organising rooms for group work and computer labs for online exams, and overcoming systems failures. Baepler et al. (2014, p.227) have clearly identified how the design and availability of conducive learning spaces really does matter, identifying how “the environment of a large lecture hall with fixed seating in rows makes peer collaboration difficult and awkward” and their results showed that “flipped, hybrid active learning classroom-based classes can yield student-learning outcomes that are at least as good as, and in one study better than, a comparable class taught in a traditional auditorium-style classroom.” Smith (2012) emphasises the considerations underpinning the diffusion of innovative learning and teaching practices, requiring senior management support, recognition of the resources, time and effort needed to change existing practices, supportive networks and institutional infrastructure. Working in close collaboration with committed and responsive Estates and IT champions helped manage organizational resistance.

Pennington (2003, p.5) recognised that: “Organisational politics are heightened and amplified during a change process as individuals and groups perceive shifts in power, authority, influence and territory. For this reason successful change requires not just technical competence from ‘managers’, but also sensitivity to political and human dimensions of organisational life.” The core team experienced cultural resistance communicated in staff scepticism and uncertainty expressed by professional programme colleagues. Flipping the classroom leads to shifts in academic roles from sage on the stage to guide on the side and in that role transition we need to recognise becoming what Wallace et al (2014, p 269) identify as cognitive coaches, enabling students to “learn to be” rather than to “learn about”. These challenges have highlighted the importance of promoting ownership and transferability through developing creative and collaborative partnerships working in flexible and supportive multi-disciplinary/professional teams where roles merge and coalesce. The team’s efforts to consider the pedagogic and structural challenges (Browne 2005) in an integrated way were evident in the collaborative team approach, with role transitions experienced by staff being not dissimilar to those identified by Anderson (2009). While it was important to recognize the behaviours, motives and beliefs of staff who may resist change (Outram 2004), the commitment to fostering an effective collaborative team, both within and across discipline areas, assisted in the process of achieving the strategic goals of the university and realizing the vision of the team designing and delivering this module. This approach was intended to avoid what Ward et al (2010 p.40) describe as situations where ‘IT-driven decisions and project management principles overrode the pedagogical considerations and autonomy of academic decisions making processes’. Mazur (2009, p.51) emphasized that “it is not the technology but the pedagogy that matters”.

6.1.4 Capitalising on networking opportunities and forming alliances for horizon scanning

Opportunities to network with and learn from colleagues with expertise in different disciplines and other HEIs facilitated through the UK HEA Enhancement Academy (Hutchings et al 2011) provided a powerful and influential resource to inform and support the project. Links established with the University of Oxford Medical Sciences Division proved invaluable for informing the computer assisted assessment. The contribution of a Leadership Foundation for Higher Education (LFHE) ‘critical friend’ was pivotal in providing focused advice and support and instrumental in ‘winning hearts and minds’. The generosity of these colleagues sharing their expertise was highly valued and brought added caché and gravitas to the initiative.

7. Conclusions

We successfully introduced a generic structure and processes through the design and development of this module. As a result, we hope the path for future developments will be made easier for other enthusiasts to follow. In placing pedagogy, informed by a life-world-led philosophy and supported by a range of technologies, at the centre of the rationale for change this collaborative and creative project challenged and moulded existing organisational and individual practices (Browne 2005). Our views resonate with those of Greener (2010) that a more detailed understanding is needed of beliefs and behaviours of students and staff and environments in which these operate when introducing and adopting technology enabled learning practices. This incorporates consideration of personal and institutional pedagogies, digital skills and self-efficacy in technology usage. Achieving ‘optimum disruption’ (Hutchings, Quinney & Scammell 2010a), whether in a flipped classroom or more traditional classroom requires institutions and individuals to accept the normality of what Ashcraft and Trehewey (2004 p81) refer to as the ‘dualities, contradictions and paradoxes’ embedded in day to day practices. This can lead to practices that foster the innovation, creativity and change (Barge et al 2008) at the heart of our ‘triple helix’ model of change. There are no guarantees of success. While students appear to prefer a flipped classroom approach (Baepler et al 2014; Moffett and Mill 2014), some can find it
disconcerting at first and “some remain dissatisfied with the change in the traditional approach despite the learning gains” (Baepler et al. 2014, p.229) and, while this may not always translate into improved performance in assessment (Moffett and Mill 2014), it may promote lifelong learning. However it is vitally important for HEIs to respond to the ‘bomb going off in the basement’ and we would like to conclude by identifying that the structure of the institution has shuddered and some bricks have come loose. These have been repositioned and further building work is in progress.

Acknowledgements

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An Assessment of Students’ Perceptions of Learning Benefits Stemming from the Design and Instructional Use of a Web3D Atlas

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Abstract: This article has a dual purpose: it describes the development of First Year Dental Anatomy (FYDA), a web-based 3D interactive application used in the dental curriculum at a major Canadian university, and it reports on the results of a research study conducted to assess the perceptions of learning benefits students experienced through the use of FYDA in a dental anatomy course. Questionnaires administered upon the completion of three semesters during which FYDA was used reveal some benefits for learning, but also a few deterrents for use, primarily related to some aspects of design. Generally, the students received the application with interest and viewed it as a useful aiding tool in learning dental anatomy. The results suggest the overall 3D models met the students’ learning objectives and expectations and, in their view, were conducive to their understanding of internal and external dental anatomy. Issues related to the over-sensitive controls, navigational flaws and manipulation difficulties caused some learners a certain level of frustration, but these were not severe enough to hinder the students’ learning.

Keywords: higher education, first year dental anatomy, web-based atlas, web3D technologies, 3D graphics, 3D animations

1. Introduction

With the development of increasingly more sophisticated digital media for graphic design and visual spatial representation of objects in virtual environments, interactive 3D learning tools drawing on cognitive and constructivist learning theories have received much attention in recent years in terms of their instructional utility and pedagogical impact (Dalgarno & Lee, 2010; Huang, Rauch, & Liaw, 2010; Salajan et al., 2009; Wu & Chiang, 2013). This heightened interest in 3D learning tools, however, has not been accompanied at the same level by empirical research designed to test their impact on teaching and learning. Consequently, there is a persistent and perceived need expressed in the educational literature for more such research to illuminate the effects of 3D environments on learning outcomes (Dalgarno & Lee, 2010; Wu & Chiang, 2013).

The medical education field, broadly defined, has been at the forefront in the development of 3D atlases or 3D simulations intended to provide students and practitioners with virtual tools that enhance, supplement and, occasionally, supplant physical tactile environments when necessary (Brenton et al., 2007; Nigel, 2007). Published articles in the relatively early years of exploration and development espoused the 3D models’ promise for the improvement of learning outcomes, but were primarily descriptive, rather than analytical in nature (Gehrmann et al., 2006; Sinav & Ambron, 2004; Trelease & Rosset, 2008). In this context, actual empirical studies have begun to emerge that attempt to support the incorporation of 3D materials in medical education and further afield. Thus, Wu and Chiang’s (2013) study provided data suggesting that 3D animations improve visual comprehension of objects featuring complex structures. O’Byrne, Patry and Carnegie (2009) found that the use of digital interactive anatomy images are of special value for kinesthetic learners and are supportive of self-learning, a process which requires active and deliberate cognitive engagement on the learners’ part (Zimmerman, 1995; Steffens, 2006). Schleich et al. (2009) showed that 3D computer graphics of atrial septation in the human heart led to a significant improvement in the teaching of complex notions and aided in the learning of the mechanics of atrial septation. Petersson, Sinkvist, Wang and Smedby (2009) reported that the Educational Virtual Anatomy program designed to teach anatomical dissection had

potentially beneficial effects on students’ knowledge testing and as an electronic resource in comparison with textbook material.

In dental education there is also mounting evidence pointing to benefits of web-based interactive models of instruction using three-dimensional objects. Such web-based tools are also known as Web3D technologies, described by Chittaro and Ranon (2007) as 3D content delivered to a user from a host server via a web browser. Gianquinto (2005) provided acknowledgment that 3D modeling and animation represent a rational progression in curriculum evolution via which students can expand their comprehension of “cavity design, discrimination learning, and procedural critique in a self-directed, self-paced learning environment” (p. 98). An example of early implementation of 3D models in dental education is the [Web-based 3D Online Crown Preparation Course](#), designed to afford students with foundational knowledge in anticipation of preclinical skill development for full crown preparations (Spallek et al., 2000). Al-Rawi et al. (2007) suggested that their web-based application including interactive 2D and 3D elements designed for the anatomical interpretation of cone beam computed tomography was at least as effective in conveying the concepts taught as traditional instructional materials. Salajan and Mount (2008) provided examples from an early project which included an application using reconstructed 3D images for the representation of cavity preparaions in restorative dentistry. In a follow-up study, Salajan et al. (2009) reported research data on the implementation of three separate web-based programs developed in-house and involving Web3D technologies: *Panoramic Radiography: Principles and Interpretation*, *Gross Human Anatomy 3D Atlas* and *Restorative Dentistry: Virtual and Interactive Cavity Preparations*. The post-implementation research indicated that the interactivity embedded in the applications were instrumental in reinforcing knowledge and in fostering students’ learning of difficult concepts.

Given the increased research interest in Web3D technologies in medical and dental education, this article presents the design, development, implementation and evaluation of a 3D multimedia interactive web-based application, *First-Year Dental Anatomy* (FYDA), intended to introduce first year students in the Doctor of Dental Surgery (DDS) program at the Faculty of Dentistry of a major Canadian university to the fundamentals of dental anatomy. FYDA was created as a modular instructional program, combining high-end interactive 3D objects that can be manipulated by the user, 3D animations of anatomical processes and galleries of still images, all of which constitute a rich media environment for DDS students to explore in learning about dental anatomy. Placed within the context of previous research on Web3D technologies informed by cognitive and constructivist learning theories, this study seeks to answer the following questions:

1. What perceived learning benefits do students draw from their utilization of FYDA?

2. What multimedia and interactive design features included in FYDA correlate with students’ perceived learning benefits?

3. How useful do the students consider FYDA as a learning aid in their exploration and study of dental anatomy?

A theoretical dyad linking together the cognitive theory of multimedia learning and constructivist learning constitute the epistemological background against which FYDA is explored and analyzed in this article.

### 2. Theoretical and conceptual framework

The design, structure and use of FYDA were informed by elements of the Cognitive Theory of Multimedia Learning (CTML) and constructivist learning. In this section, we describe these major theoretical strands and their contribution to the patterns of knowledge distribution in FYDA.
2.1 Cognitive theory of multimedia learning

It was just a matter of time before the use of Information and Communication Technologies (ICT) in education would lead to the emergence of theories in cognitive psychology that explicitly attempted to explain how multimedia technologies affect learning processes. Mayer (1997) was the first to propose a generative theory of multimedia learning. In later iterations of this theory, Mayer and Moreno (1999, 2002) re-conceptualized it as the Cognitive Theory of Multimedia Learning by incorporating concepts from dual coding theory, cognitive load theory and constructivist learning.

In Mayer and Moreno’s CTML framework, the nonverbal and verbal coding systems proposed and developed by Paivio (1969, 1986) act as the main conduits through which learners process information. As a strand of cognitive psychology, dual coding theory postulates that human cognition is processed through two separate coding systems, one nonverbal and the other verbal. The first one, also called “the imagery system” by Paivio (1986, p. 53), is concerned with the analysis of mental representations, while the second one deals with the processing of language, whether in textual or verbal form. Paivio further contends that the two systems are independent of each other, in that they may both be active in parallel or one can be active without the other.

Cognitive load theory, as described by Chandler and Sweller (1991), regards the way in which cognitive resources are prioritized and allocated during learning or problem solving. It claims that redundant or irrelevant material that is assigned in instructional tasks generates a cognitive load that may interfere with learning. The selective allocation of cognitive resources has practical implications for Mayer and Moreno’s CTML through the principles of multimedia design they proposed, which are described below.

Another theoretical element that informs Mayer and Moreno’s CTML is constructivist learning, from which they borrow the notion that learners actively engage in their learning by selecting information, organizing it into coherent representations, followed by the integration of this information with existing knowledge (Mayer and Moreno, 2002). Figure 1 synthesizes the sequence of cognitive processing that operationalizes CTML and its cognitive and constructivist elements.

![Figure 1: Conceptual map of the cognitive theory of multimedia learning (Mayer & Moreno, 2002, p. 111)](image)

Based on this conceptual operationalization, Mayer (1999) developed five guiding principles for the design of multimedia instructional aides:

1. **Multiple Representation Principle.** This principle states that it is better to utilize two complementary modes of representation (e.g., text and images) for the delivery of learning material, rather than a single mode.

2. **Contiguity Principle.** According to this principle, the learner understands the corresponding textual and visual instructional materials better if these are presented at the same time, rather than separated by a time interval.
3. **Split-Attention Principle.** Under this principle, textual information in a multimedia presentation should be presented as an auditory narration, rather than on-screen text.

4. **Coherence Principle.** This principle recommends that the presentation of both text and images be concise and clear, and extraneous information be eliminated or kept to a minimum.

5. **Individual Differences Principle.** Acting as a corollary to the previous four principles, the last principle states that the consequences of these principles have a larger impact on low-prior-knowledge rather than high-prior-knowledge learners and on high-spatial rather than low-spatial learners (Mayer, 1999).

These principles have been applied and tested in the context of the development of multimedia learning systems, thus giving empirical support to CTML (Moreno & Mayer, 2000; Mayer & Moreno, 2002; Just et al., 2004; Underwood, 2008). Through the 3D objects, animations and the textual component attached to them, FYDA fits well in this model of cognition. Both the imagery and the verbal system are engaged simultaneously, alternatively or complementarily in relation to each other once the FYDA content is processed through the learner’s cognitive functions.

### 2.2 Constructivist learning

In the educational realm, constructivism is generally seen as a deliberate process by which the learner constructs his own knowledge by virtue of analyzing and internalizing information he or she absorbs through independent thinking (Jonassen, 1994; Conceição-Runlee & Daley, 1998; Huang, Rauch, & Liaw, 2010). Resnick (1981), for instance, stated that “these constructions respond to information and stimuli in the environment, but they do not copy or mirror them” and this process has implications for the learning environment in that “instruction must be designed not to put knowledge into learners’ heads, but to put learners in positions that allow them to construct well-structured knowledge” (p. 660). A similar position is adopted by Shuell (1986) who supports the idea that “cognitive approaches to learning stress that learning is an active, constructive, and goal-oriented process that is dependent upon the mental activities of the learner” (p. 415).

FYDA’s facilitation of constructivist learning through its multimedia environment is theoretically and empirically substantiated by Mayer’s (1997), Mayer and Moreno’s (2002) and Moreno’s (2008) unambiguous interpretation of constructivism in the context of multimedia learning. Through the evidence yielded by their research into the multiple effects of multimedia on cognitive processes, they support the view that construction of knowledge occurs through the visual and verbal representations described in CTML. In this sense, FYDA is appropriately suited to facilitate constructivist learning. It observes Mayer and Moreno’s (2002) cautionary note that “the challenge for designers of multimedia instructional messages is to foster constructivist learning even when no hands-on activity or social activity is possible” (p. 110).

FYDA’s interface permits the learner to conduct a critical analysis and comparison of the different content elements contained in a certain learning module. The textual component that augments the visual demonstration serves as a means for in-depth probing of the subject at hand, allowing the student to corroborate information between the two modes of content delivery. Thus, the learner can draw his or her own judgment through a dual analysis of the interrelations between the 2D and 3D visual media and the written document. Consequently, through the content provided in FYDA, the learner proceeds to construct his/her mental representation of the objects or elements presented in the 3D atlas and the other modules of the application. He/she can reinforce this mental representation by manipulating the 3D objects as frequently as needed in order to consolidate the knowledge he/she has constructed (Chittaro & Ranon, 2007).
3. Design process and features of FYDA

Consistent with previous courseware development projects at the Faculty of Dentistry, (Salajan & Mount, 2008; Salajan et al., 2009), FYDA is the result of the collaborative work of a team of developers. This team included the faculty member who taught the dental anatomy course, an academic technology specialist who coordinated the overall direction of the project’s instructional design, a web developer who programed the application’s functionality, and a biomedical animator who produced the 3D objects and media incorporated in the application.

The content of FYDA includes interactive 3D representations of dental anatomy, as well as animated 3D representations of dental evolution and development. FYDA has twelve modules that can be accessed from the application’s main entry page shown in Figure 2. Without minimizing the importance of other modules, the 3D Atlas is described in more detail in the following subsection.

![Figure 2: Splash screen in FYDA](image)

3.1 The 3D Atlas module

The 3D Atlas module was the most complex and advanced addition to FYDA, both in terms of its graphic design and in its potential pedagogical impact. It was meant to provide a visually rich environment in which three-dimensional versions of individual teeth could be manipulated in various ways by students in meeting a required expectation of the course, that is, knowledge of the internal and external anatomy of permanent dentition.

In order to assist students, particularly those with no prior knowledge of anatomy, in acquiring a solid understanding of dental anatomy, the 3D Atlas conveys the content in several ways, in accordance with the principles of multimedia learning discussed earlier. The entry point into the 3D Atlas consists of a screen containing a partial 3D image of the human lower maxilla and mandible with selectable teeth that become highlighted in red once the mouse cursor is placed over them (see Figure 3). From this image, the user may select any of the teeth for viewing, at which point the selected tooth is displayed on the atlas’s examination field (see Figure 4).

The atlas is comprised of the following elements: 3D Teeth Models – represented by 3D images of natural specimens obtained with permission from the university’s anatomy lab, and rendered in 3D via a micro CT scanner; Transparency Panel – provides the user with the possibility to modify the transparency levels for the external and internal anatomical features; Orientation Helper – indicates the anatomical facet shown on the tooth model (e.g., buccal, lingual, distal, mesial, etc.); Text Panel – contains a description of the characteristics of the displayed tooth (e.g., definition, function, notation, etc.); Control Strip – contains command buttons...
Florin D. Salajan, Greg J. Mount and Anuradha Prakki

located at the bottom of the examination field; *Dropdown Menu* – for the selection of tooth models to be viewed (Figures 4 and 5).

![Figure 3: Entry screen of the 3D Atlas, with selectable teeth](image)

![Figure 4: Screenshot of the 3D Atlas with all navigational and functional features displayed](image)

![Figure 5: Tooth model displayed with adjusted transparency levels and hidden panels](image)

### 3.2 Implementation of FYDA in the dental anatomy course

FYDA represented a significant addition to the Dental Anatomy and Occlusion course as interactive instructional material. The course is offered once a year during the fall semester, thus FYDA can only be employed during that time. FYDA was implemented by the course instructor, following a specific protocol tailored to the goals of the course.

First, students were instructed to use FYDA as a review tool after each lecture. Subsequently, students were asked to review all lecture material by consulting the content included in FYDA. For instance, after a class
lecture on incisors using PowerPoint slides, students were asked to review the incisors content in FYDA (Descriptions and 3D Atlas Sections). Closer to their mid-term exam, students had one whole morning reserved to, again, review FYDA in preparation for the exam. Students’ use of FYDA, however, was not limited to the protocol outlined above. Therefore, some of them might have explored FYDA’s content for multiple purposes that went beyond the review of lecture material or exam preparation.

4. Research methodology and design

4.1 Research method

A survey method was used in the evaluation of students’ perceptions of learning benefits resulting from their interaction with FYDA. Since FYDA was included as supplemental material (see section 3.2), the research relied on gathering indirect evidence via two opinion-based surveys measuring student perceptions of learning benefits.

The First-Year Student Technology-Proficiency Profile (FYST) questionnaire was derived from an instrument developed in a previous study (Salajan, Schönwetter & Cleghorn, 2010) and was intended to gauge the level of familiarity and proficiency the students considered they had in using digital technologies for educational purposes. The FYST questionnaire contained 35 items, combining demographic information items, five-point bipolar symmetrical Likert-scale items and an open field for additional responses. The second instrument, First-Year Dental Anatomy Evaluation (FYDA) questionnaire, was specifically designed to evaluate the use of FYDA by the DDS students. It consisted of 18 items, combining an identifier field, 14 five-point bipolar symmetrical Likert-scale items and a final open response field. The items specifically used in the statistical analysis are presented in Table 3.

Cronbach’s alpha coefficient value for the items on the FYST instrument was 0.94, while for the items on the FYDA instrument this was 0.90. Both values were above the 0.70 reliability threshold considered adequate in survey research (DeVellis, 2011; Nunnally & Bernstein, 1994).

4.2 Data collection and response rates

Since the FYST instrument was distributed to students at the beginning of the semester and the FYDA questionnaire was deployed at the end of the semester, the two instruments contained a unique identifier field, for questionnaire matching purposes. Only completed, matched questionnaires were retained for analysis.

A convenience sampling technique was used to survey a target population limited to the first-year cohort, which typically enrolls approximately 65 students every academic year. Therefore, from a target population of 194 students, we received 107 complete matched responses, representing a 54.9% overall response rate for the three semesters combined. While no consensus exists regarding acceptable response rates in survey research (Fowler, 2009), the combined response rate obtained in this study may be considered adequate as a representative sample of the target population (Nulty, 2008).

In terms of the respondents’ demographic characteristics, of the 107 students, 45 were male and 62 were female. The ages of the respondents ranged from 20 to 35, with a median of 23 years and a mean of 23.5 years. A two-way ANOVA test with age entered as independent variable and cohort years entered as the dependent variables revealed no significant differences between the three groups of respondents.

5. Analysis and results

Descriptive statistics from the FYST questionnaire revealed that students were fairly reserved in their self-assessment of computer proficiency, as measured by a five-point Likert-scale item with the lowest level
labeled as *Novice* and the highest level as *Expert*. In turn, the students were somewhat comfortable in trying new technologies on a scale from *Very Anxious* to *Very Comfortable* at the extreme low and high ends, respectively. In terms of the purpose of computer usage, the students reported communication and information retrieval as the most important, followed by educational purpose. Gaming was a far less important purpose of computer use for the respondents (see Table 1).

**Table 1: Student self-assessed proficiency with technology and types of computer use**

<table>
<thead>
<tr>
<th>Proficiency</th>
<th>M</th>
<th>SD</th>
<th>Purposes</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expertise</td>
<td>3.06</td>
<td>1.06</td>
<td>Education</td>
<td>4.03</td>
<td>1.15</td>
</tr>
<tr>
<td>Comfort</td>
<td>3.58</td>
<td>1.24</td>
<td>Information</td>
<td>4.44</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Communication</td>
<td>4.46</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gaming</td>
<td>2.47</td>
<td>1.39</td>
</tr>
</tbody>
</table>

Regarding the purposes for which FYDA was used by the DDS students, Table 2 shows the distribution of frequencies reported for each type of use, displayed in its corresponding sequence as an answer selection on item Q2X on the FYDA questionnaire. These results evidently suggest that students found FYDA as applicable in a variety of learning scenarios that addressed some of their most immediate needs in assimilating course content.

**Table 2: Frequency of purposes of use for FYDA as reported by students**

<table>
<thead>
<tr>
<th>FYDA Purpose of Use</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) To study before exam</td>
<td>27</td>
<td>25.2</td>
</tr>
<tr>
<td>(2) To study before class</td>
<td>2</td>
<td>1.9</td>
</tr>
<tr>
<td>(3) As a supplement to lecture material during class</td>
<td>8</td>
<td>7.5</td>
</tr>
<tr>
<td>(4) To review after class</td>
<td>3</td>
<td>2.8</td>
</tr>
<tr>
<td>(5) As a reference tool throughout the semester</td>
<td>22</td>
<td>20.6</td>
</tr>
<tr>
<td>Multiple/combined</td>
<td>45</td>
<td>42.0</td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Multiple or combined use denotes the selection of two or more types of uses from the five possible responses to question Q2X: "For what purpose(s) did you use FYDA?"

The mean values reported by the respondents on some of the more relevant Likert-scale items on each instrument are presented in Table 3. For ease of presentation, the items are coded with the number of their position in each particular instrument, joined by a suffix indicating to which instrument they belong. Thus, an item coded Q1E is part of the FYST questionnaire, while an item coded Q1X is part of the FYDA questionnaire, where the suffixes E stand for *Entry* and X stand for *Exit* questionnaires, respectively. A unique descriptor for each item is also provided for ease of identification and reference in further explanations of the results in this article.
As indicated by their rating of item Q31E on the FYST questionnaire, the students expected online materials to improve their academic productivity. However, the students were somewhat more reserved in their ratings of multimedia (Q32E) and simulations (Q33E) as factors contributing to the improvement of their academic productivity. In responding to the FYDA questionnaire, the students rated fairly highly the helpfulness of the annotations, the transparency settings and the teeth models, generally in learning about various anatomical features of teeth (Q5X, Q6X and Q7X), but appeared to rate the models slightly lower as contributors to their understanding of the internal and external dental anatomy. In addition, the students provided high ratings regarding FYDA’s coverage and explanations of dental anatomy concepts which met their learning objectives (Q14X), and were particularly positive in their rating of the accuracy of FYDA’s graphic design elements (Q16X). Finally, the ratings on items Q15X and Q17X suggest the students considered that FYDA’s interface was easy to use and that FYDA had a high level of interactivity.

Table 3: Reported mean values for items used in the statistical analysis

<table>
<thead>
<tr>
<th>Item</th>
<th>Stem</th>
<th>Descriptor</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q7E</td>
<td>I use the computer for education</td>
<td>Education</td>
<td>4.03</td>
<td>1.15</td>
</tr>
<tr>
<td>Q8E</td>
<td>I use the computer for information retrieval</td>
<td>Information</td>
<td>4.44</td>
<td>0.90</td>
</tr>
<tr>
<td>Q9E</td>
<td>I use the computer for communication</td>
<td>Communication</td>
<td>4.46</td>
<td>0.98</td>
</tr>
<tr>
<td>Q10E</td>
<td>I use the computer for gaming (i.e., educational, entertainment, etc.)</td>
<td>Gaming</td>
<td>2.47</td>
<td>1.39</td>
</tr>
<tr>
<td>Q12E</td>
<td>How confident do you feel using a computer?</td>
<td>Computer</td>
<td>3.96</td>
<td>1.09</td>
</tr>
<tr>
<td>Q13E</td>
<td>How confident do you feel using a laptop?</td>
<td>Laptop</td>
<td>3.99</td>
<td>1.12</td>
</tr>
<tr>
<td>Q16E</td>
<td>How confident do you feel using the internet?</td>
<td>Internet</td>
<td>4.62</td>
<td>0.76</td>
</tr>
<tr>
<td>Q17E</td>
<td>How confident do you feel using a web browser (e.g., Internet Explorer, Firefox, etc.)?</td>
<td>Browser</td>
<td>4.46</td>
<td>0.85</td>
</tr>
<tr>
<td>Q21E</td>
<td>How confident do you feel using computer-based simulations?</td>
<td>Computer</td>
<td>3.49</td>
<td>1.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simulations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q31E</td>
<td>To what extent do you expect the online course materials (e.g., lecture notes, presentations, etc.) to improve your academic productivity?</td>
<td>Online Materials</td>
<td>4.30</td>
<td>0.97</td>
</tr>
<tr>
<td>Q32E</td>
<td>To what extent do you expect the multimedia components (e.g., audio/video clips, etc.) to improve your academic productivity?</td>
<td>Multimedia</td>
<td>3.45</td>
<td>1.08</td>
</tr>
<tr>
<td>Q33E</td>
<td>To what extent do you expect the interactive simulations (e.g., 3D atlas, virtual microscope, etc.) to improve your academic productivity?</td>
<td>Interactive Simulations</td>
<td>3.48</td>
<td>1.07</td>
</tr>
<tr>
<td>Item</td>
<td>Stem</td>
<td>Descriptor</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------------------------------------------</td>
<td>---------------------</td>
<td>-------</td>
<td>-----</td>
</tr>
<tr>
<td>Q5X</td>
<td>In learning to identify structures of the external anatomy of the tooth, the annotations (e.g., blue pins, red highlightable areas) on the models in the 3D Atlas were:</td>
<td>Annotations</td>
<td>3.87</td>
<td>0.70</td>
</tr>
<tr>
<td>Q6X</td>
<td>In learning about the internal anatomy of the teeth, the transparency settings (e.g., making parts of the tooth appear “see through”) in the 3D Atlas were:</td>
<td>Transparency</td>
<td>4.05</td>
<td>0.80</td>
</tr>
<tr>
<td>Q7X</td>
<td>Overall, to what extent do you think that the models in the 3D Atlas were helpful in learning about teeth?</td>
<td>Overall Models</td>
<td>3.87</td>
<td>0.77</td>
</tr>
<tr>
<td>Q8X</td>
<td>The models in the 3D Atlas had a major contribution to your understanding of the external and internal anatomy of the teeth.</td>
<td>Anatomy</td>
<td>3.36</td>
<td>0.93</td>
</tr>
<tr>
<td>Q9X</td>
<td>The models in the 3D Atlas helped you achieve your learning objectives for the dental anatomy section of the course.</td>
<td>Learning Objectives</td>
<td>3.50</td>
<td>0.79</td>
</tr>
<tr>
<td>Q10X</td>
<td>The models in the 3D Atlas helped you in your preparation for the course assignments.</td>
<td>Assignments</td>
<td>3.17</td>
<td>0.88</td>
</tr>
<tr>
<td>Q11X</td>
<td>The models in the 3D Atlas helped you in your preparation for the exam(s).</td>
<td>Exams</td>
<td>3.64</td>
<td>0.76</td>
</tr>
<tr>
<td>Q12X</td>
<td>In general, the manipulation of the models in the 3D Atlas was:</td>
<td>Manipulation</td>
<td>3.29</td>
<td>1.04</td>
</tr>
<tr>
<td>Q13X</td>
<td>To what extent do you think that FYDA as a whole was useful in helping you reinforce your knowledge of the course material covered in class?</td>
<td>Reinforce Knowledge</td>
<td>3.69</td>
<td>0.74</td>
</tr>
<tr>
<td>Q14X</td>
<td>The choice of concepts and topics included in FYDA as a whole met your learning expectations.</td>
<td>Learning Expectation</td>
<td>3.80</td>
<td>0.51</td>
</tr>
<tr>
<td>Q15X</td>
<td>How would you rate FYDA’s user interface?</td>
<td>Interface</td>
<td>3.65</td>
<td>0.72</td>
</tr>
<tr>
<td>Q16X</td>
<td>How would you rate FYDA’s graphic depictions (3D and 2D) of the concepts you learned in class?</td>
<td>Graphics</td>
<td>4.02</td>
<td>0.52</td>
</tr>
<tr>
<td>Q17X</td>
<td>What level of interactivity would you attribute to the content of FYDA as a whole?</td>
<td>Interactivity</td>
<td>3.66</td>
<td>0.58</td>
</tr>
</tbody>
</table>

These findings partially respond to the study’s research questions and represent the first level of data analysis that provide information on the self-reported benefits the students derived from their use of FYDA. In order to further substantiate the analysis conducted and, in addition, reveal the relationships between students’ technological competencies and their use of FYDA, a series of non-parametric correlation tests were conducted among the variables within each questionnaire, as well as among selected variables between questionnaires.
Thus, a bivariate analysis using Spearman’s test for non-parametric correlation yielded statistically significant medium to strong effect sizes among several variables in the FYST questionnaire, in accordance with Cohen’s (1992) determination of effect size values. As shown in Table 4, some of the more notable statistically significant correlations are those among the students’ declared purposes of computer use and their expectations regarding the use of online materials, multimedia and simulations to improve academic productivity. Thus, it can be observed that the use of computers for educational and information retrieval purposes (Q7E and Q8E, respectively) are strongly correlated with the students’ expectation that multimedia elements (Q32E) and simulations (Q33E) would contribute to an improvement in their academic productivity.

Table 4: Correlations for selected FYST items

<table>
<thead>
<tr>
<th>Items</th>
<th>Q7E</th>
<th>Q8E</th>
<th>Q9E</th>
<th>Q10E</th>
<th>Q31E</th>
<th>Q32E</th>
<th>Q33E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q7E Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q8E Information</td>
<td>.665**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q9E Communication</td>
<td>.392</td>
<td>.368</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q10E Gaming</td>
<td>.192</td>
<td>.200</td>
<td>.054</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q31E Online Materials</td>
<td>.152</td>
<td>.000</td>
<td>.039</td>
<td>.184</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q32E Multimedia</td>
<td>.447**</td>
<td>.319**</td>
<td>.163</td>
<td>.278**</td>
<td>.475**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q33E Simulations</td>
<td>.432**</td>
<td>.349**</td>
<td>.134</td>
<td>.191</td>
<td>.453*</td>
<td>.826**</td>
<td></td>
</tr>
</tbody>
</table>

Correlations between items on the FYST and FYDA questionnaire items were also conducted in order to ascertain the way in which connections between students’ various self-reported competencies in using computer technology and their rating of FYDA’s multiple features assisted students in consolidating their knowledge of dental anatomy. These aspects are directly addressing the study’s research questions, and further discussion and interpretation is offered in section 6.

Consequently, correlations between, on the one hand, a number of items on the FYST questionnaire dealing with student confidence levels regarding the use of computers (Q12E), laptops (Q13E), the Internet (Q16E), browsers (Q17E) and computer-based simulations (Q21E), and, on the other hand, items related to students’ use of FYDA, resulted in low effect sizes (see Table 5). Thus, it appears that the high confidence ratings students reported in using the aforementioned computer technologies were of little or no consequence on students’ perceptions as to whether: a) the 3D models were useful in their learning about dental anatomy; b) the 3D models assisted them in learning for course assignments and exams; c) the overall FYDA application reinforced their understanding of course material.

However, individual pairs of correlations between students’ expectations of interactive simulations to improve their academic productivity (Q33E) and several items on the FYDA questionnaire were of particular interest (Table 5). Thus, low to medium, statistically significant effect sizes were observed between Q33E and the students’ reported impression that the 3D models in FYDA were helpful in learning about teeth (Q7X), that the models contributed to their understanding of internal and external dental anatomy (Q8X) and that the models helped them attain their learning objectives (Q9X), respectively. A further statistically significant positive correlation was recorded between Q33E and the students’ medium rating of FYDA as a helpful tool in the preparation of course assignments (Q10X). In addition, positive correlations were observed between Q33E and items related to FYDA as a useful tool in the students’ preparation for exams (Q11X) and in the reinforcement of their course material knowledge (Q13X), but only the latter was statistically significant.
Table 5: Correlations between self-reported FYST computer competencies and student perceptions of FYDA learning benefits

<table>
<thead>
<tr>
<th>Items</th>
<th>Q7X</th>
<th>Q8X</th>
<th>Q9X</th>
<th>Q10X</th>
<th>Q11X</th>
<th>Q13X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q7E Education</td>
<td>.140</td>
<td>.250</td>
<td>.114</td>
<td>.221</td>
<td>.093</td>
<td>.161</td>
</tr>
<tr>
<td>Q12E Computer</td>
<td>-.032</td>
<td>.047</td>
<td>-.061</td>
<td>-.096</td>
<td>.005</td>
<td>-.016</td>
</tr>
<tr>
<td>Q13E Laptop</td>
<td>.024</td>
<td>.145</td>
<td>-.002</td>
<td>-.018</td>
<td>.033</td>
<td>-.023</td>
</tr>
<tr>
<td>Q16E Internet</td>
<td>-.052</td>
<td>.006</td>
<td>-.134</td>
<td>-.079</td>
<td>.072</td>
<td>-.114</td>
</tr>
<tr>
<td>Q17E Browser</td>
<td>-.034</td>
<td>.028</td>
<td>-.077</td>
<td>-.059</td>
<td>.099</td>
<td>-.073</td>
</tr>
<tr>
<td>Q21E Simulations (C)</td>
<td>.140</td>
<td>.218</td>
<td>.106</td>
<td>.219</td>
<td>.099</td>
<td>.137</td>
</tr>
<tr>
<td>Q33E Simulations (I)</td>
<td>.336</td>
<td>.321</td>
<td>.280</td>
<td>.298</td>
<td>.148</td>
<td>.300</td>
</tr>
</tbody>
</table>

*p < .05; **p < .01

In a similar fashion, correlations between the same items related to student confidence levels in using computer technologies and items measuring student perceptions regarding the various FYDA design features, such as helpfulness of annotations (Q5X), helpfulness of transparency settings (Q6X), ease of model manipulation (Q12X), usability of user interface (Q15X), accuracy of graphic depictions (Q16X) and level of interactivity (Q17X), yielded low, but not statistically significant effect sizes (Table 6). These results suggest, again, that the high levels of confidence reported by students in using various relevant computer technologies were not related to their ability to use FYDA’s interactive content.

Table 6: Correlations between self-reported FYST computer competencies and FYDA design features

<table>
<thead>
<tr>
<th>Items</th>
<th>Q5X</th>
<th>Q6X</th>
<th>Q12X</th>
<th>Q15X</th>
<th>Q16X</th>
<th>Q17X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q7E Education</td>
<td>-.020</td>
<td>.295</td>
<td>.256</td>
<td>.150</td>
<td>-.016</td>
<td>.065</td>
</tr>
<tr>
<td>Q12E Computer</td>
<td>-.034</td>
<td>-.042</td>
<td>.097</td>
<td>.004</td>
<td>-.079</td>
<td>.014</td>
</tr>
<tr>
<td>Q13E Laptop</td>
<td>-.026</td>
<td>.011</td>
<td>.145</td>
<td>.104</td>
<td>-.012</td>
<td>.024</td>
</tr>
<tr>
<td>Q16E Internet</td>
<td>-.082</td>
<td>.060</td>
<td>.085</td>
<td>.037</td>
<td>.116</td>
<td>.032</td>
</tr>
<tr>
<td>Q17E Browser</td>
<td>-.060</td>
<td>.022</td>
<td>.089</td>
<td>.005</td>
<td>.089</td>
<td>-.101</td>
</tr>
<tr>
<td>Q21E Simulations (C)</td>
<td>.158</td>
<td>.169</td>
<td>.198</td>
<td>.171</td>
<td>.111</td>
<td>.227</td>
</tr>
</tbody>
</table>

*p < .05; **p < .01

A third set of correlational analysis using Spearman’s test was conducted on FYDA items, specifically between reported mean values related to design and functional features of the application, and values recorded on items measuring perceptions of learning outcomes. As the correlation matrix in Table 7 shows, with very few exceptions, all effect sizes among items were statistically significant and specifically address the first two, inter-related research questions. Thus, statistically significant correlations on the helpfulness of the 3D models’ annotations (Q5X), transparency settings (Q6X) and overall design (Q7X), on the one hand, and reported learning results, on the other hand, yielded medium to very strong effect sizes. The overall helpfulness of the 3D models in learning about teeth (Q7X) was both positively and strongly correlated with the students’ reported ratings on achieving their learning objectives in dental anatomy (Q9X), as well as with their
understanding of the internal and external tooth anatomy (Q8X). Furthermore, Q7X yielded similar strong effect sizes in its correlations with items that measured the students’ impression that FYDA reinforced their understanding of course material (Q13X) and that the range of topics and concepts covered in FYDA had met their learning expectations (Q14X).

Although ranging from medium to high, lower statistically significant effect sizes were reported for items inquiring about FYDA’s 2D and 3D graphic design (Q16X) and FYDA’s interactivity levels (Q17X) when correlated with the abovementioned items measuring students’ reported learning outcomes. It is important to note that correlations between the ease of manipulation of 3D models (Q12X) and the interface’s user friendliness (Q15X), on the one hand, and FYDA’s helpfulness in reinforcing knowledge (Q13X) or contributing in the students’ learning expectations (Q14X), on the other hand, yielded statistically significant medium effect sizes. However, although manipulation and interface items correlated positively with items related to the 3D models’ contribution to the students’ understanding of internal and external anatomy (Q8X), and to achieving student learning objectives in the dental anatomy part of the course (Q9X), the low effect sizes were not statistically significant.

**Table 7: Correlations between design features of FYDA and student learning outcomes**

<table>
<thead>
<tr>
<th>Items</th>
<th>Q8X</th>
<th>Q9X</th>
<th>Q10X</th>
<th>Q11X</th>
<th>Q13X</th>
<th>Q14X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q5X Annotations</td>
<td>.446**</td>
<td>.528**</td>
<td>.383**</td>
<td>.446**</td>
<td>.511**</td>
<td>.412**</td>
</tr>
<tr>
<td>Q6X Transparency</td>
<td>.511**</td>
<td>.398**</td>
<td>.436**</td>
<td>.286**</td>
<td>.322**</td>
<td>.305**</td>
</tr>
<tr>
<td>Q7X Overall Models</td>
<td>.615**</td>
<td>.671**</td>
<td>.581**</td>
<td>.548**</td>
<td>.682**</td>
<td>.555**</td>
</tr>
<tr>
<td>Q12X Manipulation</td>
<td>.282**</td>
<td>.292**</td>
<td>.187**</td>
<td>.276**</td>
<td>.379**</td>
<td>.260**</td>
</tr>
<tr>
<td>Q15X Interface</td>
<td>.270**</td>
<td>.214**</td>
<td>.143**</td>
<td>.253**</td>
<td>.263**</td>
<td>.345**</td>
</tr>
<tr>
<td>Q16X Graphics</td>
<td>.301**</td>
<td>.312**</td>
<td>.271**</td>
<td>.335**</td>
<td>.270**</td>
<td>.426**</td>
</tr>
<tr>
<td>Q17X Interactivity</td>
<td>.351**</td>
<td>.312**</td>
<td>.234**</td>
<td>.397**</td>
<td>.347**</td>
<td>.400**</td>
</tr>
</tbody>
</table>

*p < .05; **p < .01

In order to test whether FYDA’s graphic design accuracy and level of interactivity could be considered predictors of perceived positive learning outcomes, a series of linear regressions was conducted on particular items of interest. Thus, as Table 8 shows, graphic design (Q16X) and interactivity levels (Q17X) are statistically significant predictors for a perceived acquisition of an understanding of internal and external dental anatomy (Q8X) and attainment of dental anatomy learning objectives (Q9X). The rest of the functionality features listed in Table 7 could not be considered predictors for Q8X and Q9X, as the regression tests among these items were not statistically significant.

**Table 8: Linear regressions results for key FYDA features impacting on understanding of external and internal anatomy and on reported learning objectives**

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Q8X (Internal/External Anatomy)</th>
<th>Q9X (Learning Objectives)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
<td>β</td>
<td>SE</td>
</tr>
<tr>
<td>Q16X</td>
<td>.420</td>
<td>.173</td>
</tr>
<tr>
<td>Q17X</td>
<td>.425</td>
<td>.154</td>
</tr>
</tbody>
</table>
Apart from the ratings recorded on the Likert-scale items on the two questionnaires, 29 subjects volunteered open responses, representing a 27.1% response rate given the sample of 107 subjects available for the study. Although very few comments suggested that the 3D models or FYDA in general were not conducive or useful to learning, the majority of the statements revolved around the ease of 3D model manipulation of the models and navigation related to the 3D atlas.

Table 9: Types of open responses on the FYDA questionnaire

<table>
<thead>
<tr>
<th>Concern</th>
<th>Respondent</th>
<th>Response text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navigation</td>
<td>R#3</td>
<td>I enjoyed the 3D models and the effects however I feel it was too cumbersome to navigate through the website and it was too text heavy for something to read on the internet.</td>
</tr>
<tr>
<td>Usability</td>
<td>R#5</td>
<td>The glossary is not user-friendly (to have to highlight one word and read its definition one at a time is inefficient) - it would be better if the 3D atlas were of different teeth (other than the artificial teeth we already have been given. Since we have the models of the artificial teeth which we can hold in our hands the digital version is useless.) - The evolution of teeth is really well done and easy to understand, however the radiographs are difficult to read.</td>
</tr>
<tr>
<td>Manipulation</td>
<td>R#6</td>
<td>The 3-D Atlas was difficult to manipulate. It was hard to get it to the angle you wanted. Furthermore, the images of teeth shown on FYDA of teeth that were depicted in our lecture notes were very difficult to see. And we were not able to zoom in. You also need a variety of pictures and in colour to help us the variations. Many times I would go google the images to understand the concept. In terms of general concepts, it was helpful I guess. The best way to learn in general for this course is through the teeth models that were given to us. This is because you are able to not only visualize, but touch and rotate things to your own needs. FYDA may be used as a supplement if needed.</td>
</tr>
<tr>
<td>Annotations</td>
<td>R#29</td>
<td>The graphics and rendering look really good and high class. It can be hard to rotate the tooth, since it seems the point of the axis of rotation changes (axis of rotation seems to be relative to the screen, not the tooth). Maybe when the mouse goes over a pin, the area that it refers to lights up. This would especially be useful for the pins locating grooves and such, since these are regions and not single points. Very clean though, so definitely shows that lots of work went into it, and that's awesome.</td>
</tr>
<tr>
<td>Purpose</td>
<td>R#55</td>
<td>I didn't use the FYDA system very often. I feel that identification of teeth is not something that can be electronically learned. Every tooth is different. It is rare that the idealized depictions of teeth in the program will ever present to you in real life.</td>
</tr>
</tbody>
</table>

6. Discussion and interpretation

In direct response to the first two research questions, the correlational analysis revealed some strong relationships between elements of FYDA’s design and perceived learning outcomes in relation to the 3D components of the atlas. Consequently, it is interesting to note that while the students considered the overall
models in the 3D Atlas useful in learning about dental anatomy, they seemed to derive fewer learning benefits from particular features of the atlas. It is possible to infer here that, when asked to think about unique details or features of the application, students were slightly more discriminative in assessing those specific elements than in ascertaining the general functionality and content coverage of the atlas as a whole. A logical implication, therefore, is that in the students' view, individual features of the 3D Atlas served specific functions as, for instance, the transparency levels controlled the overlapping graphic layers of the tooth models or the annotations supplied precise textual input about unique aspects of tooth anatomy. In turn, a 3D model in its entirety may be less subjected to distinct deconstructive analysis, since the entire object acts as instructional material with complex functionality and multiple learning purposes. Thus, it may be stated that the 3D models, as a whole, provided the students with a range and array of concepts that satisfied their overall learning expectations.

In response to the third research question, the students appear to have considered FYDA a useful application in their study of dental anatomy concepts. The ratings recorded for several items on the FYDA questionnaire appear to support this finding (see Table 3). Thus, the students particularly rated the 3D models included in the atlas as very helpful in learning about dental anatomy. However, when asked about specific purposes for which they used the 3D models, the students offered higher ratings for the use of the models in conjunction with their preparation for exams, a finding that supports the course implementation protocol described in this article, which allocates students time to explore FYDA ahead of their exams. Slightly lower ratings were offered by the students when asked about the usefulness of the 3D models for course assignments. However, it appears that the students were highly satisfied with FYDA in its entirety, when it came to their perceptions of how the application met their individual learning objectives and in helping them reinforce their understanding of course material.

While the above results may be considered positive outcomes of FYDA’s implementation in the course, some limiting factors that may have prevented a more successful experience on part of the students need to be examined at this point. Thus, in terms of functionality, it appears that students encountered some difficulties in manipulating the 3D models as well as in using the application’s interface. This aspect was evidenced partly through the statistical analysis above (see Table 7), which yielded non-significant low effect sizes on correlations between these particular design features and perceived learning outcomes. Moreover, this apparent deficiency in functionality may also be explained by the finding that students may have expected the 3D objects to have a limited influence on their learning, as suggested in part by the correlations presented in Table 4. An additional explanation may also be derived from the relatively low level of confidence reported by the students in using computer simulations, which presented a statistically significant correlation with the learning outcomes as a consequence of using FYDA’s 3D features and interactive functionality.

Yet another plausible reason for this shortcoming may rest in the learning curve the students may have experienced in order to get familiar with the 3D models and FYDA’s interface, as well as in some of the technical design inconsistencies identified by students while using FYDA and reported in their open responses (see Table 9). While the students reported no substantial objections regarding the scope and utility of the instructional content presented in the application, some fine-tuning of a number of graphic design elements that impact on the delivery of such content would be beneficial. Thus, some of the textual components of the applications could be either reconfigured as shorter modules or excluded where appropriate. Consequently, superfluous or irrelevant information would be eliminated, so that unnecessary textual information would not distract from the visual exploration of the 3D models and other graphic elements.

7. Conclusion

This article presented the development of FYDA, an interactive web-based application in dental anatomy employing Web3D technologies, and the post-implementation evaluation on the students’ perception of learning benefits conducted via survey research. The stages of development were informed by and took into
consideration the principles of design proposed by the multimedia learning theory, combining textual and 3D visual inputs of learning material for multiple avenues to deliver content to first-year dental students. The results of the study indicate that the students considered they generally benefitted from the use of FYDA. The application augmented the kinesthetic learning the students undergo via tactile manipulation of synthetic teeth replica with the high-resolution spatial representation of fine anatomical features and details on the internal and external surfaces of the 3D teeth models.

By and large, the students viewed FYDA as a useful tool in meeting their learning of dental anatomy concepts. However, the analysis of results indicate that the students were hindered to a certain extent in, but not necessarily prevented from, achieving their learning objectives because of what could be thought of as superficial, correctable concerns related to design, interface usability and 3D object manipulation. FYDA exhibited a number of graphic design and functional inconsistencies, which may explain why some students may have felt frustrated in attaining full mastery of the product’s many interactive features. FYDA appears to have provided the students with a rich visual environment, through which they could explore facets of dental anatomy otherwise difficult to visualize in flat or 2D imagery common to print-based atlases or textbooks, despite some minor technical flaws, inaccuracies and inconsistencies.

In congruence with current research on the use of 3D graphics and animations in the health sciences education, FYDA can be seen as instrumental in providing students with interactive three-dimensional spatial configurations of anatomical structures, which may facilitate learning about human anatomy. As immersive visual technologies evolve, reconsiderations of three-dimensional designs may be required, at which time research on new digital approaches to 3D visual representation could build on the work conducted in this and other studies related to interactive Web3D technologies. Based on the research we conducted in this study, we may state that the principles of design, derived from theories of cognitive and constructivist learning, on which FYDA was built, can extend to and enhance the exploration and learning of other highly visual fields of knowledge.

Acknowledgments

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References


Location-Based Augmented Reality for Mobile Learning: Algorithm, System, and Implementation

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Abstract: AR technology can be considered as mainly consisting of two aspects: identification of real-world object and display of computer-generated digital contents related the identified real-world object. The technical challenge of mobile AR is to identify the real-world object that mobile device’s camera aim at. In this paper, we will present a location-based object identification algorithm that has been used to identify learning objects in the 5R adaptive location-based mobile learning setting. We will also provide some background of the algorithm, discuss issues in using the algorithm, and present the algorithm empowered mobile learning system and its implementation.

Keywords: Augmented Reality, Object Identification, Location-Based Adaptive Mobile Learning

1. Introduction

Mobile devices have become ubiquitous in today’s learning. Now with the emergence of new functionality in mobile devices, mobile learning can be conducted in more innovative fashion. From the pedagogical perspective, the advantages of mobile learning could not be fully exploited and demonstrated if the mobile learning is only conducted by using the mobile browser to access learning contents without using the native functions and features of the mobile devices. There are more and more location-based mobile applications from location-based information services to location-based games and then location-based ubiquitous learning [Benford, et al. 2005 and Hwang, 2006]. In recent years, mobile devices with built-in Global Positioning System (GPS) receivers and A-GPS services are becoming increasingly popular. Utilizing a mobile device’s location awareness capability within mobile learning applications has now become a reality [Tan, et al, 2010]. One of the emerging research emphases is to utilize the location-awareness functionality of the mobile devices to further strengthen mobile learning. Previous research [Patten, et al, 2006 and Michie, 1998] have also indicated that the combination of location-awareness and a contextual learning approach can enable learners to better construct meaningful contextualization of concepts.

Furthermore, location-based e-learning provides a personalized learning experience and helps in keeping the learners engaged in the learning activities and enhancing their effectiveness. For example, in terms of ubiquitous learning applications, [Chen, et al, 2007] proposed a personalized context-aware ubiquitous learning system with ability to exploit appropriate context based on learners’ location, leisure learning time, and individual abilities to adapt learning contents towards learners for promoting the learning interests and performance. As early as 1950, situational learning approach for language learning [Homby, 1950] indicated that context is an important factor in the learning process and it can enhance learners’ learning interest and learning effectiveness. These examples suggest that meaningful knowledge is constructed primarily when the learning process integrates with social culture and life-context.

Augmented Reality (AR) has become a popular display and interactive technique in the past few years. It can be defined, as a technique is to display virtual contents superimposed upon real-life objects. On the other hand, the location-based adaptive mobile learning is to provide adaptive learning contents to particular learner according to the learner’s location where the real-life context is used as learning objects. To employ mobile devices to interact with real-life learning object in a context-awareness mobile learning environment, Mobile Augmented Reality (MAR) is introduced. The first generation of MAR using context-awareness was based on laptops and mainly used location information as a context [Höllerer, et al, 1999 and Bauer, et al 2001]. Later on, the convergence of context-awareness and MAR started to shift to lightweight platforms such as smartphones.
as PDAs, Ultra Mobile Personal Computers (UMPCs) and mobile phones [Henrysson and Ollila, 2004]. Then most of the researches were focused on using a domain knowledge and behavior model to improve interactions in MAR.

Ubiquitous learning offered through the Mobile Augmented Reality Systems (MARS) requires well-engineered system/software architecture in order to deliver on-demand instructional services. Target applications generated from the architecture require instructional capabilities for understanding individual learning strengths while tailoring empirically evaluated pedagogical techniques to enhance learning performance. In order to significantly impact learning, a MARS e-learning tool needs to consistently measure learning progress and continuously update information about the learner for the duration of the learning interaction. Hence, a MARS e-learning tool may continually process learning data associated to a given context for a given learner.

In this research, Augmented Reality is considered as an emerging content display technique that can improve and enhance learning content presentation as well as interaction between learners and learning contents associated with location-based real-life learning objects (RLO). To apply AR technique for the learning, the major technical challenge is to identify real-life objects (the realities). In order to tackle the technical issue, this paper presents a Location-Based Object Identification Algorithm that we proposed and have implemented in a mobile learning application. The algorithm aims to identify the real-life learning objects by matching the tagged location information of the RLOs with the current location and orientation of the mobile device. Furthermore, the algorithm also provides the guidance capability to navigate learner to the right RLO among the nearby RLOs for learning. A real-life learning object is a real-life object used as a location-based learning object in the location-based mobile learning setting.

A location-based adaptive mobile learning application, called Multi-Object Identification Augmented Reality (MOIAR) has been developed to apply AR technique into mobile learning application. It is empowered by the Location-Based Object Identification Algorithm to identify the real-life learning objects in the mobile learning setting. The implementation of the mobile learning application has proven the usability and the practicality of the Location-Based Object Identification Algorithm. To improve the learning content adaptability, the MOIAR also utilizes the 5R adaptive mechanism, which not only provides adaptive learning contents but also assists real-life learning object identification (Chang & Tan & Fang, 2010). The 5R adaptation concept for location-based mobile learning is stated as: at the right time, in the right location, through the right device, providing the right contents to the right learner (Tan, et al, 2011).

In this paper, we will review the related work following by this section. Then in section 3 we will present the Location-based Object Identification Algorithm in detail. In section 4, we will give a location-based mobile learning scenario study where the MOIAR application is used at the Legislative Assembly of Alberta as a real-life learning object to show usability and effectiveness of the algorithm. Finally this paper will be concluded with discussion of future works.

2. Related Work

In Augmented Reality, markers are often used in the environment due to their low setting up cost and robustness (Rohs, 2004). However, it is an invasive solution since objects have to be tagged with these codes. On the other hand, emerging tracking systems offer various ways to identify objects in the real world. They range from the well-known Global Positioning System (GPS) to GSM, GPRS and UMTS systems, which enable identification and location of mobile phones within an area of influence (Kalkbrenner & Koppe, 2002). Radio frequency identification systems (RFID) enable non-contact reading of transponders equipped with a worldwide unique identification number (Ferscha, 2002). The emerging wireless sensors network (WSN) systems enable the tracking of mobile devices that are connected to the network through a wireless network card (Ferscha & Beer & Narzt, 2001).

There are many positioning approaches (GPS, WLAN, GSM, transponders, indoor positioning systems, etc.) and orientation identification methods (digital compass, accelerometer, gyros, etc.). They provide all types of tracking information and support different location identification systems. For instance, an active sensing system is able to determine its current position and/or orientation by itself. Built-in A-GPS receiver and digital compass on a mobile phone enable the mobile phone to be able to detect its current position and direction.
Augmented Reality (AR) has the ability to combine digital media/information and augment the physical world. This ability to fuse digital media within the physical world gives way to the potential for AR learning which creates the ideal conditions for locative, contextual and situation-based learning scenarios. Prior research has concluded that the incorporation of various sensors provides new ways in which we are able to interact with the world around us [Nokia Research Centre, 2009]. Furthermore, the tools (software) and technologies (hardware) are more evenly distributed and are at our disposal to deploy mixed reality learning scenarios that deliver rich and immersive AR content which could potentially re-shape how individuals and groups approach learning and education.

Majority of the prior research about applying AR into education has indicated that the intuitive interaction of AR has greatly improved learning efficiency, motivation, and overall performance. For example, [Chen, et al, 2010] proposed a novel game-based English learning system with context-aware interactive learning mechanism which can appropriately provide a corresponding game-based English learning scene to the learner’s handheld device based on the learner’s location context. The proposed system aims to construct a mixed reality game-learning environment that integrates virtual objects with real scenes in a university library. The preliminary experimental results reveal that the proposed learning mode provides likely benefits in terms of promoting learners’ learning interests, increasing learners’ willing to learning English. A research [Liu, et al, 2007] constructed a learning system called HELLO (Handheld English Language Learning Organization). It consisted with 2D barcode and handheld AR that has 3D animated virtual learning partner (VLP) over the real world. The student can complete the context-aware learning process by talking to the VLP and to learn in the designed game-based pedagogic scenario to improve students’ English level. Another research [Juan & Beatrice & Cano, 2008] presented an AR system for children of the Summer School of the Technical University of Valencia for learning about the interior of the human body. In addition, they presented two AR interactive storytelling systems that use tangible cubes for the same students as mentioned above to learn with the 8 different ends of the Lion King story [Juan & Canu & Gimenez, 2008]. [Wagner and Barakonyi, 2003] proposed a piece of educational software that uses collaborative AR on fully autonomous PDAs running the application which is laid out as a two player AR computer game, together with an optical marker-based tracking module to teach learners the meaning of kanji symbols. [Kaufmann, 2003] developed a collaborative AR application, called Construct3D, specifically designed for mathematics and geometry education. Construct3D is based on the mobile collaborative AR system “Studierstube” within the greater context of immersive virtual learning environments.

3. Location-Based Object Identification Algorithm

3.1 The MOIAR Overview

AR provides an excellent learning interface in a mobile learning application. The learner’s view is augmented with digital information at the correct geographic location, thus providing an intuitive way of presenting such information (Reitmayr & Schmalstieg, 2003). In this paper, the MOIAR application focuses on identifying location-based outdoor real-life learning objects. The MOIAR aims to not only provide the learning contents but also allow learners to interact with the Real-life Learning Objects (RLO) in the simplest and most intuitive way. The MOIAR can also provide learning contents that are adapted and personalized to learners through AR display. In the MOIAR, a mobile AR client application running on a mobile device that is equipped with a built-in A-GPS and a digital compass is used as the tracking device and the learning terminal. The mobile device can continuously track a learner’s movement without the need for external references. Sometimes it may be assisted with secondary sensors such as motion sensors (accelerometers) and rotation sensors (gyroscopes). Further, with the implementation of AR and mobile device’s location awareness and mobility, the MOIAR has the potential to eliminate some of the learning limitations and disadvantages that exist in the traditional learning. Figure 1 shows the MOIAR application system architecture diagram.

3.2 Location-Based Object Identification Algorithm

In the MOIAR application, AR is used to display digital learning contents related to the real-life learning objects by superimposing upon the video stream of real-life object on the mobile device’s screen. This means that the learner carrying the mobile device has to be at a location that is nearby the real-life object, and the learner has to face the mobile device’s camera lens towards the real-life object, so that the contents can be seen superimposed upon the real-life learning object on the screen. To display the right learning contents on the
real-life object, the MOIAR has to be able to identify the real-life object i.e. to find which the location-based learning object stored in the database of the mobile learning application match with the real-life object; then the 5R adaptive mechanism will generate right learning contents superimposing on the object.

![Figure 1: The MOIAR system architecture diagram](image)

The idea behind the location-based object identification algorithm for mobile Augmented Reality is based on location-awareness of mobile devices and known geographic coordinates of location-based learning objects in the location-based mobile learning environment. The MOIAR mobile application first obtains the current geographic coordinates of the mobile device acquired by the built-in A-GPS sensor. The MOIAR then uses the geographic orientation information to obtain the absolute orientation, which is detected by the built-in digital compass. On the other hand, each location-based learning object predefined and stored in the database has been tagged with its geographic coordinates. When the learner with the mobile device approaching into a pre-configured distance toward a real-life learning object, the MOIAR application will find the object then calculates the relative distance and orientation between the mobile device and the real-life object, which is accomplished by the location-based object identification algorithm.

In fact, in the outdoor learning environment, the locations of real-life objects used as location-based learning objects are known and fixed. When the learner carrying a mobile device is standing nearby a real-life object, it is easy and would make sense for the learner to change his/her current orientation to face the camera lens to the real-life object. Particularly when the object is located in an open space, which means there are no other objects close by or right next to it, the learner can walk around the object as long as he/she is close enough or nearby the object’s location, and has mobile device facing the object. Hence, the mobile device’s orientation related to the real-life learning object becomes very important.

The location-based object identification algorithm utilizes the concept of the Relative Orientation that will be discussed later in this section. This algorithm also uses two-dimension geographic coordinate information, namely latitude and longitude, to calculate the distance between the learner and the real-life objects. The mobile device’s digital compass can get the angle between the mobile camera face and the true north, and then the algorithm can calculate out the angle between mobile camera face and the real-life object. Both of the angles are then used to decide whether the identification tags and the 5R adaptive learning contents should be displayed on the screen or not.

### 3.2.1 Distance Between Mobile Device and Real-life Learning Object

In the MOIAR mobile learning environment, there could be multiple real-life learning objects related to the learner at a particular location. In order to effectively utilize the limited screen space on the mobile device, as well as to provide the 5R adaptive learning contents, only a certain number of real-life object identification tags and contents should be displayed at the place and time. In the MOIAR application, only objects that match the learner’s personal learning profile and status are included into the AR data model as Objects of Interest, and the
real-life object identification tags of only those objects may be displayed on the screen at the right location. In fact, in the MOIAR learning environment, learner could be nearby and see several real-life learning objects in different views at one location. However, the learning contents are displayed on the screen only for the real-life learning object that the learner’s mobile device’s camera lens is pointed to within the pre-configured distance range.

Hence, the relative object identification algorithm is designed to compute the orientation subtended from the learner’s current location to each real-life learning object at the location. The MOIAR utilizes two coordinate systems to implement the algorithm. The first coordinate system is the original geographic coordinate systems, known as the Polar coordinate system, which utilizes the latitude, longitude, and the North Pole based orientation. Based on the Polar coordinate system, each real-life learning object’s location is indicated as \((\phi_o, \lambda_o)\) as a known parameter, which is predefined and stored in the RLO data model. The learner’s current location is indicated as \((\phi_m, \lambda_m)\) as a sensor parameter. The subscript “o” and “m” represent respectively real-life learning object and the mobile device (i.e. refers to the learner’s current location). Firstly the algorithm is to compute the distance, \(D\) from the learner’s current location to each real-life learning object. The calculation is based on the Spherical Law of Cosines is shown in formula (1):

\[
D = R \times \arccos \left[ \sin \phi_m \sin \phi_o + \cos \phi_m \cos \phi_o \cos (\lambda_o - \lambda_m) \right] \tag{1}
\]

The \(\phi_o\) and \(\phi_m\) indicate their latitudes of the learner and the real-life learning object, the \(\lambda_o\) and \(\lambda_m\) indicate their longitudes, and the \(R\) is the radius of the earth in meter. In the formula, \(R=6.371 \times 10^6\) meters. The geographic coordinates of the learner are acquired from the GPS receiver of the mobile device, and real-life learning object’s geographic coordinates are stored in the database of the MOIAR application system. The latitude and longitude coordinates have to be converted into Radian if their unit of measure is in degree.

Based on the difference of the distances from the real-life learning object to the learner, the real-life objects are filtered out if they are not within a pre-configured distance range from the learner’s current location.

### 3.2.2 Orientation Between Mobile Device and Real-life Learning Object

The orientation of the mobile device defines the angle between the mobile device camera lens and the real-life learning object, which is one of calculation criteria for the content display. For example, the learner might be standing on the different side of the real-life learning object, which would require the learner to turn the camera lens to a different direction in order to get the right content to be displayed on the screen properly. As mentioned above, the mobile device’s current Azimuth, each real-life leaning object’s Azimuth, and the angle subtended between the two Azimuths, are the critical elements to accomplish this algorithm. The mobile device’s current Azimuth is indicated as \(\Theta_m\), which is also a sensor parameter and is measured in Radian, discussed in the later paragraph. Another coordinate system is the MOIAR coordinate system that based on the Cartesian coordinates, which computes the Azimuth of the each real-life learning object that is subtended to the learner’s current location and the North Pole. In the MOIAR coordinate system, the learner’s current location is indicated as the coordinate origin.

The MOIAR coordinate system contains two key variables, \(\phi\) and \(\lambda\). They respectively indicate the computed west to east axis and north to south axis variables that are subtended from the learner’s current location to each real-life learning object at the location. The formula (2) for calculating the \([\Delta \phi, \Delta \lambda]\) is shown as follows:

\[
\Delta \phi = \phi_o - \phi_m \tag{2.1}
\]

\[
\Delta \lambda = \lambda_o - \lambda_m \tag{2.2}
\]

After \([\Delta \phi, \Delta \lambda]\) is computed, which indicates the new coordinate variable between the real-life learning object and the learner’s current location, the Polar coordinate system is then conceptually converted into the MOIAR coordinate system, which utilizes the learner’s current location as the coordinate origin. As mentioned above, in order to identify the right real-life object and display the right content when the learner is facing the mobile device on the right orientation to each real-life learning object, and to further guide the learner regarding which direction to face the camera lens, the Azimuth of the learner’s current orientation and the Azimuth of each real-life learning object is computed. The concept of the Azimuth in the MOIAR coordinate system is shown in figure 2 and the computing formula to further calculate the Azimuth \(\Theta_c\) is presented as follows:
In the MOIAR coordinate system, the angle between the line from the coordinate origin to the North Pole and the line from the coordinate origin to \( \mathbf{e} \) refers to the Azimuth of real-life learning object represented as \( \theta_c \). In order to compute \( \theta_c \), the angle \( \theta \) between the learner, the real-life learning object, and the \( \Delta \phi \) axis have to be computed first by using the Tangent Trigonometric Functions. Further, according to \( [\Delta \phi, \Delta \lambda] \) that locates the quadrant in the MOIAR coordinate system, the complete Azimuth \( \theta_c \) will be found. When \( \Delta \phi \) is positive and \( \Delta \lambda \) is positive, it means the real-life learning object is located in the first quadrant and \( \theta_c \) will be \( 90^\circ + \theta \). When \( \Delta \phi \) is positive and \( \Delta \lambda \) is negative, it means the real-life learning object is located in the fourth quadrant and \( \theta_c \) will be \( 90^\circ - \theta \). When \( \Delta \phi \) is negative and \( \Delta \lambda \) is negative, it means the real-life learning object is located in the third quadrant and \( \theta_c \) will be \( 270^\circ - \theta \). When \( \Delta \phi \) is negative and \( \Delta \lambda \) is positive, it means the real-life learning object is located in the second quadrant and \( \theta_c \) will be \( 270^\circ + \theta \). Table 1 displays different cases when Azimuth \( \theta_c \) is located in each quadrant.

The Object Identification algorithm proposed and implemented in this paper is for the MOIAR application to effectively identify the real-life learning objects based on the calculated Azimuth and the subtended angle, whatever the learners’ current location and orientation are, and whenever learners change them. Unlike prior AR learning applications that require learners to stand within a certain distance from the object or focus the camera lens in front of the optical marker, the MOIAR application lets the learners walk around the real-life learning object and still see the identification tags and the adaptive learning contents, as long as the camera lens is facing the real-life learning objects. Further, the MOIAR can also guide the learner to other real-life learning objects located with the object identification tags. Also, the 5R adaptive mechanism tailored the learning contents according to the learner’s learning status and the mobile device’s current location status. Comparing the MOIAR approach developed in this research with prior mobile AR learning research applications, most of the prior applications can only provide learning contents based on the textbook or tailored to the object itself. The MOIAR system can not only identify the objects of interest but also provides the contents of interest. The 5R adaptive mechanism helps the learners in constructing more meaningful knowledge because the learning process and learning contents are integrated with societal culture, life-context, and personal learning preferences.
Table 1. Azimuths in different quadrants of the algorithm

<table>
<thead>
<tr>
<th>Mobile Device Coordinate</th>
<th>RLO Coordinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

North West: Second Quadrant

\[ \theta_c = 270^\circ + \theta \]

North East: First Quadrant

\[ \theta_c = 90^\circ - \theta \]

South West: Third Quadrant

\[ \theta_c = 270^\circ - \theta \]

South East: Fourth Quadrant

\[ \theta_c = 90^\circ + \theta \]

Once Azimuth \( \theta_c \) is computed, the last step is to compute the subtended angle. The subtended angle is computed according to the difference between Azimuth of the learner’s current orientation, which is sensed by the built-in digital compass on the mobile device, and the Azimuth of each real-life learning object \( \theta_c \). Further, the object identification algorithm can determine whether the object identification tags and the 5R adaptive contents of the object should be displayed on the screen or not, according to the formula (4) below:

\[ \theta_d = |\theta_m - \theta_c| \leq R \text{ (ex: } R = 5^\circ) \]  \( (4) \)

In the formula (4), \( \theta_d \) refers to the angle difference between the Azimuth of the learner’s current location and each real-life learning object. Variable \( R \) refers to the Rule in the algorithm that is used to determine the error band for displaying the object identification tags and the 5R adaptive contents. The reason to compute \( \theta_d \) as an absolute value is that the MOIAR system should display the object identification tags and the 5R adaptive contents no matter whether the real-life learning object is on the left side or right side of the learner. For example, if \( \theta_m \) is 45° and \( \theta_c \) is 50°, the original \( \theta_d \) is +5°, which means the object is slightly left to the learner. On the other hand, when \( \theta_m \) is 45° and \( \theta_c \) is 50°, the original \( \theta_d \) is -5°, which means the object is slightly on the right side of the learner. If we set the rule as 5°, after computing \( \theta_d \) with an absolute value, the object identification tags and the 5R adaptive contents would be displayed in both cases.

4. The MOIAR Implementation

This section describes how the MOIAR works in the research environment created for the purpose of demonstration through a scenario study. There are three students in this scenario. Will is currently enrolled in the English program, and he is taking course 604 “Traveling English” and he is on unit one with knowledge level one. Jimmy is currently enrolled in the Politic program, and he is taking course 704 “Politic Science” and he is
on unit one with knowledge level one. Alex is currently enrolled in the Architecture program, and he is taking course 804 “Introduction to Architecture” and he is on unit one with knowledge level one. The real-life learning object is the Alberta Legislature building.

4.1 Learner Authentication Interface
The learner authentication interface contains two parts of information, the personal learning profile and status and the learner’s current location. The screen shots are shown in figure 3. The MOIAR mobile client application shows to the learners the courses and units that they are currently learning with the MOIAR application, the knowledge level of the learning contents that they will be getting, and their mobile device’s current GPS location information.

<table>
<thead>
<tr>
<th>Hello! Will</th>
<th>Hello! Jimmy</th>
<th>Hello! Alex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program: English</td>
<td>Program: Politic</td>
<td>Program: Architecture</td>
</tr>
<tr>
<td>Course: 604</td>
<td>Course: 704</td>
<td>Course: 804</td>
</tr>
<tr>
<td>Unit: 1</td>
<td>Unit: 1</td>
<td>Unit: 1</td>
</tr>
<tr>
<td>Level: 1</td>
<td>Level: 1</td>
<td>Level: 1</td>
</tr>
<tr>
<td>Latitude: 53.538984°</td>
<td>Latitude: 53.539305°</td>
<td>Latitude: 53.539333°</td>
</tr>
<tr>
<td>Longitude: -113.507411°</td>
<td>Longitude: -113.507579°</td>
<td>Longitude: -113.507539°</td>
</tr>
</tbody>
</table>

Figure 3. Personal learning profile and status

4.2 Location-based Reality Learning Object Identification
When the learner clicks the MOIAR button, the application will launch the object identification process powered by the Location-based Object Identification Algorithm to start identifying the real-life learning object around the learner’s current location and display identification tags of the location-based learning objects as shown in figure 4.

The screenshot (4 - A) shows that the MOIAR application successfully identified one of the real-life learning objects, the Alberta Legislature Building, with the object’s name and the distance displayed upon the screen. The screenshots (4 - B) and (4 - C) display different identification tags at the same location according to their orientations and motions. In screenshot (4 - B), the learner was standing in front of a house that is located at the address 2422 111B Street, where the house was 0.02 km away from the learner. When the learner faced to the house right next to it, the tag shows the neighbor house’s address, the distance from the learner is now shown as 0.03 km (screenshot 4 - C). The houses are predefined and stored as a real-life learning object in the database. Further, when there are more than one object in the camera view, the MOIAR mobile application will change the size of the object identification tags according to the distance; the closer the object is to the learner, the bigger the tag will be.
4.3 The 5R Adaptive Learning Contents

The object identification tags are touchable buttons, and the learner has just to click the tags to get the detailed learning contents. The MOIAR application can identify multiple learning objects at the same time, but the screen space on the mobile device is limited. So it is better to display only the object identification tags at first because the learners do not need to see the contents until they are right in front of a real-life learning object and are ready to learn. Figure 5 shows different location-based learning contents superimposed on the real-life learning object, the Alberta Legislature building adapted to their personal learning profiles and statuses of three learners. There are three parts of contents in the content view. The first part on the top shows the name of the learning object; the second part below shows the learner’s current personal learning status, and the third part shows learning contents. As shown in figure 5, screenshot (5 - A) is tourist information of the Alberta Legislature Building for the course “Travelling English”. Screenshot (5 - B) shows the political history of the building for the course “Political Science”. The last screenshot (5 - C) gives the design and architectural of the building for the course “Introduction to Architecture”
5. Conclusion and Future Work

The Location-based Object Identification algorithm presented and implemented in this paper is for the MOIAR mobile learning application to effectively identify the real-life learning objects based on the learners’ current location and orientation and real-life learning object’s location information. The MOIAR application allows the learners walk around the real-life learning object and still see the identification tags and the adaptive learning contents, as long as the camera lens is facing the real-life learning objects. Further, the MOIAR can also guide the learner to from one real-life learning object to others marked by object identification tags. The 5R adaptive mechanism can tailor the learning contents according to the learner’s learning profile and status and the mobile device’s current location. The MOIAR application can not only identify the objects of interest but also provide the contents of interest. The 5R adaptive mechanism helps the learners in constructing more meaningful knowledge because the learning process and learning contents are integrated with societal culture, life-context, and personal learning preferences. The focuses of this research are on the algorithm development and its implementation to support using AR technique in location-based mobile learning setting. Further research should be on how the AR technique enhances the mobile learning application and how the MOIAR has impacted on the learners in the mobile learning setting.

References


