Towards a Responsive Pedagogy: Using ICT as a Tool to Engage Access Students' Academic Identities in Mathematics

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Abstract

Access students in a Foundation Programme at the University of KwaZulu-Natal were exposed to a range of Information and Communication Technology (ICT) interventions in their Foundation Mathematics module. ICT interventions consisted of PowerPoint presentations; Venn Diagram software; an Excel spreadsheet programmed to scaffold the learning of the Gauss Reduction algorithm; and the use of email to send solutions, extra learning materials and messages of encouragement to students. Working within the interpretive paradigm, thirteen semi-structured interviews were carried out with participants from the 2008 cohort of Foundation Programme students. A purposive sampling strategy was used to select participants into the study after calling for volunteers. The data generated from the interviews was analysed using thematic content analysis. This article draws on Bandura's concept of self-efficacy to discuss how ICT engaged participants in learning mathematics. I will argue that ICT improved participants' self-efficacy, thereby helping them to see new learning trajectories for themselves. In effect, ICT boosted participants' self-efficacy, giving students new actual and designated identities (Sfard & Prusak 2005). This article concludes with recommendations for curriculum designers within higher education.

Keywords: Access, ICT, identity, self-efficacy, academic behaviour, pedagogy, mathematics

Introduction

A student's first year at university is of critical importance to all stakeholders within a country. The shortage of skills in areas such as health sciences, engineering and education can only impede the goals of a developing country like South Africa (Mkhize & Nduna 2010). It thus becomes imperative to find ways of maximising student's learning experiences within our lecture rooms so as to ensure that students achieve their academic goals. Given South Africa's apartheid past, this becomes even more important when catering for the learning needs of Science Access students at the University of KwaZulu-Natal (UKZN). Science Access students are from historically disadvantaged learning communities, the majority of whom have been under prepared for tertiary study by the schooling system and are thus academically vulnerable to the demands of tertiary study (Maree, Fletcher & Sommerville 2011).

This article is based on a larger study by Aungamuthu (2009) of Science Access students' perceptions of learning mathematics with the aid of Information and Communication Technology (ICT). I draw on data from that study to argue that ICT engaged students' academic identities in mathematics. In using the term ICT, I draw on Czerniewicz, Ravjee, and Mlitwa (2006: 13) conceptualisation of ICT as '... a term that can be defined as the amalgam of computing and telecommunications technologies [which] includes equipment, such as computers, the Internet, CDROMS and other software as well as digital cameras that can be used as part of the teaching and learning process'. The above conceptualisation of ICT embodies the range of ICT interventions used within this study and is described in the methodology section of this article.

Why is this article important? Amidst calls on higher education institutions in South Africa to provide students with epistemological access to knowledge (McKenna 2004; Morrow 2007) and the dismal throughput rates of South African universities (Scott, Yeld & Hendry 2007); this article contributes to the knowledge base on first year teaching within South African higher education. This article demonstrates the viability of ICT as a learning tool for first year students within an Access programme thereby highlighting the potential use of ICT as part of a responsive pedagogy.

Literature Review

Access programmes were initiated to address the historical education imbalances in the South African schooling system. The aim of access programmes is to develop students, from previously disadvantaged schools, academically so that they will be able to cope with the academic rigors of university. For a description of the Science Access programme at UKZN see Downs (2010) and for a description of Access programmes in South Africa see Bass (2007), Reynolds (2008) and Rollnick (2010).

Researchers in education have acknowledged that the majority of students entering higher education in South Africa lack necessary mathematical skills (Maree *et al*. 2011; Mkhize & Nduna 2010). It was within this context that I found it necessary to explore the potential of ICT as a learning tool in mathematics. Thus this literature review examined the learning affordances associated with ICT, which are as follows:

- For many students, mathematics is a difficult subject to enjoy; ICT can be used to overcome this obstacle by creating learning environments that stimulate interest in and enjoyment of mathematical concepts (Acelajado 2011; Ng 2011). ICT can be used to create active learning environments which enhance the learning experience for students (Apawu 2011; Marshall, Buteau, Jarvis & Lavicza 2012).

- Changes the traditional role of students, from passive learners to active and autonomous learners who are in control of their knowledge construction, while teachers take on the role of a facilitator who responds to students' exploration of a concept (Kay 2012; Safdar, Yousuf, Parveen & Behlol 2011). In their new role as facilitators, as opposed to their traditional role of an expert who merely transmits knowledge, teachers can help students construct knowledge thereby personalising the learning experience for students (Lokar 2011). This has led some researchers to posit that ICT can mediate a teacher's transition from traditional to more learner centred progressive pedagogies (Jethro, Grace & Thomas 2012; Ng 2011).

- Promotes conceptual understanding by allowing for abstract ideas to be explored in a concrete way through the use of the animation, manipulation and visualisation features offered by various ICTs (Demirbilek & Tamer 2010; Kilicman, Hassan & Husain 2010; Liang & Sedig 2010; Marshall *et al.* 2012). However, the depth of conceptual understanding depends not only on the ICT tool itself but on how the ICT tool is used in concert with other learning activities to engage students in reflection on their learning (Berger 2011).

- Motivates student to develop better study habits and to take responsibility for their learning by making learning convenient (Aungamuthu 2011; Kay 2012; Kilicman *et al.* 2010). On the part of students, this can promote greater investment in their studies and so foster more dialogue with teachers about concepts. Such investment in their studies can widen the field of opportunities for students by creating study and career paths in mathematics related disciplines (House 2011; Marshall *et al.* 2012; Wenner, Burn & Baer 2011).

Conceptual Framework

In this section I conceptualise the terms self-efficacy, academic identity, actual and designated identity; I later, in the findings and discussion section, draw on these concepts to explain my findings.

Self-efficacy

Bandura (1994: 71) defines self-efficacy '...as people's belief about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives'. Self-efficacy refers to a person's belief in their ability to successfully complete a task; essentially it is a perception about one's abilities and what one believes can or cannot be accomplished with those abilities. Within the context of this study, self-efficacy as a concept is of particular relevance as Access students are from historically disadvantaged education backgrounds; an education background in which the education system has failed the majority of secondary school learners, especially in gateway subjects like mathematics. In view of their educational background, it is reasonable to assume that the majority of Access students would be entering university with low levels of self-efficacy in mathematics. This study examines whether or not ICT can influence students' self-efficacy beliefs.

Why is self-efficacy important? Bandura (1994) asserts that self-efficacy impacts a range of psychological processes, processes which underpin our thoughts and actions in relation to: the choices we make and the processing of information in various situations; goal setting and the action steps required to achieve the goals set; the management of stress; and the control of our motivation levels. For example, studies have found a correlation between self-efficacy and students' academic performance (Purzer 2011). Students with high levels of self-efficacy tend to be more persistent with a task thereby increasing their chances of successfully completing a task (Fantz, Siller & DeMiranda 2011; Tsai, Chuang, Liang & Tsai 2011).

What influences self-efficacy? A person's experience of success can bolster their self-efficacy whilst failure can negatively influence self-efficacy (Fantz *et al*. 2011). However, easy challenges are necessary but not sufficient in building a robust sense of self-efficacy; a person needs to experience learning from failure and the overcoming of difficult challenges so as to develop persistence in solving problems (Bandura 1994). By learning to persist with solving a problem, a person starts to believe in their abilities which builds develops their sense of self-efficacy.

Another influence on self-efficacy comes from role models; the more a person can identify with a role model the greater the chances of the role model being able to have an influence on the person's self-efficacy beliefs (Bandura 1994). Role models can be peers, teachers, parents, family members or a person who one feels connected to and can relate to. Role models can influence a person's self-efficacy beliefs in three ways (Bandura 1994): firstly, by teaching or exhibiting effective skills and strategies that can be used to successfully complete a task; secondly, by being able to verbally mobilise a person to action so that a person may believe that they are capable of accomplishing a task ; and thirdly, by helping a person to interpret their failures and to see that setbacks are a stepping stone to success thereby managing emotions and stress levels, in effect teaching the person to persist with a task.

Self-efficacy cannot guarantee academic proficiency in a discipline because students first need to acquire the knowledge and skills associated with proficiency in that discipline (Corkett, Hatt & Benevides 2011). Such proficiency requires students to take on the academic practices of a discipline; this makes demands on a student's academic identity since learning influences identity development (Lave & Wenger 1991).

Academic Identity

In this article, academic identity refers to academic practices that lecturers expect students to take on and develop. Academic practices such as time management, study techniques, checking solutions, making conjectures, asking questions, seeking help, doing corrections, willing to engage with new ways of thinking and taking responsibility for one's learning to name but a few. Such practices assume a particular understanding of learning, a particular idea of being a student – a particular way of being within academia (McKenna, 2004). It is this notion of being within academia, of taking on the practices valued by academia, which the term academic identity encompasses.

How do I operationalise students' academic identity? Sfard and Prusak (2005) use a narrative approach to conceptualise identity in terms of actual identity and designated identity; actual and designated identity is couched in the stories people position themselves within. The stories individuals scripts for themselves arise from their life experiences through their interaction with people and various social artefacts (Bull 2009; Chinn 2009; Fayez 2010). Peoples' life experiences generate stories which can form positive associations and a platform to engage in positive learning paths. However, life experiences can also have negative associations which make participation in learning difficult; a person engages in habits that are associated with a negative learning path which in turn leads to failure. By exposure to positive learning experiences, negative associations can be re-scripted to allow a person to engage in positive learning paths.

How is actual and designated identity applied in this study? Actual identity reflects a student's current association with a particular aspect of learning mathematics and is revealed in present tense statements like 'I do not understand addition of fractions', 'I am afraid of using the computer software' and 'I understand the Gauss reduction algorithm' (Sfard & Prusak 2005). Designated identity is revealed in future tense statements like 'I am going to fail the test on fractions', 'The computer software will not help me understand maths' and 'I am going to do some harder problems on the Gauss reduction algorithm'(Sfard & Prusak 2005). Designated identity arises from associations within actual identity and determines the learning path a student may follow; positive associations storied within actual identity can promote positive learning behaviours whereas negative associations storied within actual identity can generate feelings of hopelessness which promote negative learning behaviours.

Methodology

In this article I answer the following research question: Does learning mathematics with the aid of ICT engage students' academic identities?

Working within the interpretive paradigm, a case study research design was used. A case study design was considered appropriate due to the exploratory nature of the larger study.

In their Foundation Mathematics module, students were exposed to the following ICT interventions:

- PowerPoint slideshows that made use of the animation feature within the programme to introduce and explain concepts in Set Theory like sets; intersecting sets; subsets; disjoint sets; union; intersection; compliment of a set; and cardinal number. The slides were not 'text heavy' and relied on graphics to convey a concept. After a concept was introduced on a slide, questions were posed to the students requiring them to give examples of the concept from their life experiences. The examples generated from the students were used to discuss and elaborate on the concept introduced and so give students multiple representations of a concept.

- Venn Diagram software was used to teach students how to apply their understanding of the set operators (union, intersection and complement) to problems requiring the graphical representation of expressions like $A \cap B'$ and $(B \cup C)' \cap A$, where A, B and C represent sets. The software was used during a lesson in class and then students were given an opportunity, in a follow up lesson and a tutorial, to experiment with the software in groups of four for fifteen minutes. The software facilitated scaffolding of the problem by allowing students to see each stage of their solution to a problem. The software also allowed students to see the full and scaffolded solution to a problem. The students were emailed a personal copy of the software to use in the university computer rooms and on personal computers.

- Gauss Tutor, an Excel spreadsheet programmed with the Gauss Reduction Algorithm, was used to aid students' understanding of the Gauss Reduction Algorithm. The spreadsheet required students to input values so as to progress through each stage of the algorithm. Students received feedback and hints from the software as they worked through the algorithm in groups of four for fifteen minutes. The software was introduced to students after the Gauss Reduction algorithm was taught to students in class during four of their forty five minute maths lessons. The software was used to consolidate their learning of the algorithm and, like the PowerPoint slides and Venn diagram software, a copy was emailed to them for their personal use.

- Email was used to send students the solutions to assignments and exercises after they had submitted their work for marking. Email was also used to congratulate students on their test performance and to offer them words of encouragement when they were not doing well in their studies. Extra examples that were regarded by the lecturer as a follow up to classroom discussion examples were emailed to students to further support them in their learning.

Based on the above ICT interventions, data was collected by conducting semi-structured interviews with thirteen participants from the 2008 cohort of Foundation students on the Pietermaritzburg campus of the University of KwaZulu-Natal (UKZN). A purposive sampling strategy was used to select participants for the study. Based on a survey of the research literature, gender, previous ICT experience and frequency of ICT use were used as criteria to select participants into the study. The table below summarises the sample used in this study based on the above three criteria.

Table 1: Sampling matrix with number of participants in each category and participants pseudonyms in brackets

		Male			Female		
		Frequency of use			Frequency of use		
		A[1]	B[2]	C[3]	A[1]	B[2]	C[3]
Previous ICT experience	Not at all	1 (K)	1 (Tok)				1 (G)
	A little	1 (T)	1 (M)	2 (J and Mb)	1(Mo)		
	Very well		1 (SDK)	2 (L and T)	2 (S and N)		

From the above table, nine of the thirteen participants were male and four were female. Five of the thirteen participants classified themselves as having extensive previous ICT experience whereas the majority of the sample had a little or no previous ICT experience. Five participants used ICT at most twice a week, three participants used ICT at most four times a week and five participants used ICT everyday. Participants chose pseudonyms for themselves in an attempt by the researcher to share power with them. The interviews were recorded, with the permission of the participants, and later transcribed. Member checks were used to validate the accuracy of the transcription.

Thematic content analysis of the interview transcripts was conducted by reading across transcripts, reducing sentences to phrases or a word that captured the essence of what was being communicated by a participant and by grouping similar words and phrases into themes. The themes were

[1] Participant uses ICT at most twice a week
[2] Participant uses ICT at most four times a week
[3] Participant uses ICT everyday

validated in three ways. First, throughout the research process a peer was used as a sounding board for interpretation of the data. Secondly, a panel consisting of participants in the study was used to establish cultural validity; the researcher presented his themes to the panel as a way of checking that a participant's experience of ICT had been accurately captured by the themes. This process helped the researcher to refine his understanding of the research problem. Thirdly, themes were compared to literature findings.

Findings and Discussion

In this section I present the themes that emanated from my analysis of the data. The themes below reflect the impact ICT had on participants' academic identities in their study of mathematics. Through the influence of ICT on their self-efficacy, participants' actual and designated identities underwent a transformation. These themes capture that transformation thereby illustrating that ICT engaged participants' academic identities.

Theme 1: Decreased Mathematics Anxiety

This theme describes the effect ICT had on participants' mathematics anxiety. Participants expressed their fear and trepidation of studying mathematics at university. The high level of mathematics anxiety felt by participants is encapsulated in the two comments below:

> *SDK*: ...like errrr first semester I mean we all come here being traumatised, we were failing maths [at school]...I came to university] with a very big mathematic[s] anxiety.

> *Mb*: ... because we know we are afraid to do anything [by ourselves]...

As *SDK* explains, students come to university petrified of mathematics; in effect hating mathematics from day one of lectures. This 'intrinsic' dislike for mathematics caused participants to have high levels of anxiety with regard to mathematics; this is similar to other studies which report on student anxiety and an associated low sense of self-efficacy in studying mathematics (Bull 2009; Chapman 2010; Chinn 2009). These high levels of mathematics anxiety caused participants to construct negative actual identities in mathematics. In other words, participants saw themselves as academically weak in mathematics. These imposed negative actual identities caused participants, as *Mb* points out, to be afraid of trying out mathematically related activities by themselves. In effect, participants' fear of mathematics caused them to feel that their mathematical endeavours were destined to end in failure if attempted without support. The belief that their unassisted mathematical activities would be unsuccessful reflects participants' negative designated identities. Thus, participants' negative actual identities in mathematics reinforced their negative designated identities in mathematics, heightening their mathematics anxiety and constraining their vision of being successful in mathematics.

However, through participants' exposure to, and engagement with, ICT learning tools their self-efficacy began to improve. They felt confident enough to risk challenging an answer:

> *J*: It [using the software] was good because it actually helped us and gave us more surety of our answers because [pause] when you got an answer with you and you want to tell your lecturer that something is wrong with the memorandum case you don't have, you're not sure enough to actually tell them.

Participant *J* explained that using the software to confirm his answer gave him the confidence to challenge an answer given in the memorandum to a mathematics tutorial exercise. Ordinarily he would be afraid to risk such engagement out of fear of being wrong. Thus the software helped him overcome his self-doubts thereby improving his self-efficacy.

With this heightened sense of self-efficacy, participants started to feel that they were capable of learning mathematics:

> *K*: …I didn't feel so bad [about being wrong about a problem because by then I got power.

Yougan: You got power?

K: Yes, I got knowledge.

Participant *K* explained how he and his peers would settle a dispute about a mathematics problem by making use of the software to explain their respective arguments. This helped participant *K* to test and improve his reasoning in mathematics, developing his confidence and belief that he was capable of learning mathematics. This finding is similar to studies that found that ICT promoted students' confidence in mathematics; see for example Bakar, Ayub, Luan, and Tarmizi (2010) and Freeman (2012).

Participants felt empowered, able to envision more successful learning trajectories for themselves:

M: There's that feeling that you know now you can tackle any sum.

Participant *M* explained that using the Venn diagram software helped him to see that he could solve the difficult problems in Set Theory. That realisation gave him a sense of personal power over the problems that were previously causing him confusion and anxiety. Participants were able to overcome content areas in mathematics that they initially perceived as difficult. As a result of being able to overcome their difficulties, participants moved beyond their anxieties surrounding mathematics:

> *T*: ...the Gauss reduction but at the same time it [Gauss reduction] was not coming right. But with the software that helped me. I called it my friend...So I was able to solve the problem. And as time goes on and you get to do this thing it didn't become more difficult to do this thing...

Participants started to believe that mathematics was a subject within their sphere of understanding. In effect, ICT helped reduce participants' anxiety in mathematics allowing them to see that they could learn mathematics. Participants were able to use ICT to meet their learning needs and so script new actual and designated identities for themselves. Participants' original negative actual identities were replaced with positive actual identities; positive actual identities that told them that they no longer needed to be afraid of mathematics. Similarly, participants' designated identities were realigned to their new actual identities; their designated identities told them that they could learn mathematics.

With their increased self-efficacy; their new actual and designated identities participants developed their academic identities thereby allowing them to engage with learning mathematics. This engagement with learning mathematics influenced participants' academic behaviour in mathematics that is discussed in the next theme.

Theme 2: Academic Behaviour of Students

I use this theme to describe the academic behaviours participants engaged in as a consequence of ICT's influence on their self-efficacy and their academic identities. As argued above, ICT inspired participants to move beyond their anxieties about mathematics. Such a shift in mind-set allowed participants to write new actual and designated identities for themselves, creating opportunities for them to take on the academic behaviours expected of them. This theme highlights participants' engagement and understanding of concepts in mathematics and the academic behaviours they took on in the process.

Participants explained that ICT made it convenient for them to check their work for mistakes in the evenings and weekends as it was not always possible to get help on a problem from peers or lecturers at those times. For some participants, instead of assuming that their answers were correct, ICT provided a space for them to check their work and develop their understanding of mathematical concepts:

> *Tok*: And like after I've done a problem I then … I like took a problem which I was doing and put it in the software and to see like if it were properly done or were there mistakes I did...

In a similar vein, for other participants, instead of becoming frustrated and demotivated at not being able to find the error in their solution to an exercise, ICT supported their learning in this regard:

> *N*: ...coz if I didn't get the answer correct I wanted to see where I've gone wrong.

> *G*: ...so I would check [my solutions] and stuff, if the step is wrong I would know that somewhere in my, in my calculation I went wrong. So I would start afresh…

Participants were able to use the ICT software to identify and correct their mathematical misconceptions. In the process of checking their work and finding their mistakes, ICT engaged participants' understanding and exploration of mathematical concepts. Through such engagement, participants improved their understanding of mathematical concepts and so their self-efficacy. This allowed them to script new actual identities and designated identities. This finding resonates with studies which have shown that ICT promoted conceptual development and learning among learners, see for example Saha, Ayub, and Tarmizi (2010), Zengin, Furkhan and Kutluca (2012) and House (2011) .

With their re-scripted actual and designated identities, participants invested in learning practices valued by academia. Participants experimented with their own ideas and understandings of mathematical concepts, thus moving away from passive learning:

> *S*: I felt safe coz I feel that that it was my own method coz there was a greater chance that I will get wrong and most the time I will get it wrong and it [software] right. The more I used it [software] that's where I saw it [software] was really accurate.

> *L*: It [software] makes the problem simpler because you are using your own ideas.

In this way, ICT acted as a sounding board for their mathematical understanding allowing participants to conjecture and hypothesise; helping participants construct meaning of concepts. ICT supported participants meaning making by creating a space for them to self-direct and take charge of their learning. This echoes the findings of studies which report that learners enjoy the autonomy ICT affords them; see for example Acelajado (2011), Kay (2012) and Liang and Sedig (2010) . Consequently, participants used ICT resources in new ways.

Participants invested more of their time in academic endeavours, effectively changing the way they used ICT resources such as the university computer LANs:

> *M*: Ja they, those they made it a lot easier for me to, cos errrr usually when we are at the LAN we go for the internet and then you, errrr I studied, I really studied using the Power Points and …
>
> *SDK*: You don't think, oh I got to study, you know, I'm going to the LAN, I'm going to play with the computer, maybe the computer is going to include some work that we did in class and is very helpful...

As *M* and *SDK* explain above, their visits to the university computer LANs became revision sessions in which they studied mathematics. Previously they would use the LAN to surf popular internet websites and play computer games; now they used the LAN to support their learning of mathematics thereby engaging in new study habits. Participants made use of the LAN to find ICT related mathematics resources; the LAN was no longer a leisure tool, it was now also a learning tool for them. As a result of ICT's influence on participants' academic identities, participants' actual identities were orientated to more academic pursuits in the LAN. ICT had transformed their learning behaviour by changing participants' actual and designated identities, in effect changing their academic behaviour.

Conclusion

This study explored science access students' perceptions of a range of ICT interventions within a Foundation maths module. Venn diagram software, an

Excel spreadsheet, PowerPoint presentations and email were used to teach mathematical concepts to students. This study found that the ICT interventions engaged participants' academic identities by decreasing their maths anxiety and improving their academic behaviour. Participants experienced improvement in their mathematical confidence, were able to self-direct and self-regulate their learning and engaged in new study habits.

However, given the exploratory nature of this study, the findings reported must be viewed with caution. While the small sample size and gender bias within the sample prevents generalisation, at the same time this creates areas of exploration for further research. Empirical research is required to test questions surrounding the use of ICT within higher education contexts. For example, is there a generic pedagogy for all ICT tools or does each ICT tool require a specific pedagogy? What factors contribute to students' use of ICT tools and what pedagogy can facilitate that? How can lecturers integrate ICT into their pedagogy and for what purpose? These are some of the questions that need to be answered if ICT is to be effectively harnessed so as to help lecturers respond to students' diverse learning needs.

Based on this exploratory study, it is recommended that curriculum designers begin to experiment with ICT tools by including some form of ICT within curricula. This can be done in 'baby steps' with reflection on how the ICT tool affected the teaching and learning process for both students and lecturer. Such engagement may allow academics to dialogue their ICT experience and so further develop a pedagogy that is responsive to students.

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