THE USE OF TECHNOLOGY IN ADDRESSING THE MATHEMATICS EDUCATION CRISIS IN SOUTH AFRICA

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The use of technology in mathematics education has produced many positive outcomes, as reported in the literature. However, there is little evidence of technology making a substantial impact on the education crisis in a country such as South Africa. In this proposal, we consider a case study of an innovative project run by the organization Numeric, as seen through the eyes of a tutor for the project. School students worked through selected Khan Academy videos and quizzes aligned to the South African school curriculum. This was done in after-school centres with tutors guiding students through the website and assisting where necessary. We describe how the project will be executed, the theoretical framework underpinning it and relevant literature.

THE FOCUS OF THE PROJECT

This project takes the form of a case study of the use of technology in a South African context, drawing on one of the authors' work as a tutor on an after-school programme where students use the Khan Academy website (khanacademy.org) to supplement their school work. This website has a large collection of short videos (mostly 8 to 15 minutes) on a wide and growing list of topics. The inspiration for the videos was the discovery by the founder, Salman Khan, that the relatives he tutored preferred recorded explanations that they could pause and watch repeatedly. The website has expanded to include mastery quizzes connected to video topics. The organisation Numeric links the Khan Academy videos to the South African curriculum and provides a repository of videos that can be accessed offline.

We are particularly interested in the potential impact this project could have on addressing the mathematics crisis in South Africa. In particular we want to know:

- Does learning through watching videos and taking mastery quizzes improve students' performance in school, in mathematics as well as in other subjects?
- Does knowing how to access the Khan Academy have other benefits for students, e.g. being able to advise friends and relatives on how they can access the website, or being able to explain work to friends and classmates, having more confidence in mathematics classes and in other classes?
- What are the difficulties associated with the use of Khan Academy videos and quizzes?

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MOTIVATION FOR THE PROJECT

Mathematics education in South Africa can be described as being in a crisis (Fleisch 2008). Despite efforts to improve the situation, the majority of South African school students are likely to be taught mathematics by a teacher who does not have the required qualifications (Reddy 2006). The Khan Academy videos might provide a means of delivering a higher quality of education than is currently received by these students. In addition, the game-like design of the mastery quizzes on the Khan Academy website seems to encourage students to practice basic skills.

A large meta-analysis by Means, Toyama, Murphy, Bakia & Jones (2010) found that students performed slightly better with online learning compared to face-to-face learning. As technology is becoming more available, there is a greater need for decision-makers to have access with relevant studies on online learning. This study will add to existing research by considering the potential and pitfalls from the use of the Khan Academy resources, as tailored by Numeric, in South African schools.

THEORETICAL FRAMEWORK

The Khan Academy website is designed around two main features: video explanations on a wide range of topics and mastery quizzes for which 'badges' can be earned. This design suggests an implied position on learning theories and the nature of knowledge. Hung (2001) points out that because of the complexity involved in human cognition, it is acceptable to simultaneously adhere to different learning theories that play larger or smaller roles depending on the objectives and contexts of the learning situation. We shall justify why we see elements of behaviourism and constructivism in the Khan Academy website.

The display of topics in a tree-diagram with links between some topics gives the impression that knowledge exists independently of the student (an objectivist epistemology) and that the student's task is to gain the unknown knowledge. An objectivist view of knowledge is associated with learning theories such as behaviourism, which uses repetition, rewards and punishment to help students retain knowledge. In the Khan Academy quizzes, a series of eight similar questions must be answered in a row before a reward (in the form of a badge) can be earned. If a question is answered incorrectly, the 'punishment' is the withholding of the badge until eight consecutive questions have been answered correctly, which costs the student more time.

Although watching videos does not allow for immediate question and answer interaction for the student, watching a video explanation has some advantage over a live explanation because the viewer is able to repeat parts or pause the explanation. This allows for the experience to be more interactive. Allowing the student to have control of their learning reflects constructivist underpinnings.

Tracking students' progress allows teachers/coaches/tutors to identify students who seem stuck, possibly because the gap between their current knowledge and what they

are attempting to learn is too large. They can then review a suggested topic so that this gap can be reduced to a manageable size. This fits with a constructivist view of learning famously described by Vygotsky (1978).

In Vygotsky's (1978) discussion of the conditions for optimal learning, he describes the gap between what is known and what is still to be learnt (and cannot be done without help) as a "zone of proximal development." Assistance from someone more knowledgeable can help the progress of the learning, and this underlies many models of teaching. The difficulty of a classroom situation is that there is usually great variation in what is known by each individual. Providing assistance for a task far beyond one student's level of what is known results in a breakdown of learning. The advantage of self-paced learning through watching videos is that students can get access to a knowledgeable assistant when they are most able to make use of their advice.

LITERATURE REVIEW

The body of literature on the use of Khan Academy is currently small. This case study aims to fill a gap in the literature about the use of the Khan Academy in a South African setting. In this paper we consider literature that characterizes the Khan Academy, showing positive and negative issues associated with the use of the platform.

How does the Khan Academy work?

Khan academy videos are presented by the founder Salman Khan. They generally run for seven to fourteen minutes, with Salman's voice explaining the concept while his hand-scribbled formulae and diagrams appear on screen. The website also enables users to practice unlimited problems and earn videogame-like badges in return for good performance. Impressive statistics about users' progress through topics are created for every user. If students link their school teacher as their 'coach,' the teacher can use a dashboard application to identify places where the student is struggling and provide individualized, focused help. Teachers are able to 'flip the classroom' (Mazur 2009; Tucker 2012) by assigning video viewing as homework so that class time can be spent on collaborative work and addressing specific difficulties.

Positives issues arising from the use of Khan Academy

Research points to the best instructional approach being one-to-one attention (Bloom 1984) but this is very expensive when done live. Instruction by videos is an effective approximation to this, particularly when students can choose the topics that they must work on. The casual style evident in the Khan Academy videos and the lack of a 'talking head' help to keep the one-to-one feel. Audiences also appreciate that the explanations move from step to step (Thompson 2011).

Where there is access to Khan Academy videos at home, the videos may help to fill a gap that some children may experience due to the lack of parents or care-givers who are able to help with homework. This is particularly relevant in a South African

context where there is political motivation to address the generally poor quality of education for the black population (Chisholm 2012). Another space where access to face-to-face help is limited is prison. Schneider (2012) describes the use of the Khan Academy in this context.

Thompson (2011) reports on some interesting and positive phenomena arising from the use of the Khan Academy. The feature of allowing students to learn at their own pace resulted in a ten-year-old completing over 642 inverse trigonometry problems. A teacher reported that by allowing students to move through the practice exercises at their own pace, the proportion of her class classified as average or lower in end-of-year tests reduced from 13% to 3%.

The drill style of the Khan Academy quizzes suggests an adherence to old-fashioned rote learning, which has negative connotations of conformist ideologies. However, it is widely accepted (e.g., Siegler 2003; Sfard 2003) that in mathematics a certain amount of memorization provides foundational elements from which to develop further learning. The motivation for mastery learning through the quizzes was to build students' basic skills so that they could better understand more advanced topics and provides motivation to students by gaming elements, such as collecting points and reaching levels of achievement. Allowing for the mastery of basics to happen outside the classroom frees up time for active, creative learning during school lessons.

Negative issues arising from the use of Khan Academy

Studies on learning styles (Felder & Brent 2005) show that a single instructional method is unlikely to be optimal for all students. The style of Khan Academy videos does not include the variety that is recommended for reaching audiences with diverse learning styles, as noted by some educationalists (Thompson 2011). Teachers who incorporate the Khan Academy videos into a variety of activities may be able to minimize this limitation.

The use of Khan Academy videos and quizzes requires appropriate computer facilities and internet access. Numeric provide a repository of videos that can be downloaded to a network so that the videos only need to be downloaded once and thereafter can be accessed by computers on the network without using the internet. However, the quizzes can only be completed with internet access. Problems with computer facilities include the need for staff and funding for the maintenance, security and upgrading of facilities. In parts of South Africa, these issues are frustrating obstacles to those who would like to use the Khan Academy website.

METHODOLOGY

The weekly involvement of one of the authors in this project afforded the opportunity to examine the progress of the group over 2- 3 terms as a case study. The limitations of a case study are that they do not provide evidence for large-scale generalizations or policy adoption. Vickers (1965) warns that even a large number of case studies may

not be representative of the population. However, the merits of case studies as an emerging methodology in education was noted by Case & Light (2011) who described case studies as

> particularly appropriate to address research questions concerned with the specific application of initiatives or innovations to improve or enhance learning and teaching.

This study therefore aims to provide a detailed look at the activity of the group in order to understand it better and help us to answer the research questions.

The tutor will have weekly meetings during school terms in 2013 with a group of 20-30 grade 8 students from a variety of schools in a community centre in Khayelitsha, Cape Town. The tutor's role is to make sure that the school students can connect to the Numeric and Khan Academy sites and follow the programme of work outlined for them. He can also help to explain anything the students do not understand, if necessary translating into a different language.

The students' progress in syllabus-related mathematics topics will be monitored on the Khan Academy site. The tutor will keep a record of scores in timed multiplication tests. To determine whether participation in this project improves students' performance in school mathematics as well as in other subjects, we will ask participants to share their school reports for the previous year as well as for the period during which they partake in the project. A comparison of marks in mathematics and some other subjects from 2012 as well as the first half of 2013 for the students in the Khan Academy project will be made with the average performance of students in the schools from which these students come. This will provide a baseline comparison from which we can determine whether the students in the Khan Academy project perform differently from their peers, regardless of their pre-existing performance in mathematics.

Interviews with students and observations by the tutor could help to find out in what other ways the project has benefitted students. An analysis of marks for subjects other than mathematics for students in and out of the Khan Academy project would provide some evidence to support or refute the conjecture that there could be a rub-off effect that improves learning in other subjects too, despite the project focusing only on mathematics. This could be a topic for further research.

Finally, it would also be useful to record the problems that were encountered with running the project (such as poor internet connections, people dropping out of the project or missing sessions and the reasons for this) and how these were dealt with. This would be helpful for others planning to implement similar interventions.

REFERENCES

Bloom, B. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher*, 13(6), 4-16.

Case, J. M. & Light, G. (2011). Emerging methodologies in engineering education research. *Journal of Engineering Education,* 100(1), 186-210.

Chisholm, L. (2012). Apartheid education legacies and new directions in post-apartheid South Africa. *Storia delle Donne*. Available at 91.121.146.53/index.php/sdd/article/view/11892, accessed 17 March 2013.

Felder, R. M. & Brent, R. (2005). Understanding student difficulties. *Journal of Engineering Education*, 94(1), 57-72.

Fleisch, B. (2008). *Primary education in crisis: Why South African schoolchildren underachieve in reading and mathematics*. Cape Town: Juta.

Hung, D. (2001). Theories of learning and computer-mediated instructional technologies. *Educational Media International*, 38(4), 281-287.

Mazur, E. (2009). Farewell, lecture? *Science*, 323 (5910), 50-51.

Means, B., Toyama, Y., Murphy. R., Bakia, M. & Jones, K. (2010). *Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies*. Washington D. C.: U. S. Department of Education

Reddy, V. (2006). *Mathematics and science achievement at South African schools in TIMSS 2003*. Cape Town: Human Science Research Council.

Thompson, C. (2011). How Khan Academy is changing the rules of education. *Wired Magazine*, 15 July 2011. Available at www.wired.com/magazine/2011/07/ff_khan/, accessed 17 March 2013.

Schneider, D. (2012). Khan Academy unplugged [Hands on]. *Spectrum IEEE*, 49(8), 22-23.

Sfard, A. (2003). Balancing the unbalanceable: The NCTM standards in the light of theories of learning mathematics. In J. Kilpatrick, G. Martin & D. Schifter (Eds.), *A research companion for NCTM standards* (pp. 353-392). Reston, VA: National Council for Teachers of Mathematics.

Siegler, R. S. (2003). Thinking and intelligence. In M. Bornstein, L. Davidson, C. L. M. Keyes & K. A. Moore (Eds.), *Well-being: Positive development across the life course* (pp. 311-320). New Jersey: Lawrence Erlbaum Associates.

Tucker, B. (2012). The flipped classroom. *Education Next*, Winter, 82-83.

Vickers, G. (1965). *The art of judgement: A study of policy making*. London: Chapman & Hall.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, Massachusetts: Harvard University Press.