PROJECT MATHS ACADEMY: USING KHAN ACADEMY'S EXERCISE PLATFORM AS AN EDUCATIONAL AID IN A POST-PRIMARY MATHEMATICS CLASSROOM

Stephen Lawless Eabhnat Ní Fhloinn Brien Nolan

CASTeL, School of Mathematical Sciences, Dublin City University

The focus of this paper is a First Year post-primary mathematics class in which Khan Academy's online exercise platform was used weekly for an academic year. Interviews were conducted with the teacher, and students were surveyed about their opinions of the platform and its usage. Regular classroom observations took place to gain an insight into the context of these opinions. A subsequent survey compared these students' attitudes towards mathematics classes with those of their peers who were not using the platform. Test scores were compared between three classes (one using Khan Academy; two not) to ascertain whether the platform had any effect on student performance. The platform was found to be an invaluable tool for class management: the teacher was able to provide the capable students with enough work while attending to students in need of support. Students enjoyed their time spent on the platform and the more capable students were able to work at their own pace and tackle more challenging exercises. Test results show that the platform may have a negative effect on student performance in the areas of integers and probability, but a positive effect in coordinate geometry. We comment on the evidence for statistically significant differences in the general results of those using the platform and those not.

INTRODUCTION

In his TED (Technology, Entertainment and Design) presentation in March 2011, Salman Khan, creator of Khan Academy (KA) (www.khanacademy.org), gave an introduction to his "exercise platform" (TED, 2011). This exercise platform supports a large range of instructional videos on mathematics which form the core of the KA. Both the videos and exercise platform are available online at no cost, and neither requires specialised software. Khan emphasised the importance of mastery, comparing the alternative to giving a unicycle to someone who is unable to ride a bicycle perfectly. Khan suggested that a student in a "traditional" classroom [1] may appear to fall behind the rest of the class and end up with lower grades but may in fact just lack understanding of a few concepts and consequently be held back in other areas. Mathematics builds on prior knowledge to a large extent, so these situations could occur on a continual basis. In the extreme case, a student at Leaving Certificate may be forced to take their maths exam at Ordinary Level due to having misunderstood some of the material covered early in their course of study.

In this paper, we consider the following research question:

> How effective is the Khan Academy's exercise platform in facilitating the Project Maths Common Introductory Course for First year post-primary maths students?

The effectiveness of the platform may be interpreted in a number of ways. It may be effective from the point of view of the teacher implementing it: it may help with class management, offer a superior learning experience to their students, facilitate a better learning environment and differentiated teaching, and provide details of student ability that are not available on the same scale, in the same quantity or with the same efficiency. From the perspective of students, it may provide a more individualised learning experience, allowing them to learn at their own pace. The approach of mastery learning and the interlinking of related exercises that are built into the platform may prevent students from tackling material that is too difficult for them due to not having covered or fully understood the prerequisite material for any given exercise. Lastly, the platform may be effective in leading to higher attainment levels as measured by summative assessment. As such, the specific aims of this research are:

1. to analyse the platform from the perspective of a teacher who has implemented it in his classroom;
2. to analyse the platform from the perspective of students who are using it in their classroom; and
3. to analyse the test results of students who have used the platform, and compare them to the results of control students who have not used it.

KA exercise platform

The platform is heavily influenced by the idea of mastery: students are not considered to have completed an exercise until they consistently answer questions correctly. This is evidenced by the leaf and stack system of grading questions. Each attempt at an exercise consists of a 'stack' of eight questions, represented as cards. Each card is imprinted with one to three leaves based on how well students answer the question on that card. Three leaves are awarded only when students answer questions correctly on their first attempt. If a student gives any number of incorrect answers before answering correctly, asks for a hint from the system, or asks for a portion of the worked solution, two leaves are awarded. Lastly, if a student asks the system for the full solution, the award is one leaf. The system is highly reactive – a student can attain mastery of an exercise by answering as few as the first four questions correctly, though a long string of incorrect answers may need to be followed by a string of more than two full stacks in order for mastery to be deemed attained. At the end of the stack, students are shown an animation of a progress bar filling up based on how well they performed. Too many one or two leaf cards will show a less-than-full progress bar, with the suggestion that another stack be attempted before moving on. A long string of three leaf cards is reflected in a progress bar filling up significantly, or even completely.

KA management tools

The exercise platform includes view for the teacher that displays a wealth of information about the students. Students may be grouped together into custom lists. The teacher can view the details of every exercise, showing the number of students at each stage of completion (not started, started, struggling, proficient, and review), allowing for fast overview of the state of the class for any given exercise. There are many benefits here in terms of discovering difficulty with an exercise (which may indicate that the material needs to be repeated and/or presented in a different way) or difficulty experienced by a student (which may indicate the student requires extra attention). Statistics related to that student's attempts at an exercise are easily accessed: a bar graph is displayed, showing the number of problems attempted, the status of the questions, whether hints were used, how long each problem took, and each bar may be clicked to take the teacher to the exact problem attempted, as well as each action the student took, including time between actions, hints checked and answers given.

BACKGROUND

IT in mathematics education assessment

In a study by the University of Pretoria, a system of online assessment in a university level calculus course was implemented (Engelbrecht & Harding, 2004). Aside from paper assignments based on the use of software, the students completed a quiz online once a week. There is a time limit to the exercises given, but the system offers rapid feedback in a similar way to KA. There were also two online tests taken and one online final examination. Students answered a questionnaire, where the response was more in favour of the online assessment – the students liked the instant feedback, the lack of stress that came with the system, and the flexibility of the environment. On analysing the test results, there was found to be no significant difference between the online and paper forms of the test. The authors conclude that there is no reason to believe that performance standards cannot be maintained. They determine that there is a benefit to the teacher due to reduced grading, and to the diagnostic features that come with the online software. We note the difference in emphasis here, which is on creating a student-friendly and time-efficient summative assessment system.

A study by the University of Leeds investigated the effect of computer-based assessment on the performance of 260 ten-year-old students (Hargreaves, Shorrocks-Taylor, Swinnerton, Tait and Threlfall, 2004). Two groups of 130 students of similar performance levels were formed, diminishing the need for student ability bias to be taken into account. Two tests were created, each of which was developed into a printed paper version and a software version – the content of the paper test and its corresponding software version were identical. Each group of students took one paper test, followed a month later by the *opposite* computer test, meaning each group acted as its own control. The mean of each test was higher for the computer assessment than for the paper assessment: by 10% for test 1 and by 2% for test 2. While each group performed better on the computer tests, there is evidence that one group was less competent than the other. Thus we note that the effects of the online assessment system should not be read in isolation.

Available exercise platforms

MyMathLab (MML) is a commercial online exercise platform developed by Pearson, focusing on mathematics instruction and assessment. Pearson have produced a document entitled ‘Making the Grade’ which contains 77 case studies in which its MyMathLab, MathXL, or other mathematics exercise platforms were used (Speckler, 2012). The studies were voluntarily submitted by instructors who had designed their own curricula involving the platform. They are primarily set in US schools ranging from high school up to four-year colleges, but also contain three international studies, two based in Canada and one in Singapore. A range of study types were conducted: observational; historical or retrospective, where MML module results were compared to previous years; longitudinal, where students in

MML modules were monitored as they progressed through further modules; and experimental, where students were divided into control groups and MML groups. Among the case studies, 18 (23%) showed increased final exam scores, 51 (66%) showed increased pass rates, and 28 (36%) showed increased retention and/or completion rates.

An independent case study of MyMathLab was carried out at Fayetteville State University in North Carolina (Kodippili & Senaratne, 2008). This study consisted of a module on college algebra, where the students' final grades were primarily determined by homework and test/exam results. 72 students were split into two groups for the duration of the module: one group was assigned traditional paper-based homework, whereas the other group completed homework on the MML platform. The final scores for the groups indicate that the MML group scored 6.3 percentage points (pp) higher on average than the traditional group. A significant result of the study is that the pass rate is 21pp higher in the MML group than the traditional group. However, the study cites small sample sizes and a high p-value as reasons why no definitive conclusions can be made about whether the platform significantly increases student achievement. The results attained are based entirely on final scores and do not indicate contextual learning or understanding of the material covered. The study indicates a common theme among users of exercise platforms: teachers/lecturers feel they have more time to interact with the students, since numerical assessment is taken care of by the platform itself, and that students are freer to learn at their own pace.

Critical analyses of Khan Academy's exercise platform

KA has been the subject of much debate over the last few years, primarily by teachers who are dubious about KA's styles of learning. Very little of this material appears in peer-reviewed journals or books, but is largely contained in newspaper articles and blogs. Much of this scrutiny relates to the videos on Khan's website rather than the exercise platform. Nevertheless, we consider these critiques to be relevant because similar issues may arise in relation to the exercise platform.

An article by Ani in the Washington Post (Ani, 2012) criticises Khan's preparation methods for making an educational video, as there is no prepared script involved. Given that each exercise in the exercise platform links to a related video on the same topic, there is a danger that students who are already experiencing problems with the material may watch a video that contains incorrect statements. This could hinder the students' progress more than if they had never watched it. Ani (2012) mentions that instructional problems exist, e.g., in Khan's Multiplying and Dividing Negative Numbers, where Khan implied that any number of negative numbers multiplied together result in a positive number. As this was an instructional error, it was possible that it might have been reproduced within the exercise platform itself in the hints or solutions to a problem (however, this particular issue is not present in the platform).

KA has been piloted in a number of schools since the exercise platform's inception and is soon to be piloted in nearly 50 grade schools in Idaho to earn credits for their mandatory online learning module. A pilot study took place at Oakland Unity High School (Castillo, McIntosh & Berg, 2012), using results from common tests given over several years. It focused on the use of the KA exercise platform in a classroom and was not concerned with the videos on the site. A pre-test was used as a means of finding a baseline to compare classes. Over the course of three tests, the mean scores increased by approximately 20% in each case. In the case of the final test taken, the mean doubled. Similarly, 40-50% of students achieved 80% or higher in this final test, while only 5% did so previously.

Based on the studies reviewed, exercise platforms seem to be widely considered to be useful to teachers. Every implementation studied shows improved results in some way, and teachers appreciate the simplified class management that comes with using the platforms. They feel they are able to focus on the students' needs, and that students appreciate being able to learn at their own pace.

METHODOLOGY

A variety of qualitative and quantitative research methods were employed as appropriate to the aims stated above. These included survey and interview methodologies, statistical analysis of test scores and observations of the classes in which the exercise platform was applied.

The study focused on three first year post-primary maths classes from September 2012 – April 2013. One of these classes (Class 1) implemented the KA exercise platform as part of its curriculum, while Classes 2 and 3 used more traditional textbook-based exercises. The students had not been streamed; however the results of the *Drumcondra Primary Mathematics Test – Revised* (Educational Research Centre, 2007) taken in primary school were available, and there was minimal difference between the mean scores for each class-group and so the classes were assumed to have started the year with the same attainment level on average.

Each class had four 40-minute mathematics lessons per week, with 21 students in Class 1, and 20 students in each of Classes 2 and 3. Each had a dedicated mathematics teacher, except that Class 1 was taught once a week by a student-teacher for the first term of the academic year. The curriculum for all first year mathematics classes was designed so that the Common Introductory Course (CIC) was completed, and they used a common textbook. The teachers aimed to keep a similar pace in their lessons in order to be able to give common tests and exams throughout the year. Apart from the KA classes, all three classes only experienced formative assessment of traditional form (text-book based practice of exercises).

Class 1 was examined in detail. These students typically attended their mathematics lessons in the school's computer room once per week, during which they completed exercises using KA's exercise platform. Students were given a list of exercises to be completed in a given topic. These exercises typically assessed the content students had been learning in their traditional lessons and were structured so that the exercises considered essential were to be attempted first, with more difficult versions available if students had time remaining. These lessons were observed by the first author (SL). These observations provide a context for the discussion below of the results of the interviews and surveys. They included marking progress made on exercises, and listening to students discuss the platform, and the lesson material among themselves. On days where lessons were not held in the computer room, the students' knowledge was assessed in a more traditional manner, with time during the lesson given over to answering textbook questions. Classes 2 and 3 were used as control groups for the purposes of this study. In formal assessments, their knowledge was assessed solely in the traditional manner.

As the year progressed, Class 1's teacher was interviewed informally about the progress he was making with his implementation of the exercise platform. These interviews took place if the teacher was available following an observed lesson, which was about once every two weeks during term. A formal, recorded interview was conducted at the end of the study with prepared questions. Particular attention was paid to the teacher's changing methodology, as well as the process of linking the platform to the Irish curriculum.

Students were also surveyed over the course of the year using author-created surveys with questions of variable response type. The first survey was aimed at gauging student attitudes towards the exercise platform and website: only Class 1 was given this survey. The key areas assessed were student attitudes towards maths lessons in general, attitudes towards various aspects of the platform, as well as how much benefit students felt they got out of the platform. The second survey was distributed to all First year students, and looked more closely at how students felt after a mathematics lesson. The intention of the survey was to ascertain the differences between students using KA and students not using it in terms of their attitudes towards mathematics, and the quality of their mathematics lessons.

Over the course of the study, four common tests were taken by the classes on the topics of natural numbers, integers, probability, and coordinate geometry. Further tests were taken by each class, which were not common, and so were not analysed. The classes also took a common Christmas exam on the subjects of natural numbers, integers, fractions, decimals, and percentages. Analysis of these tests yields some interesting results, as shown in the next section.

RESULTS AND DISCUSSION

Teacher insights

The teacher of the KA class echoed the feelings of others who have implemented similar platforms in their classrooms. In his opinion, the platform is capable of holding the attention of all students, regardless of ability. The more capable students are free to work at a pace that suits them – they do not need to continue doing questions of the same type while the rest of the students catch up. The ability of KA to assess whether or not an individual student is ready to move on is an invaluable one in a classroom of 20 or more students. However, although the platform has been in development since 2006, it is still changing on an ongoing basis, which is a hindrance to planning usable lessons. As a result, the teacher's methodology changed from preparing an entire booklet at the beginning of the year to selecting exercises at most a few days in advance.

The main points made by the teacher who implemented the KA exercise platform in his classroom after the period of research concluded were:

General

1. KA is a free-gratis platform; this was a major consideration prior to implementing it.

2. After trialling the platform with a second year class, he decided in January 2012 to use it with his First year students the following year.
3. Prior to September 2013, he made connections between the curriculum he was implementing and the appropriate exercises on the platform, and developed a booklet to give to students containing the exercises required to complete a topic, as well as instructions for getting started with the platform (creating accounts, navigation, etc.)
4. It was worth the time and effort and would be implemented again the following year.

Successes

1. Students really seemed to love using the platform and were fully engaged.
2. He was able to spend more time with struggling students. More than half the class rarely (if ever) required assistance to answer questions.
3. Students were able to work at their own pace.
4. He did not need to think about getting students to focus or run out of things to do.

Issues

1. There were issues initially getting students set up with Google accounts and some students were not sufficiently familiar with using computers.
2. The platform is constantly in flux: exercises change names or content, or disappear completely. The booklet he initially created quickly became obsolete.
3. There was not enough content for the CIC.
4. The management platform was not that useful: students who were working more slowly than others might have been marked as struggling by the system when they were just working at their own pace.

Student surveys

Two surveys were conducted over the course of the study. The first was completed solely by Class 1 while the second was completed by students from each of the three classes. The first comprised eight short-answer open questions. The second contained 11 fixed-response items on a Likert scale. The number of students returning each answer was compiled and compared. Results and discussion of the main findings are given below.

Survey 1

The first survey was designed to discover how the students felt about their experience in computer room classes, particularly with regard to the nature of the implementation of the platform and their teacher's methodology. It was distributed to 17 students present in Class 1 during a lesson mid-way through their academic year: they had been using the platform for approximately five months at the time. 12 of these surveys were returned and analysed.

Firstly, the students were asked where they ranked mathematics in terms of their favourite subjects. Two thirds placed mathematics in their top five and the remainder in their bottom five. Interestingly, no student ranked it as their favourite: the majority placed it second or third, with two students stating it was their *least* favourite subject. Despite this, every student answered that they preferred lessons in the computer room to traditional classroom lessons. This preference for computer lessons reflects the feeling of students in the Pretoria study, though with even greater preference for the computer-based assessment.

Next, the students were asked whether or not there was much competition with regard to the platform's reward system of points, badges, etc. There was a mix of answers here and it is unclear whether those students who felt competitive were driven to perform differently because of it. During observed lessons, there were only minor indications of competition: occasionally students would compare avatars available to them, or remark that they had just earned a badge, but it appeared to be more of a matter of pride to have earned these items rather than competition between students actually *trying* to get them.

No students stated that they had watched any videos on the website, showing that students received help primarily from their teacher. However, the hints and solutions offered in each question appeared helpful to those who used them. Nearly three quarters of students who used hints found that they were usually able to move on from the question they were stuck on. It was noticed in lessons that students typically would opt *not* to use these hints wherever possible, but instead rely on their teacher for assistance: it is possible that students were attempting to minimise their workload on each exercise by getting help from their teacher rather than the platform, since this does not affect their progress bar. It is also a good indication that the students felt that they could ask questions from the teacher without embarrassment, and may simply be the case that they found the teacher's help more useful than that offered by the platform.

When asked if they have ever had to move on from an exercise because they got stuck for too long, most said they had not. This is despite the fact that in observed lessons students rarely managed to finish every exercise assigned in the available time. Reasons for this disconnect can only be speculated upon. Students may not consider this situation as "being stuck for too long". Students also indicated that they tended not to go back to complete these unfinished exercises.

While five students believed that the platform was perfect as is, a further five suggested that it is too tough on mistakes and should require fewer questions to succeed in an exercise; that too much progress is lost when a mistake occurs, and that it should be possible to get three leaves on a question even after making a mistake. However, having seen students make mistakes even after getting several questions correct in a row, it is suggested that the platform handles student progress adequately within the purview of its mastery objective.

Survey 2

Survey 2 was administered to each of the three first year classes at the end of the year. It was returned by 20 students in Class 1, 19 students in Class 2, and 20 students in Class 3. The focus of the survey was a more general survey of students' opinion on the classroom environment, and whether students felt sufficiently supported by their teachers. While some questions show a greater than 20pp difference in answers between the three classes, most do not show more than a 20pp difference between answers.

Students were asked about their attitudes towards their mathematics lessons. They were asked to respond to the statement "Maths is one of my favourite subjects in school", choosing from the responses *very/always true*, *a little/sometimes true* or *not at all/never true*. In Class 1, only 15% chose the first option, compared to 63% and 45% respectively in Classes 2 and 3. Based on discussions with the three teachers, we have not been able to identify any significant difference in the pupils' experience of mathematics during the school year that could underpin this variation in opinion. Equally, our observations of the KA classes do not lead us to conclude that these contributed significantly to a lack of enjoyment of the subject. The difference could relate to the different teaching styles of the teachers.

When asked if they can see how mathematics is useful in everyday life, only 45% of Class 1 thought this was *very true*, compared with 79% and 67% of Classes 2 and 3 respectively. KA is not particularly known to provide context in its exercises; in many cases, questions are presented as numbers and equations requiring a calculation. However, each class was using the same Project Maths textbook, so the additional context is likely not being provided by the textbook.

When presented with the statement, "My teacher shows us how to do questions, then we answer similar questions*",* all three classes strongly agreed that there is some level of rote learning occurring in lessons, and most (70%, 74%, and 80% for Classes 1, 2 and 3 respectively) students believe that that is all they do. As KA's platform typically is question-and-answer, there was not expected to be a significant difference in student attitudes between classes here. This was also reflected when students were asked if they fully understand a topic once the class finishes it – neither KA nor traditional rote learning appear to be more effective in terms of helping students' understanding, from their own point-of-view, with 40%, 53%, and 55% reporting that they always fully understand topics when they finish them.

When asked whether they felt they could ask their teacher for help when they were stuck, a wider gap developed; while Classes 2 and 3 are no more than 10pp apart when answering *strongly agree* (79% and 75% respectively), students in Class 1 appear to be more reserved about asking for additional help with their work (55%). In contrast to the previous survey, KA students appeared not to want to ask their teacher for help. Given that this survey was more general, and the first survey focused on their KA lessons specifically, this disconnect may be in the nature of the lesson: students in Class 1 may feel as though they cannot ask questions during their traditional lessons, but can do so in the computer room. When asked if they get enough help from their teacher during lessons, the difference between Classes 1 and 2 fell below 20pp. Interestingly, while 25% of students in Class 3 felt they could not always ask for help when they needed it, 35% felt that they did not get enough help. Similarly, 21% of Class 2 felt they were not able to ask for help when they needed it, while 32% were not getting the help they needed. This suggests that there are students who feel comfortable asking questions, but do not act on it when they need to. The reasons for this are unclear. Class 1 had a similar, but smaller difference between responses to these two questions. It should be noted that this difference may be due to the different teaching styles of the individual teachers.

Class 1 had the highest percentage of students who felt they were getting a variety of explanations from their teacher. The explanations provided on KA may be different to those that would be provided by their teacher in a traditional lesson, or possibly the teacher of Class 1 had a greater tendency to provide additional explanations than the other teachers.

Most surprisingly, when asked if they sometimes get help with mathematics from sources other than their teacher, Class 1 had the lowest proportion (15%) of students who felt this was *very true*, compared with 26% for Class 2 and 20% for Class 3. Almost the same proportion of each of the three classes (circa 40%) felt it was *not true*.

Comparing test results

We give here a brief quantitative overview of the comparative performance of the students in the three classes in the summative assessments undertaken during the school year. There were five common tests taken in all: these were completed as paper exams in all cases. Four of the tests covered specific topics (natural numbers, integers, probability and coordinate geometry). A fifth Christmas test covered a range of topics in the Number strand of the syllabus.

	N	Mean	Sample Standard Deviation (SSD)	Median	Standard Error	Range	Interquartile Range
Class 1	21	73	22	77	3	100	30
Class 2	20	77	19	80	2	87	22
Class 3	20	81	15	84	2	59	23

Table 1: Summary statistics for the common tests taken by each class

We consider first the pooled results of the four tests. Summary data are presented in Table 1. As can be seen here, the summary results are broadly similar for each class. Between Classes 1 and 2, the difference in means of 4pp is not statistically significant even at the 90% confidence level ($t = 0.55$, $df = 39$). Similarly, there is no statistically significant difference between the means of Classes 1 and 3 ($t = 1.30$, $df = 39$), or between Classes 2 and 3 ($t = 0.76$, $df = 38$), at these confidence levels.

Similar results arise for the results of the test on natural numbers, where Classes 1, 2, and 3 have means 77, 77, and 80; and SSDs 12, 12, and 12 respectively. No statistically significant difference is found between these results at the 90%, 95%, or 99% confidence level.

In the case of the test on integers taken by each class, the means were 70, 79, and 79; with SSDs 22, 14, and 16 for Classes 1, 2, and 3 respectively. Here, no statistically significant difference in the ability of Classes 2 and 3 was found (90% confidence). Class 1 appears to have lower results at 90% confidence, but there does not appear to be a statistically significant difference at 95%, or 99% confidence.

The probability test showed the largest differences between scores, with means 77, 88, and 89; and SSDs 15, 13, and 10 for Classes 1, 2, and 3 respectively. Class 1 performed worse than both Classes 2 and 3 at a statistically significant 99% confidence level ($t = 2.46$, and $t = 2.97$ respectively).

In the coordinate geometry test, students from each class performed at mostly similar levels, with means 68, 63, and 75; and SSDs 29, 27, and 18 for Classes 1, 2, and 3 respectively. The t-test suggests that Class 1 did not perform statistically significantly differently to either Classes 2 or 3 (t = 0.28, and t = 0.83 respectively), whereas Class 2 performed worse than Class 3 at 90% confidence (but not at 95%, or 99% confidence).

Christmas Exam

The common Christmas exam was delivered as a summary exam, assessing the retention of all the material covered by the classes in the first school term. The test covered some areas previously tested - natural numbers, and integers - as well as areas that had not been commonly tested - fractions, decimals, percentages. The results are summarised in Table 2.

	N	Mean	Sample Standard Deviation (SSD)	Median	Standard Error	Range	Interquartile Range
Class 1	21	67	20	65	4	63	30
Class 2	20	75	16	76	4	48	29
Class 3	20	74	17	68	4	51	30

Table 2: Summary statistics for the common Christmas exam taken by each class

The difference in means of 8pp between Classes 1 and 2 implies that Class 1 performed less well than Class 2 at the 90% confidence level (t = 1.39), but this does not extend to the 95% or 99% confidence levels. Classes 1 and 3 did not have this performance difference at any significance level tested.

CONCLUSIONS

From a teacher's perspective, the exercise platform is an effective educational aid. It allows for simplified class management: students can remain occupied with the platform through their own initiative while struggling students can be aided by their teacher. The teacher suggests that the platform is not entirely suitable for the Common Introductory Course, so is of limited use until algebra is studied in second year. The exercises are also in constant flux, showing care and growth for the platform, but this was a hindrance to preparing for lessons.

Students appear to enjoy the platform for the most part, but do not fully utilise it. They do not want to use the hints or solutions to increase their knowledge of the questions. A possible reason for this is that they do not like to lose progress in an exercise. Students in each of the three classes appear to have a broadly similar attitude to their lessons, although students in Class 1 seem to be more reluctant to ask their teacher for help.

The test results are broadly similar for the three classes: similar numbers of students achieved each grade letter. The only statistically significant difference arises in the test on Probability, where Class 1 students were outperformed by their peers in Classes 2 and 3. Insofar as differences can be ascribed to the use of the exercise platform, on a per test scale, KA appears to be more effective for coordinate geometry, and less so for integers and probability. The extra graphical capabilities and interactivity of the platform might allow the students to develop an intuition for coordinate geometry that is not available in some other topics. The overall weaker performance of Class 1 is dissimilar to the results of other studies considered in the literature review. This is perhaps noteworthy, as previous studies appear to suggest that the KA exercise platform engenders increased levels of attainment. That said, these studies typically involve deeper engagement with the KA system, rather than using just the exercise platform. It is clear that further research is necessary to make definitive conclusions on the validity of the use of the Khan Academy system in Irish mathematics classrooms.

NOTES

1. The term "traditional" refers to a class where direct instruction and practice dominate the teaching and learning approach. Practice questions are drawn from textbooks, and there is an emphasis on rote learning.

REFERENCES

Ani, K.K. (2012). Khan Academy: The hype and the reality. *The Washington Post.* Retrieved May 16 2013 http://www.washingtonpost.com/blogs/answer-sheet/post/khan-academy-the-hype-and-the-reality/2012/07/22/gJQAuw4J3W_blog.html

Castillo, D., McIntosh, P. & Berg, K. (2012). *Are we asking the right questions?* Retrieved May 16 2013 http://gettingsmart.com/wp-content/uploads/2012/03/Are-We-Asking-the-Right-Questions.pdf

Educational Research Centre (2007). *Drumcondra primary mathematics test - revised.* Dublin: ERC.

Engelbrecht, J. & Harding, A. (2004). Combining online and paper assessment in a web-based course in undergraduate mathematics. *Journal of Computers in Mathematics and Science Teaching*, *23*(3), 217-231.

Hargreaves, M., Shorrocks-Taylor, D., Swinnerton, B., Tait, K. & Threlfall, J. (2004). Computer or paper? That is the question: does the medium in which assessment questions are presented affect children's performance in mathematics? *Educational Research, 46*(1), 29-42.

Kodippili, A. & Senaratne, D. (2008). Is computer-generated interactive mathematics homework more effective than traditional instructor-graded homework? *British Journal of Educational Technology, 39*(5), 928-932.

Speckler, M. (2012). *Making the grade, v.5* (Technical report). Retrieved May 16, 2013 http://www.mymathlab.com/files/MTGv5_2.pdf

Technology, Education and Design (TED) (2011). *Let's use video to reinvent education* Retrieved May 16, 2013 http://www.ted.com/talks/salman_khan_let_s_use_video_to_reinvent_education.html