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# Khan Academy as a resource for pre-service teachers: A controlled study

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*Khan Academy<sup>1</sup> (KA) is an online learning system of videos and exercises that is freely available and widely used. In this study, 131 students in a mathematics education class were split into two groups. Both groups followed normal instruction, but the treatment group was introduced to KA and given the opportunity to substitute their compulsory mathematics assignment with exercises in KA. This paper presents the results of students' performance on a mathematics pre- and post-test. The results show a statistically significant learning gain for both groups, but there were no statistically significant differences between the two groups on either test. This suggests that using the free and automated KA for self-study and assigned work was as effective for students' learning as other standard resources. Student usage of KA beyond the compulsory exercises, however, did not correlate with results on the mathematics test, possibly due to the limited focus of the test.*

*Keywords: Mathematics education, electronic learning, teacher education.*

## Introduction

Pre-service teachers in many countries struggle with mathematics. In Norway the TEDS-M study concluded that “a big problem in Norwegian teacher education is the poor academic skills of students in mathematics” (Grønmo & Onstad, 2012, p. 55, our translation). To address this challenge, the mathematics entry requirements for all Bachelor of Education students were increased from 2 to 3 (where 2 is the passing grade and 6 the highest grade) in 2005 (UFD, 2005), and increased again to 4 in 2016 (KD, 2014).

Fluency in school mathematics is essential for studying mathematics education. A consequence of pre-service teachers' weaknesses in mathematics is that class time has to be devoted to learning mathematics rather than mathematics education material. *Khan Academy (KA)* is one of many recent online resources offering structured sequences of videos and exercises. This paper reports on a first attempt to integrate KA as part of the mathematics instruction in a mathematics education class. More specifically, the research questions were: How do the learning gains of KA users compare to those in a control group? How much did the students use KA, and what were the associated learning gains?

## Khan Academy

*Khan Academy* began as a collection of YouTube videos made by the founder Salman Khan to help his cousins with their schoolwork. These videos were later integrated into an online learning tool, which had 10 million unique users a month in 2014 (Murphy, Gallagher, Krumm, Mislevy, & Hafter, 2014). Beginning in 2010, the Bill and Melinda Gates Foundation and Google made a significant

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<sup>1</sup> <https://www.khanacademy.org/>

investment in KA to develop new content and to translate it into other languages (Murphy et al., 2014).

One of the features of the tool is “missions”, which are suggested sequences of videos, exercises and other materials. Learners can reach a level of “practiced” on an exercise by correctly answering 3–5 (depending on the exercise) questions correct in a row without using any hints. The level “mastered” is achieved by answering a mixed selection of questions a set time after the student has achieved the level “practiced”. Gaming features, such as “badges” and “energy points”, are designed to further incentivise completion of exercises and missions.

A KA user can also be a “coach” for other users, such as a class of students. A coach can see the time used by each learner, exercises practiced and mastered, and suggest other exercises, which then appear on the learners’ KA home page.

## **Related research**

There is a small but growing amount of research literature on use of videos for learning mathematics. These report that students see them as useful learning resources (Kay & Kletskin, 2012; Loch, Gill, & Croft, 2012; Loch, Jordan, Lowe, & Mestel, 2014; Wilson, 2013) and there is some indication that such videos can improve exam performance (Jordan, Loch, Lowe, Mestel, & Wilkins, 2012).

Wilson (2013) reports on the use of a flipped classroom approach with a university level statistics class, which resulted in increased student examination performance. KA was one of the resources used by Wilson to supply content to the students. A similar flipped classroom approach was employed by the second author in a physics course for pre-service science teachers (Lindstrøm, 2015). KA was found to have added value to the course based on the following: student compliance with using KA; positive student attitudes to KA; a learning gain measured using a pre-test–post-test design; and useful data in KA for the instructor to tailor teaching to the students’ needs.

In California, (Murphy et al., 2014) conducted an implementation study using KA in nine schools. Schools were of varying type (public, charter and independent) and level (elementary, middle and high schools), and were located in areas with a spread of social-economic profiles. The amount of class time spent on KA varied, and KA was not used outside of school hours. The teachers who used KA reported positive outcomes for student engagement, and an increased capacity to meet the mathematical needs of all students. There was a positive relationship between KA use and test scores as well as students’ attitudes towards mathematics.

In all of the studies mentioned above, the learning gains cannot be uniquely attributed to the online resources, because a control group was not used and there may have been other unreported factors that influenced the learning. This project is a first attempt at a controlled study of mathematics learning with KA.

## **Context**

The requirements to qualify as a primary teacher in Norway are a four-year Bachelor of Primary Education or a relevant bachelor degree and a one-year Diploma of Education. The majority of primary teachers take the Bachelor of Primary Education. In this programme, students must take

courses in mathematics education equivalent to half a year of full time study, and have the option of taking additional courses in mathematics education to become a mathematics specialist teacher.

The students in this study were in their second year of the Bachelor of Primary Education. By the end this year, the students had completed the compulsory mathematics education requirement, which was spread evenly over the first two years. Teaching comprised of 22 sessions of 2 hours and 45 minutes over the course of the academic year with occasional breaks for study trips, thematic weeks and two placement periods (of two and four weeks duration). There were also four 2 hour and 45 minute plenary lectures for the whole year group.

## Methodology

Four of the five parallel classes were included in the study, and two instructors each taught two classes. The first author held two of the four plenary lectures and taught the fifth class that was not included in the study, but was otherwise not involved with the instruction of the students. The other authors were not involved in the instruction of the students in any way.

One class from each of the two instructors was selected at random to be the KA group (the treatment group). There were 59 students in the KA group and 72 in the control group. In the third week of the first semester, the first author gave these two classes a short introduction to KA (10–15 minutes), which included showing how to set up an account, and an example of the videos and the exercises. The students were encouraged to get an account with the first author as coach. Only four students created an account in the first half of the semester, however, so the first author visited these classes a second time in the tenth week of the first semester to remind the students of how to set up an account. Throughout the first semester, the first author sent suggestions to the students for exercises related to the content in their mathematics education course both in KA and through the students' online learning management system, which was the main portal for communicating with the students. At the end of the semester there was still only four students with an account.

During the second semester, the students in the KA classes were given the option of completing their obligatory mathematics assignment in KA or as a written assignment. The KA assignment consisted of reaching the level “practiced” in the following KA exercises<sup>2</sup>: Recognizing fractions 2; Finding 1 on the number line; Equivalent fraction models; Naming the whole; Understanding multiplying fractions by fractions; Percentage word problems 1; Ordering fractions; Multiplying fractions by fractions word problems; and Converting multi-digit repeating decimals to fractions. The written assignment consisted of eight multi-part questions covering the same topics. For example two of the questions were:

Write a number story for the following calculations and illustrate the last two:

a)  $13 \times 0.8$     b)  $10,5 \div 0.3$     c)  $\frac{1}{2} + \frac{1}{3}$     d)  $\frac{1}{2} \times \frac{1}{3}$

Convert to a fraction or a mixed number. Show your working.

a) 0.375    b) 0.545454 ...    c) 1.88888 ...    d) 2.16666 ...    e)  $0.4615384\overline{61538}$

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<sup>2</sup> KA is under constant development. These were the names of the exercises in the spring semester of 2015.

The assignment included instructions on how to set up an account (identical to that given in the first semester), and included the names of the KA exercises. The first author also sent the exercises as suggestions (three per week for three weeks corresponding to when the topics were covered in class). For the final submission, 42 students chose the KA assignment and 17 the written assignment. The control classes submitted the written assignment.

Progress was measured in all classes by a pre-test–post-test design using a 24-item mathematics test developed by the authors. The items were on mathematical topics associated with the second year mathematics education course, and all were within the scope of the grade 10 Norwegian mathematics curriculum (KD, 2013). The test contained: 11 items on fractions, decimals and percentages; 3 items on multiplication and measurement; 4 items on functions; and 6 items on algebra. There was an emphasis on fractions, decimals and percentages because that was the focus of the assignment. The authors wrote eight of the items and used published sources for the other items (Brekke, 1995; Brekke, Grønmo, & Rosén, 2000; Gjone, 1997; McIntosh, 2007; Utdanningsdirektoratet, 2011). Here are two examples of the questions on fractions:

Which of these fractions is half of the value of  $\frac{3}{8}$ ? A:  $\frac{3}{4}$  B:  $\frac{6}{4}$  C:  $\frac{3}{16}$  D:  $\frac{6}{16}$

Place in ascending order:  $\frac{5}{8}$   $\frac{7}{6}$   $\frac{1}{2}$   $\frac{2}{3}$   $\frac{4}{9}$

The pre-test was administered during the first teaching session of the first semester for each class. The same test was used for the post-test and was administered in the second semester during a session for the whole year group approximately one month before the final exam and after the compulsory mathematics assignment was submitted. The students had 30 minutes to complete the test on both occasions. On the cover page of the post-test, there were four brief questions about the students' use of KA, including an estimate of how many hours the student had used KA during the academic year. This information served as a check on the data collected from KA, and to see if anyone in the control group had used KA. The students filled out this information before the 30-minute testing period began. The first author marked the pre-test and post-test according to a marking key written by all the authors. Every item was allotted 2 points, so there was a maximum possible score of 48.

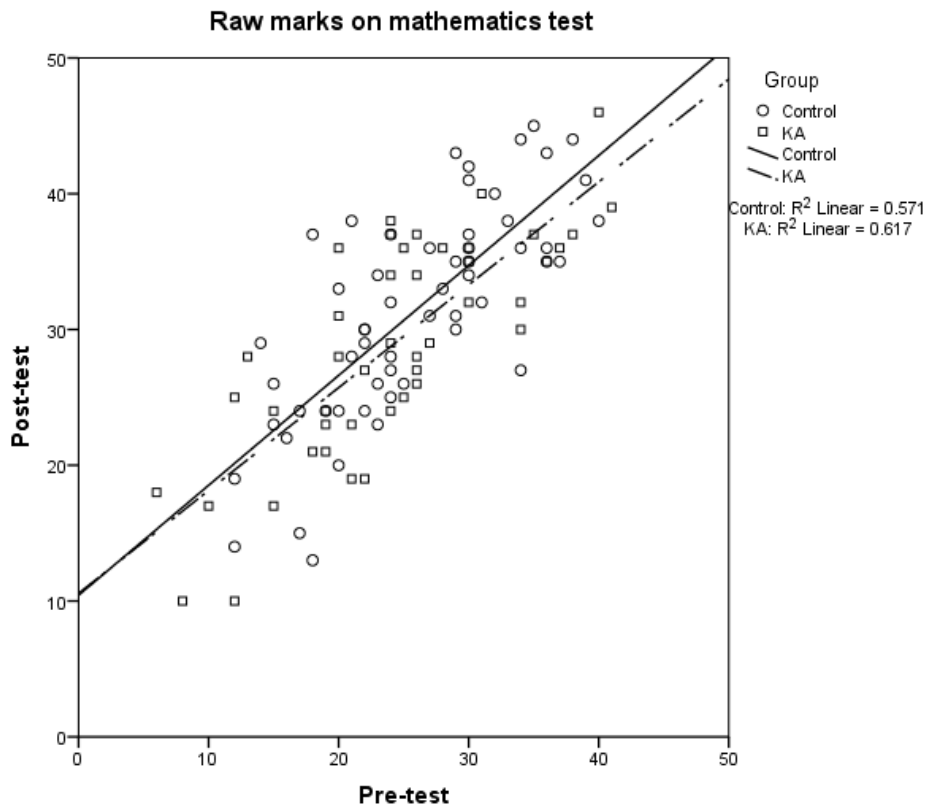
Matched pre- and post-test data were available for 51 students in the KA group and 58 students in the control group. Of the 51 students in the KA group, six students did not register any activity in KA or report using KA on the post-test cover sheet and were thus omitted from the analysis. Of the 58 students in the control group, two students reported on the post-test cover sheet that they *had* used KA during the trial period, and were also omitted.

The student data from KA on time usage was inconsistent (e.g. some students had completed many exercises but had a time usage of 0 minutes) and was thus discounted. On the post-test cover-sheet, not all of the students gave an estimate of their KA usage. In the KA group, those who did, reported an average of 4.4 hours total usage ( $SD = 3.6$ ;  $N = 45$ ). Historical self-reporting of work time is very unreliable (see e.g. Chambers (1992), so this estimate is only a very rough indication.

## Results

The average score on the pre-test for the KA group was 24.1 ( $SD = 8.3$ ;  $N = 45$ ) and for the control group 25.9 ( $SD = 7.2$ ;  $N = 56$ ). This difference was not statistically significant ( $t(99) = 1.17$ ;  $p = 0.246$ ). The average score on the post-test for the KA group was 28.8 ( $SD = 8.1$ ;  $N = 45$ ) and for the

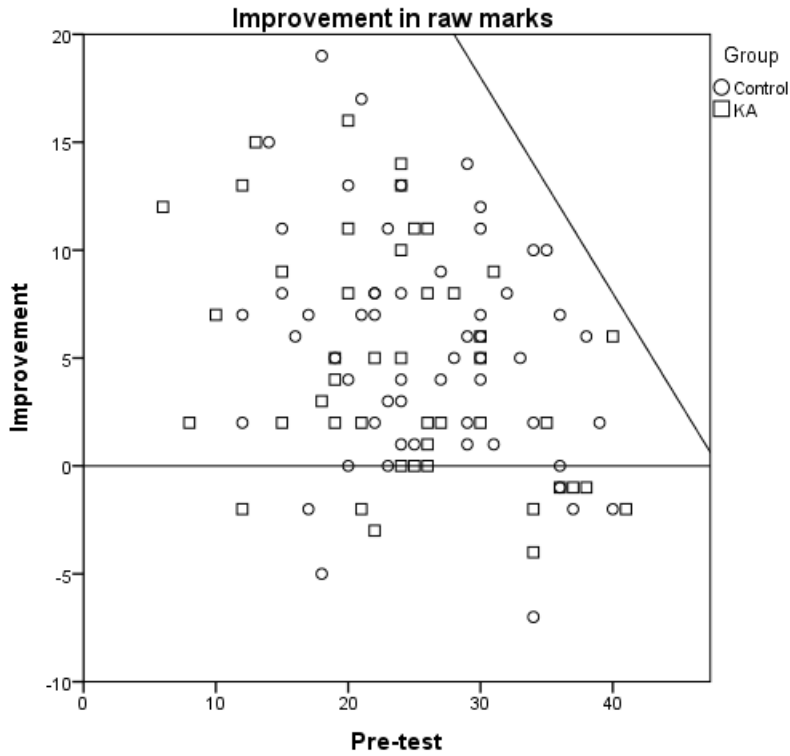
control group 31.4 ( $SD = 7.8$ ;  $N = 56$ ). Again, the difference was not statistically significant ( $t(99) = 1.63$ ;  $p = 0.107$ ). However, the gain for both groups *was* statistically significant: the gain for the KA group was 4.7 ( $t(44) = 5.86$ ;  $p = 0.000$ ) and for the control group was 5.5 ( $t(55) = 7.74$ ;  $p = 0.000$ ). Corresponding results were obtained when just the items on fractions, decimals and percentages were analyzed: there was a statistically significant improvement for both groups, but the difference between the groups was not statistically significant on either the pre-test or the post-test.



**Figure 1: Post-test vs. pre-test results for KA and control groups**

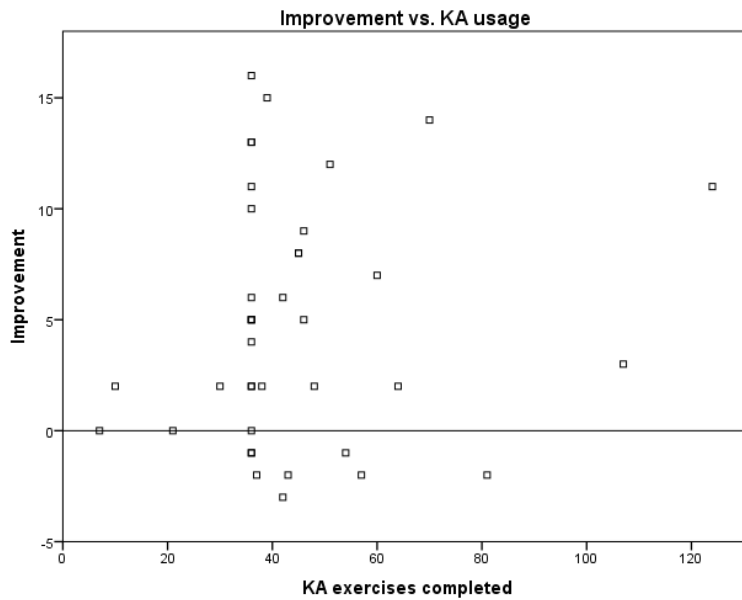
Analyzing the post-test versus pre-test scores, the linear regression lines for the two groups show similar trends (Figure 1). Again, corresponding results were obtained when performing the analysis using only the items on fractions, decimals and percentages.

“Improvement” refers to be the pointwise improvement on the mathematics test from pre to post. When compared with the pre-test results (Figure 2), there is no discernable difference between the two groups.



**Figure 2: Improvement vs. pre-test results for KA and control groups. The diagonal line shows the ceiling for the scores, i.e. the total number of available marks minus the pre-test score.**

Of the 59 students in the KA group, 49 set up a KA account with the first author as a coach by the end of the trial period, of which 44 registered activity by watching videos or doing exercises. Since the data on time usage was unreliable, “KA usage” refers to number of exercises in which the students achieved the level “practiced”. The average KA usage was 44 exercises ( $SD = 21$ ;  $N = 44$ ).



**Figure 3: Improvement in raw marks on the mathematics test vs. KA usage, as measured by number of exercises completed.**

Of the students who registered KA activity, there were 39 who submitted both the pre-test and the post-test. In Figure 3, KA usage is plotted against improvement for these students. The "vertical line" corresponding to 36 exercises represents completing the compulsory assignment. There were 21 students whose KA usage was greater than 36 exercises. It is clear from Figure 3 that there is no correlation between KA usage and improvement on the mathematics test. A similar analysis for the subset of items on fractions, decimals and percentages also showed no correlation.

## Discussion

There were no statistically significant differences between the groups on either the pre-test or the post-test. Both groups had statistically significant gains over the trial period and they showed similar patterns in the scatter plots in Figures 1 and 2. Thus, in this study, KA was *equally beneficial* to the students as the other learning resources available to them. This non-significant result is of interest because KA has practical advantages over other learning materials (e.g., it is free and easily accessible) and the marking time saved by the instructor can be invested in other learning activities. In addition, Lindstrøm (2015) found KA to be beneficial for the instructor as a tool for formative assessment. KA may have yet other advantages for the learners, which could be investigated using qualitative methods. We are aware that the similar gains of the two groups may be due to the testing instrument being too coarse. However, addressing this is outside the scope of this study, and would require a qualitative analysis of students' learning processes with KA to develop a new testing instrument.

In the first semester, despite encouragement from the first author and messages with links to relevant topics, only four students set up an account. In the second semester, without any additional interventions, 45 students set up an account when the compulsory mathematics assignment could be completed using KA. This is consistent with the findings of Lindstrøm (2015) and Murphy et al. (2014) that high KA use is associated with a well planned integration into the course, including using it as part of the compulsory assigned work with consequences for non-compliance.

There were 21 students whose KA usage was greater than 36 exercises (which corresponded to the compulsory assignment), and some of these made extensive use of the tool (Figure 3). It may be surprising that there is no correlation between KA usage and improvement, with no indications of additional gains for the students who completed additional exercises. This may indicate a failure of the test to detect the learning gains; however, it may also be that the students worked on topics not covered by the test. Further qualitative research may be conducted to investigate what motivated these students and what possible learning gains resulted from the additional exercises completed.

## Conclusions

A group of students who used KA showed similar learning gains to a control group that had no restriction on their learning resources but were not encouraged to use KA (and indeed did not, with two exceptions, use KA). As has been seen in earlier studies with KA, high use of KA was associated with a well-planned integration in the course. Some students made extensive use of KA, but there were no correlations between KA usage and measured learning gain. This raises the questions of what motivated the students to complete more exercises than required and whether there were other benefits not detected by our test.



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<sup>3</sup> <http://www.uia.no/en/centres-and-networks/matric>