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# Research on the language barriers of students who use Khan Academy as a mathematics homework platform

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*Homework is a routine practice in maths classes, and research has shown that the immediate feedback and acknowledgement of effort is important for students. Unfortunately, the traditional classroom setting does not allow for this degree of feedback. Khan Academy offers a free tool that allows teachers to monitor students' activity and provide them with feedback and guidance. In this study, we investigated one Czech high school's use of Khan Academy as a homework platform, focusing specifically on language barriers and their impact on the ability of non-native English-speaking students to benefit from Khan Academy. We found that students who faced a lower language barrier were able to make better use of Khan Academy's educational resources. Surprisingly, we also found that a reported language barrier does not significantly correlate with a student's English grades.*

*Keywords: Homework, online assessment, language barrier, electronic resources.*

## Introduction

Every student does maths homework during his or her high school studies. I remember doing most of mine on the way to school or during the break before my maths classes. At the beginning of each maths class, my teacher would walk around the classroom, checking some notebooks randomly to see if there was anything that looked like homework. Since I really enjoyed maths, I did most of my maths homework by myself and then lent it to others to copy. We did not receive much feedback on our homework, so it was no wonder that many students were not very motivated to do their homework on their own. Unfortunately, maths teachers in large classes did not have much of a choice back then. Today, however, new online technologies, such as Khan Academy (KA), offer individualisation, guidance and immediate feedback for students, as well as a great amount of data about student activity for teachers (Khan Academy, 2016a).

The Khan Academy (KA) is a non-profit organisation that runs the website [www.khanacademy.org](http://www.khanacademy.org). Since 2008, it has undergone a great deal of development. What started as a list of instructional maths videos has developed into a network of vast educational resources, including interactive exercises covering mathematics, the natural sciences and more, from the elementary to the undergraduate level. Thanks to generous donors, KA is able to provide all of its content for free, and it probably will not be cancelled or monetised any time soon. At the moment, KA's exercises and most of its educational videos are offered in English only, as is the case with many other online resources. We therefore decided to investigate the effects of language barriers on the preferences and attitudes towards KA of students who practise maths using KA exercises.

## Theory

### Homework and feedback

Homework assignments are routine in most mathematics classes, including those in high schools in the Czech Republic. There is a great deal of evidence suggesting that monitoring students' work and acknowledging their efforts is very important for students, as it increases the effort they put into their homework (Strandberg, 2013). When teachers do not grade a homework assignment and return it promptly, students report feeling like they have wasted their time on this activity (Strandberg, 2013; Wilson & Rhodes, 2010). Students need to believe that their homework is meaningful and that teachers value their efforts (Bempechat, Neier, Gillis & Holloway, 2011).

When it comes to feedback, there are still important gaps in our understanding (Shue, 2008). There is some evidence suggesting that when a task requires material or procedural understanding and analytical problem solving (e.g. mathematics), providing hints and allowing multiple attempts may lead to a greater increase in student performance than simply revealing the correct solutions (Clarina & Koul, 2003; Attali, 2015).

Students benefit greatly from timely and meaningful homework feedback. Unfortunately, it is often beyond a teacher's capacity to provide this to every student in a traditional classroom setting. However, technology might be able to help teachers with this. Moreover, technology can prevent misunderstandings between students, teachers and parents about the amount of time students spend on homework, as accurately estimating this can be difficult for teachers in the traditional classroom setting (Strandberg, 2013).

### Language barriers

We did not find many recent studies investigating English language barriers in terms of learning mathematics or learning in general. There have been some studies that have investigated non-native English-speaking students in an English-speaking environment, both at the high school (Adams, Jessup, Criswell, & Weaver-High, 2015) and university (Variawa & McCahan, 2012) levels. However, these are not very relevant to our investigation, as they study foreign students in English-speaking communities and focus on different subjects (e.g. chemistry, engineering).

For the purposes of this study, we define a language barrier as English language difficulties, as perceived by students when interacting with the Khan Academy website.

### Khan Academy

KA has been providing interactive exercises for only a few years, so it has not yet been heavily researched. However, videos have been used for educational purposes for decades. Two recent studies have investigated data from several Massive Open Online Courses to determine the attributes of the more engaging videos (Guo, Kim, & Rubin, 2014; Kim et al., 2014). In our previous study, we concluded that KA's videos align well with most of the aforementioned recommendations (Vančura, in press). Our investigation into the possible impact of KA as a homework platform on student attitudes towards mathematics demonstrated that negative impacts are very unlikely (ibid).

A large study was also conducted concerning the implementation of KA in U.S. classrooms (Murphy, Gallagher, Krumm, Mislavy & Hafter, 2014). The results revealed that only 45% of

American students reported being able to learn new skills using KA without teacher assistance. We found similar results (46%) in our previous study (Vančura, in press).

## Context

In this study, student participants were assigned homework on a weekly basis in the form of KA's interactive exercises.

< ALGEBRA II | ADVANCED EQUATIONS & FUNCTIONS | SOLVING EQUATIONS BY GRAPHING

**Solve equations graphically**  
Solve advanced and complicated equations using the power of graphs.

Let  $f(x) = 2^{x^2}$  and let  $g(x) = -x + 3$ .

The graph of  $y = f(x)$  is shown below.

Use the interactive graph to sketch a graph of  $y = g(x)$ .

1

Let  $x_1$  and  $x_2$  be solutions of  $2^{x^2} = -x + 3$ , where  $x_1 < x_2$ .

Estimate the value of  $x_1$ .  
Answers within 0.5 units of the solution will be accepted.

3

4 [Get a hint](#)

5 **Stuck? These things might help.**  
Don't worry, you won't lose your streak.

- [Solving equations graphically \(1 of 2\)](#)
- [Solving equations graphically \(2 of 2\)](#)

Scratchpad

[Report a mistake](#)

6

[Check answer](#)

**Figure 1: Interactive exercise (Khan Academy, 2016b)**

Every exercise consists of a series of problems related to very specific topics. In the exercise shown in Figure 1, students are asked to practise estimating equation solutions using graphs. Specifically, students are required to select the shape of the graph for function  $g$  [1]; to graph the function  $g$  using the interactive graphing tool [2]; and to estimate the lower solution of equation  $f(x) = g(x)$ , where function  $f$  is given by the graph. Students cannot move on to the next problem until they solve the exercise correctly. If they cannot solve the problem, there are hints [4] that demonstrate step-by-step solutions. Even after the whole solution is revealed, students are still required to graph the function  $g$  and estimate the solution correctly. Only then can they continue on to the next problem. Students can also watch instructional videos that explain the solutions to a sample problem in detail [5]. Each student's progress is captured and displayed at the bottom of the screen [6]. Students receive a check mark for solving the problem correctly on the first try without any hints. They get an x mark for entering the wrong solution and a light bulb icon for solving the problem correctly on the first try with some hints.

In order for students to successfully finish an exercise, they must get five (or sometimes three) check marks in a row (i.e. solve five problems on the first try without any hints). This multiple-try

mechanism aligns well with the findings on feedback (Attali, 2015). However, this feedback does not tell students where they have made their mistakes, and it usually provides only one way to solve a problem. Some exercises consist of multiple-choice answers, and students might be tempted to guess the solutions—although the requirement of solving five problems in a row makes guessing time consuming. For example, even if students were able to narrow the choices down to two, they would still need to answer 62 questions on average in order to get 5 in a row correct. If students guessed blindly from 4 choices, they would need to answer 458 questions on average.

Another important tool that KA offers is the teacher dashboard, which allows teachers to monitor student activity. Teachers can see when students work on exercises, which exercises they work on and how well they solve the problems. Teachers can even see the amount of time students spend on each problem, as well as the total time they spend on KA. This data allows teachers to monitor, acknowledge and assess students' homework objectively and meaningfully. Moreover, in our study, these attributes allowed teachers to grade homework on a weekly basis.

Based on the results of one SRI study (Murphy et al., 2014), student participants were not required to learn new skills on KA; rather, they had to practise skills they had already acquired.

## **Methodology**

### **Research questions**

1. Does a student's language barrier influence whether he or she prefers KA homework over homework from traditional textbooks?
2. How does the language barrier influence students' attitudes towards KA and their ability to learn maths while using it?

As the research progressed, we saw that language barriers did play an important role, which made us add a third question of interest:

3. Can the language barriers of individual students be easily and reliably estimated (i.e. by asking the student's English teacher)?

### **Data collection**

We developed two surveys based on the surveys used in the SRI study (SRI, 2015), although we added some questions about English language usage and omitted some questions that were irrelevant to our investigation. The first survey was administered in December 2015, and the second was administered in June 2016. Both surveys contained several pairs of verification questions to detect inconsistencies or carelessly filled-out surveys. To measure the language barrier, we used Likert-scale questions, such as, "My limited English knowledge prevents me from using Khan Academy effectively." To measure the preference for the KA homework platform, we used Likert-scale questions, such as, "I prefer to solve examples from common textbooks rather than from Khan Academy." Surveys were administered during an ordinary maths class so that the students had no reason to hurry. We also collected students' midterm and final grades in mathematics and English for the 2015–2016 school year.

At the beginning of September 2016, we asked the students' English teachers to estimate the reading and listening abilities of the participating students, as well as the effects of the students'

language barriers when using English mathematical software. The teachers were asked to use the Common European Framework of Reference for Languages (A1–C2) for their estimations (Council of Europe, 2016), which were then recoded on a scale of 1–6.

### **Participants and criteria of analysis**

The first survey was administered to 141 non-native English-speaking students aged from 15 to 20 years old from 7 maths classes in 2 Prague high schools. For the second survey, the participants included 83 students from 5 out of the 7 classes that participated in the first survey. All of the students were learning English as their second or third language. A total of 64 students participated in both surveys. The students in our study were taught by six different English teachers, who were asked to estimate the students' language barriers. The author of this paper was the maths teacher for two of the seven classes. Therefore, we looked for relative patterns (i.e. connections between the students' language barriers and their learning independence) rather than for absolute results. When investigating absolute results, such as student preference for KA over traditional textbooks, we also considered the differences between the students who were taught by the researcher and those who were not.

To measure the language barriers, we required Cronbach's alpha to be greater than 0.7, which is generally considered to be an acceptable level of consistency. When it came to correlations and hypothesis testing, we used the 5% significance level.

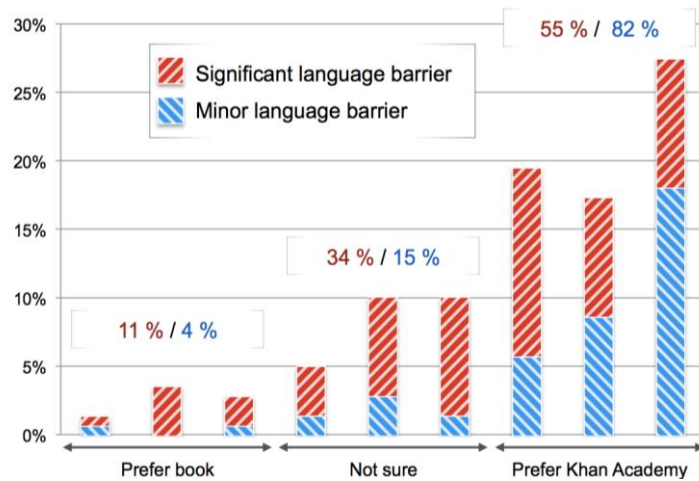
### **Results**

In the first survey, students reported a strong preference for KA over traditional textbooks (Vančura, in press). This preference decreased significantly in the second survey, although KA was still preferred. In both surveys, the students who were taught by the researcher did not report a stronger preference for KA than the other students. Students' preference for KA was significantly correlated with reported language barriers (see Figure 2). Students with greater language barriers tended to prefer KA less. Even so, students who reported significant difficulties with English preferred KA over traditional textbooks.

Both surveys revealed a significant connection between the students' reported language barriers and several other factors. In both surveys, students with lower language barriers

- a. found KA videos and exercises to be more helpful for them (correlations 0.18–0.45);
- b. reported higher autonomy when learning new skills using KA (0.17–0.28); and
- c. reported a more adequate understanding of their skills while working in KA (0.22–0.29).

The reported levels of language barriers decreased slightly between the two surveys, but this decrease was not statistically significant. Surprisingly, the reported language barriers did not significantly correlate (-0.02, 0.14) with the English grades. We assumed that different teachers would have different grading strategies and standards, so we normalised the English grades within the groups of students taught by each teacher. The resulting correlation increased slightly to 0.16, which is still insignificant in our case. We also calculated the correlation between English grades and the decrease of language barriers between the two surveys; again, the correlation was insignificant (0.02).



**Figure 2: Student preference for the KA homework platform by language barrier in the first survey**

Driven by these results, we asked the English teachers to evaluate the students' English listening and reading skills, which correlated moderately (0.45, 0.48) with the language barriers reported by the students.

## Conclusions and discussion

Homework remains an important part of mathematics education in the Czech Republic. KA can provide students with guidance and immediate feedback, which we believe is the main factor that leads students to prefer KA over traditional textbooks. The decrease in KA preference over time may be attributed to the novelty of this new system wearing off. Still, it is worth noting that even six months (and many working hours) later, KA remained the preferred choice of the majority of the student participants.

We found that language barriers play an important role in both preference and reported utilisation of KA. Students with greater English-language capabilities reported a higher ability to use KA learning resources, which we believe to be a strong factor behind their stronger preference for KA over traditional textbooks. We can assume that similar patterns would appear with other online educational resources—the number and quality of which continues to grow rapidly, and which would take a great deal of time to translate into Czech. Notably, KA is one of the most-translated educational resources in the Czech Republic. However, despite great effort from the non-profit organisation Khanova Škola (Khanova škola, o.s., 2016), only about 35% of KA's videos have subtitles, while fewer than 1% have Czech dubbing. If we want students to benefit from these growing resources, then we need to prepare our students for learning in English.

The last result of our study was that students' English grades did not significantly correlate with their reported language barriers (i.e. the 'best' English students did not typically feel better able to overcome their language barriers than the struggling students). This pattern held true even after six months of using KA. We assumed that the students would learn to overcome these barriers over time, as they used the English resources over the course of the study. Our study did indeed show that the reported language barriers decreased slightly, albeit insignificantly.

The teachers' evaluation of the students' English reading and listening skills correlated significantly (0.45, 0.48) with the language barriers reported by the students, so such evaluation could provide a

very rough estimate of the language barriers faced by a group of students. However, this correlation was not strong enough to provide a reliable estimate of the barriers faced by the individual students, as it only explained about 23% of it ( $0.48^2 = 0.23$ ). Ultimately, we were unable to find a quick and reliable way to estimate the individual students' self-reported language barriers.

## Limitations and future research

The small size of our sample made it impossible for us to find small correlations or inconspicuous patterns. Larger samples would have also allowed us to verify our results at a higher confidence level. The disconnection between the reported language barriers and the students' English grades could also be a local phenomenon, since every Czech school has its own curriculum.

In this study, we relied mostly on students' opinions, which might not have been completely accurate (i.e. even though students reported that they could make good use of KA resources, that does not necessarily mean that they did).

The results also showed that the English courses currently being offered to students might not be sufficient to prepare them to learn mathematics in English using tools like KA. Therefore, determining how to help students learn in English might be an interesting question for researchers and a challenge for both maths and English teachers.

While KA offers a great variety of exercises, its narrow focus (i.e. graphing quadratic functions in vertex forms) and repetitive nature might produce very formal knowledge that cannot be transferred. In future study, we would like to investigate what students actually learn using KA and how it might be affected by their language barriers.

As with every digital resource, KA sometimes experiences technical problems. Exercises can fail to load properly and data might not show up in the teacher dashboard. Therefore, it is a good idea to consider possible technical problems before judging students too quickly.

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