HOW THE INTEGRATION OF KHAN ACADEMY (AND OTHER TECHNOLOGIES) AFFECTS STUDENT LEARNING IN THE HIGH SCHOOL MATH CLASSROOM

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Abstract

Chapters I-II of this thesis examine Khan Academy and its uses in the modern mathematics classroom. Consideration is given to several Blended Learning Models, and the benefits of each, as well as to user experiences when implementing technology in the classroom. Chapters III-V investigate the implementation and results of utilization of Khan Academy in two high school math classrooms at an urban Midwest performing arts high school. Students in a geometry course who used Khan Academy as a secondary resource, as well as students in a remedial math class who used Khan Academy as a primary tool, made significant gains in mathematical knowledge in comparison with students from the same classes in previous years. This study examines the effective implementation of technology in the classroom and supports the effectiveness of the classroom model described by Salman Khan in his book *The One World School House.*

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CHAPTER I: INTRODUCTION

In 2004 a hedge fund analyst named Salman Khan took on a noble, though humble task: tutoring his twelve year old cousin Nadia in mathematics. Nadia was struggling with algebra, and though Khan lived hundreds of miles away he took time to video-conference with Nadia about mathematics. He began to create short, five to ten minute video tutorials on algebra that Nadia would watch and re-watch at her convenience. His goal was to help Nadia gain mastery of every introductory algebra-related skill before moving on to more complex material (Khan, 2012).

This process yielded two results – one expected, and one unexpected. As expected, Nadia gained proficiency in math and began to progress faster than her peers. Nadia overcame her fear of mathematics and began to feel more comfortable in the classroom. But quite unexpectedly, Khan began to gain fame and prestige in the internet community. His videos, posted publically, were viewed by hundreds, and then thousands of children and teens eager to boost their understanding and confidence in mathematics (Khan, 2012).

Over the next several years, Salman Khan became the most watched teacher in the world. His videos were praised by students and parents who claimed that their struggles with mathematics were alleviated by using Khan's self-paced, mastery-centered approach to learning. Khan quit his job as a hedge fund analyst and began to work full-time to develop his educational website, KhanAcademy.org, which featured free games and interactive problem-solving activities in addition to his videos. As of July 2014, Khan had attracted approximately 10 million active students per month, and his videos had been viewed over 500 million times (Khan, "Khan Academy", 2014).

Khan has since become a notable lecturer on modern education, often encouraging a Blended Learning model – one where students work at their own pace on sets of skills. The Blended Learning model allows for some amount of learning – usually of rote skills – to be completed in a digital manner. He discourages use of the standard note-and-lecture model, where students sit idly and learn very passively, instead encouraging a new classroom dynamic where dozens of students and multiple teachers all work towards the same goal: mastery of mathematics (Khan, 2012).

While the successes and goals of Salman Khan and KhanAcademy.org are laudable, they have met some criticism. Classroom teachers often feel that Khan's vision of the ideal classroom is unrealistic, and that individualized instruction for every child is impossible given time constraints and other teaching responsibilities (Khan, 2012 & Thompson, 2011). In addition, students often do not have access to the technology necessary to sustain a Blended Learning model.

In Chapter II, the literature review, the following questions are investigated:

1) What are the advantages (and disadvantages) of our current Prussian education system?
2) How could the classroom described in Salman Khan's *One World Schoolhouse* address these issues?
3) What have users experienced who have adopted Khan Academy in the classroom?

4) What classroom model best fits today's tech-driven learners as they proceed through the 21st century?

Following my literary review in Chapter III I offer data from my own classroom experience of exposing my students to Khan Academy, both as an additional resource in a geometry class, and as a central tool in a "Khanesque" remedial math course.

The needs of the 21st-century learner are different from the needs of those born in previous centuries. "Reading, writing and arithmetic" can no longer constitute a student's entire education. Basic skills need to be learned quickly and thoroughly so that time can be allocated to teach higher-order thinking-skills. How can technologies like Khan Academy be used to effectively teach mathematics? This essential question will guide chapter II.

CHAPTER II: LITERATURE REVIEW

Khan Academy

Introduction, Funding, and How Khan Academy Came to Be

As noted in Chapter I, Khan Academy, like many software start-ups, had humble beginnings. Salman Kahn worked out of a closet in his home and funded his website out-of-pocket. He had a few students at first, including his cousin Nadia, but the value of his software spread quickly through word of mouth. Yet, his work yielded him no income with which to support himself and his family. Khan struggled in the early months. "My son had just been born, my wife was still training; it seemed irresponsible even to consider quitting my job. […] The stress began to build by the fourth month – nothing like burning $5,000 a month out of savings while having a toddler in the house to put a strain on a marriage" (Khan, 2012, p. 154-156). Khan spent almost a full year largely unfunded, charitably creating educational videos on Youtube full time.

The videos that Khan produced were approximately 10 minutes each (which was the limit in those days for the length of a video on Youtube). This was serendipitous: Khan found later that ten minutes was just the right length. Two researchers from Indiana University, Joan Middendorf and Alan Kalish (1996), published a study that detailed students' focus over the course of a typical class period. They found that students tend to lose concentration after 10-18 minutes of lecture and retain information poorly thereafter. Khan affectionately refers to his 10 minute tutorials as *no frills* videos – they are concise, and get right to the point.

As his interest in education grew, Khan became more eager to observe the results of his work, and in 2007 he was given an opportunity to do so. The Peninsula Bridge camp, which provides educational enrichment opportunities to students during the summer, gave Khan an opportunity to supplement their students' education with Khan's product. Khan observed fantastic growth, particularly in students with huge deficits in mathematical understanding (Khan, 2012).

Unlike other software startups, Khan Academy was (and is) a not-for-profit organization. Khan did not seek public education funding or tuition, but rather asked for donations from those who saw the benefit of such a program. Khan received small donations from early users, usually in the sum of $5-10, but struggled to find big investors. "I had no experience running or raising money for a not-for-profit. Most discouragingly, the few foundations willing to talk to me were afraid to support something that no one else had" (Khan, 2012, p. 156). Investors would not commit to his cause without the support of other investors. It was not until one year after quitting his job as a hedge fund analyst that Ann Doerr, the wife of an investment banker, donated $10,000, and then $100,000 to support Khan's efforts. Two months later Bill Gates, CEO of Microsoft, applauded Khan's efforts, citing Khan as his "favorite teacher." Two months after that Khan found himself with a check in hand for $1.5 million from the Gates Foundation (followed by $4 million), and $2 million from the Google Corporation. Khan utilized his new funds to hire a team of five and acquire an office space in preparation for the exponential growth in number of pupils that Khan Academy saw in the subsequent years.

Khan Academy's Mission Statement and Goals

The Khan Academy website (khanacademy.org) boasts a simple, but meaningful motto: "Our mission is to provide a free, world-class education for anyone, anywhere." Has Khan Academy succeeded in following its mission statement? It has certainly remained free: thanks to continued financial support from Academy users and tech giants like Microsoft and Google, Khan has been able to keep his software free for everyone, and he has no intention of charging for Academy services in the future (Khan, 2012). The services are also widely available to anyone, anywhere, with an internet connection, and even for some without. As of January 2015, only 35% of the world had internet access (Khan, 2015). In order to make Academy services more readily available, Khan created a product called "KA Lite" – a portable program that can run without internet access, but still provide lessons and content.

Whether the education is *world-class* is open for debate, partly, of course, because this term is so nebulous. In any case, the data from experimentation (see the "case study" sections of this chapter) suggest that students who utilize Khan Academy - even students previously labeled "remedial" or "behind grade level" - outperform those who do not. Additional work can be done to improve Khan Academy (see "case study" sections), but it is generally agreed upon by users at Palo Alto, Los Altos, Rocketship schools, and my own school alike that the team that Khan put together is well on the way to meeting its mission of providing a "free, world-class education for anyone, anywhere."

The Khan Academy Classroom Model & Structure

The Broken Model and Mastery Learning. In *The One World Schoolhouse*, Salman Khan criticizes the Prussian system upon which modern schools in the United States (as elsewhere) are based. Many aspects of American schooling, including the length of the school day, the school year, the compartmentalization of academic subjects, and the standard "lecture, regurgitate, and repeat" classroom model come from the eighteenth century, and are often seen by teachers and educational researchers as outdated and detrimental to the education of students. Khan notes that the goal of the Prussian educational system was "not to produce independent thinkers, but to churn out loyal and tractable citizens who would learn the value of submitting to the authority of parents, teachers, church, and, ultimately king" (Khan, 2012, p. 76). Students were taught to memorize and follow sets of rules (both procedural rules of the school, and basic mathematical rules), but they were not often given opportunities to question why the rules worked, nor to derive new rules for themselves. Information was fragmented into modular *subjects* and largely learned through rote memorization. This was an effective educational tool at the time: it facilitated Germany's rise as an industrial power, and lifted millions into the middle class. However, students had little opportunity to delve deeper into academic topics before moving on to the next compartmentalized lessons. This Prussian model of education was efficient, but it left much to be desired in the realm of creativity (Khan, 2012).

In the early nineteenth century this model of lecture-and-regurgitate was adopted by most educational institutions in the United States. Students were taught patriotic duty, as well as reading, writing, and arithmetic, and by 1870 the United States had become one of the most literate countries in the world (Barker & Burrows, 2007, p. 141). Soon after, in 1892, the National Education Association (NEA) formed the Committee of Ten, which was tasked with determining which important topics should be learned in secondary school. This group broke away from the Prussian model slightly by encouraging students to think independently after mastering basic skills. The Committee of Ten went so far as to say:

> As soon as the student has acquired the art of rigorous demonstration, his work should cease to be merely receptive. He should begin to devise constructions and demonstrations for himself. Geometry cannot be mastered by reading the demonstrations of a text-book, and while there is no branch of elementary mathematics in which purely receptive work, if continued too long, may lose its interest more completely, there is also none in which independent work can be made more attractive and stimulating. (National Counsel of Education, 1893, p. 115)

This declaration ran counter to the traditional Prussian model of education by recommending independent work rather than pure rote learning. The Committee of Ten recommended that after basic rote understanding of lower-level material, students must be allowed to learn mathematics for themselves. Unfortunately, much of education, especially early, traditionally rote pieces of education, is left to be lecture-and-regurgitate with little opportunity for creativity.

In addition to its over-reliance on rote memorization, the education system we have in place today has also become fixated on compartmentalizing human knowledge into subjects, which themselves are broken into units, sections, lessons, etc. This causes two large issues. First, students rarely connect various disciplines with one another. Students learn about the Silk Road in history class without learning about the accompanying evolution of trigonometry and trigonometric reasoning. They learn physics without realizing that it is simply applied geometry and pre-calculus. They see statistics in social studies or biology, but they do not connect it to the work done in math class. Their subjects are disjointed (Khan, 2012). As a result, students, even the "brightest" ones, have trouble connecting what they learn to real life situations (Khan, 2012). What use is the ability to solve for 'x' if you are unable to use math to maximize profit for a small company, or read a news article critically for misleading statistics?

Secondly, and possibly more concerning, units of a subject are typically taught on a predetermined timeline. Students are given a number of days to learn a topic and, at the end, have some unit assessment. Occasionally remediation is available for students who did not grasp the topic the first time, but even so, the setup is fundamentally flawed. Suppose a student "passes" a math unit with an 80%. That sounds satisfactory, but it implies that he or she did not grasp 20% of the material. Each unit builds on the previous, so now this student is missing 20% of the requisite knowledge for the next unit. What results is what Khan refers to as Swiss cheese learning. Small deficits throughout a student's educational career, after iteration, become large gaps in the student's understanding of a subject. Khan (2012) notes that even a straight-A, 95% student may struggle with advanced material if she lacks understanding of 5% of the requisite material.

What is the solution to the broken model of education that Khan critiques? This thesis examines Khan's solution to the *disconnected subjects* problem in the next section and a proposal called *mastery learning* that combats Swiss Cheese Learning in the section titled *Personalized, Custom Learning*.

The One World School House. In the fourth section of *The One World Schoolhouse*, Khan proposes solutions to some of the problems mentioned in his previous chapters. First, he proposes ditching the standard lecture/notes/exam, set-paced model. Rather, he recommends that students work at their own pace. Something that takes a student one week to master may take another student three weeks. This type of self-pacing can be done through resources like Khan Academy, which give students control over how quickly, and with what repetition materials are presented to them. This model of instruction comes by many names*: Blended Learning, Hybrid Instruction, Web-enhanced Instruction*, etc., but all endorse the idea that students benefit from being able to rewind and play back instructions as necessary, and from a variety of learning mediums: technology-enhanced included.

Second, he proposes that students not be grouped by age level. He states that "there is nothing natural about segregating kids by age. That isn't how families work; it isn't what the world looks like; and it runs counter to the way that kids have learned and socialized for most of human history" (Khan, 2012, p. 92). Students, both younger and older, can benefit from working with other age groups. The older students have the opportunity to take on leadership roles while younger students emulate the older – everyone behaves more maturely. At Khan's proposed schoolhouse, students work towards mastery of topics through self-paced courses.

Hence, lumping students by age group is not beneficial. Rather, having older students tutor younger helps both parties: younger students learn from experience while older students sharpen their understanding of a topic by explaining it.

Third, he proposes team-teaching. A standard brick-and-mortar school groups 20-30 kids with a single teacher. Though 25 students in ordered rows with a single teacher is a comfortably familiar idea, this often leads to passivity in classroom, Khan argues, and is counter-productive. Khan envisions groups of students working at different stations with a group of teachers on a variety of activities – some computer-based (perhaps one in five activities), but many not. The role of the teacher in this scenario is very different from what one finds in most classrooms. Teachers are not lecturers, but facilitators of knowledge and activity. They function more like a team of coaches, and this shift in function, Khan believes, helps to cultivate a healthier student-teacher relationship (2012).

A team-teaching structure offers a host of benefits: students get to hear about a topic from a wide range of view-points, and through varied teaching styles, each unique to the teacher; teachers get to collaborate more readily and can teach in tandem with smaller sections of heterogeneously-aged kids. Like their students, younger teachers learn from the experiences of the older ones, while older teachers draw new pedagogical ideas from the younger ones (Khan, 2012). This method of team teaching, combined with utilization of a technology like Khan Academy, allows teachers to provide more personalized learning environment for their students.

Personalized, custom learning. As noted in the "Broken Model" section above, students often suffer from "Swiss Cheese learning" as a result of set-paced curriculum. They may grasp some concepts, but they miss portions of others. The consequence of missing some basic concepts is that they struggle through more difficult subsequent material. These gaps can be hazardous. Khan says "a gap or misconception in a previous subject therefore becomes a stumbling block in the one that follows" (Khan, 2012, p. 54). Students who struggle with linear equations, for example, struggle further with systems of equations.

Khan recommends one solution for fixing gaps in fundamental knowledge: review older material from time to time. It is rare in a standard math classroom for a teacher to take time reviewing material from previous years, and students are often without the resources to do so. They have turned in previous text-books, and have likely discarded old materials (Khan, 2012). As a student works through Khan Academy exercises, they are frequently presented with problems from older material. This keeps knowledge of basic concepts fresh as they encounter newer material. Review material is always available if a student has forgotten fundamental concepts relevant to a new lesson. So, whether in class, or at home at 3:00 AM, a student can review Pythagorean Theorem on Khan Academy before moving on to trigonometry. This allows students to transform their Swiss Cheese understanding of basic math into a less holey *cheddar* or *gruyere*.

Khan also promotes what he calls *mastery learning*. A student who scores 80% consistently on quizzes may be a "B" student, but he/she still lacks mastery of 20% of the required material. In order to make progress on Khan Academy, students must answer five to ten questions correctly *in a row*. This may seem daunting and is, in my experience, sometimes frustrating for students (especially when they miss the tenth problem and need to restart!), but I have noticed a strong correlation between students who persevere, and those who perform well on unit or course summative assessments later. Students who miss one in ten problems have room for improvement, and Khan Academy, being an automated system, will always have additional practice and support for students who struggle. Khan (2012) notes:

> Best of all, when students nailed ten problems in a row – a feat that generally seemed quite daunting at the start – they really felt that they'd accomplished something. Their confidence and self-esteem had been boosted, and they looked forward to the challenge of the next, more difficult concept. (p. 138)

Khan also focuses on repetition. Getting ten problems in a row on one day grants a student *level one* knowledge of a topic. Over the subsequent days, to make sure a student retains the new information, students complete *mastery challenges* where they are presented problems from various level one topics they have already completed. Correct answers move them along to level two, level three, and eventually to *mastery status* of that skill, while incorrect answers point the student to remedial opportunities. The philosophy behind this is iteration: if a student can correctly solve a problem from a particular topic multiple days in a row, they have probably internalized the skill.

These two concepts of "filling in the gaps" and "mastery learning" allow students to take ownership of their education. Students themselves can identify their mathematical strengths and weaknesses and can personalize their curriculum to best serve their needs. They can set goals for themselves, and when they meet these goals, students feel a great sense of accomplishment (see the "student motivation" section for more).

Khan Academy Users' Experiences and Implementation

Salman Khan first piloted his software in a summer camp where he found the importance of mastery learning and "filling the gaps." Other early adopters of Khan Academy were Menzi High School (who used Khan's videos), various schools in Chile, and schools in Los Altos. All experienced promising results (Barman, 2013).

Khan Academy at Menzi High School. University of Southern California graduate student Naman Barman (2013) conducted a research project titled "An Evaluation of the Effectiveness of the Khan Academy Videos for Teaching Mathematics at Menzi High School." For this project Barman traveled to Menzi High School in South Africa, and helped teachers there complement their lessons with videos from Khan Academy. Barman showed students videos from Khan Academy that were related to, though not a repeat of, the lessons they learned in class. After videos were viewed, short quizzes were taken that covered the video's core concepts. It is important to note that this experiment lasted only three weeks, and that Khan Academy software was not used due to low availability of technology – only videos from the site were viewed.

Barman introduced students to Khan videos without a question/answer opportunity at the end of the videos, and then he gave short quizzes immediately. Students scored moderately on these quizzes, though Barman (2013) "began to notice that many students struggled with basic arithmetic," (p. 10) which was not directly tested through the quizzes. In addition to taking the quizzes, students responded to a questionnaire at the end of the three weeks.

After analyzing his data and examining the responses from the questionnaire, Barman (2013) concluded that due to significant Swiss Cheese understanding of mathematics, students struggled with Khan videos that went over more difficult concepts. He concluded that simple concepts could be learned via Khan videos, but more complex videos required some teacher intervention. Anecdotal evidence indicates that students responded favorably to the videos, and that they felt the videos were beneficial.

Khan Academy in Chilean classrooms. In the fall of 2014 researchers Daniel Light and Elizabeth Pierson from the *Educational Development Center: Center for Children and Technology (USA)* traveled to Santiago, Chili to assess the effectiveness of Khan Academy in five Chilean schools, and to generate a set of best practices for Khan Academy implementation. Research on this topic had not been conducted previously in South America - The Khan Academy website showcases several classrooms, including one from Peru, but provides no data or instructions on implementing Khan Academy in a classroom.

The five schools with which Light and Pierson (2014) worked were part of a non-profit group called Sociedad de Instrucción Primaria (the Society for Primary Instruction, or SIP), whose mission is to educate at-risk populations. Mathematics teachers at these SIP schools were part of a professional learning community that was piloting Khan Academy in their classrooms. Students in the experiment were in fourth through twelfth grade, and eight teachers, six administrators, and 32 students were interviewed regarding their experience with Khan Academy (Light & Pierson, 2014).

Teachers in this study used Khan Academy in their classrooms as a learning tool so that students could practice skills and develop procedural fluency, but it was not used as a direct instructional tool, unlike Menzi High School or Los Altos [see next section]. They used Khan Academy for two main purposes: to reinforce recently learned material, and to remediate and revisit older material. Light and Pierson (2014) note that like their United States counterparts, Chilean teachers keep all of their students moving at a prescribed pace, though they hope to soon redesign the curriculum to allow students to proceed at slower or faster paces as needed (Light & Pierson, 2014).

Light and Pierson (2014) observed that utilization of Khan Academy allowed students to have increased instruction time with math, and it promoted both engagement and learning (p. 114). Students who completed non-Khan Academy math labs would often chatter about unrelated topics, and they often shared answers with one another as they worked. By contrast, students in a Khan Academy lab were each presented unique problems to solve, so they were forced to explain mathematical procedures to one another (p. 109). Researchers also observed that self-regulated math learning was a motivator. Chilean students, when given the opportunity to take control of their own learning, would work hard to earn the check ✓marks, points, and badges available on the Khan Academy website.

Light and Pierson (2014) emphasized that unlike other studies in the United States that examined the use of Khan Academy, teachers in Chili did not fully *flip the* *classroom.* Rather, they utilized Khan Academy as a supplemental resource to remediate, reinforce, and extend math lessons. The Chilean math teachers found the program useful in that capacity and intend to continue to use Khan Academy as a supplemental tool in years to come.

Khan Academy and Los Altos. One of the earliest experiments of adding Khan Academy to a classroom was performed in Los Altos, California, and was overseen by Kahn himself. Prior to the Los Altos project, Khan (2012) had experimented with summer enrichment camps and other opportunities outside of a formal education setting, but this was the first time that he had been invited into a standard classroom. Beginning at the end of November, 2010, two fifth grade and two seventh grade math classrooms were taught purely through Khan Academy. Students were given the opportunity to work at their own pace, and teachers were able to monitor their students' progress and intervene when necessary. If a student began to struggle, or multiple students were struggling through a single topic, a teacher would tutor the single student or create a small-group lesson. Students who were not hindered by the concept could move on to more advanced material. Students were expected to work on Khan Academy during their math hour, but they were encouraged to do additional work outside of class as well. To accommodate students without internet access, the school kept its computer lab open for several hours after the normal school day. The fifth grade classrooms were heterogeneous with respect to student mathematical ability, and the seventh grade classrooms were homogenous and comprised of students in need of remediation.

Khan (2012) observed that student motivation increased right away once students began to use Khan Academy: "it was clear from the very start of our program [at Los Altos] that the energy level had been boosted. Kids were eager to start 'Khan time' and didn't want to go to recess afterwards. They started exploring concepts on their own; they spontaneously began helping one another. In the seventh-grade as well as the fifth-grade classes, kids were starting to take control of their learning" (p. 165). The students also felt proud to be part of the development of Khan Academy – their input molded the software. As they utilized the software more and more, students began to take ownership of their own educations and were, according to Khan, very motivated to gain mastery status of their assigned math skills. Students often went far beyond their assignments. Clive Thompson, an author for Wired Digital, observed fifth graders working on basic trigonometry at Los Altos. Even though the requisite algebra skills had not yet been mastered, Clive notes that students were able to pick up on patterns in mathematics and were able to work towards a mastery of basic trigonometric ratios (Thompson, 2012, p. 1).

Thompson (2012) attributes part of Khan's success to the way he built the product: students feel that they have a personal tutor to whom they can turn as needed. "Teachers have long known that one-on-one tutoring is effective, but in 1984, the education scholar Benjamin Bloom figured out precisely how effective it is. He conducted a metastudy of research on students who'd been pulled out of class and given individual instruction. What Bloom found is that students given one-on-one attention reliably performed two standard deviations better than their peers" (p. 2). Thompson also applauded the format and amount of data generated by Khan

Academy. Teachers were able to keep track of student progress and intervene as needed. One of the seventh-grade teachers, Courtney Cadwell, compared Khan Academy to a typical Prussian Model environment: "In those, I give a quiz or a test and I'm blindsided when they don't know something – or when they ace something" (p. 4). Now, Ms. Cadwell can access student understanding statistics with a few clicks on the Khan Academy website.

Salman Khan was admittedly nervous about the results of the Los Altos experiment. Despite their completely new educational paradigm, the Los Altos students were still bound by state standardized tests. Luckily, Khan (2012) was met with happy news! Previously, 91% of the fifth-grade students had scored "proficient" or "advanced" for their grade level. This value rose to 96%. This result brought credibility to the program – at least the scores didn't fall. More impressive, though, were the remedial seventh-grade results. Students' scores improved by an average of 106 percent (note: not by 6 percent, but by 106 percent - over double). Most rose from "below basic" level to "basic", and a few took two or three steps to "proficient" or "advanced." Khan was ecstatic: "Our underserved, underperforming, and purportedly 'slow' kids were now operating at the same – or higher – level as their more affluent peers" (p. 168). These results supported Khan's hopes that his software could help underperforming students catch up to their higher performing peers.

The results of this experiment in the four classrooms sparked a district-wide initiative, and the 1200 students in Los Altos district joined 10,000 other teacher-led classrooms and 350,000 students around the world who were picking up Khan

Academy in its early stages. This experiment confirmed for Khan what he already believed: that a flipped classroom with personalized instruction, student-based activity, mastery learning, and the frequent review of basic concepts before progressing to more advanced material is a wildly effective way to educate children.

Khan and his staff continue to work with schools, offering help and refining the Khan Academy software. In a 2013 article in Educational Leadership, Khan and his school outreach coordinator Elizabeth Slavitt examined schools around their area that had implemented Khan Academy in different ways. At Summit San Jose School, ninth-grade teachers had utilized Khan Academy as a central resource for their lessons. Unlike the Los Altos experiment, San Jose students were taught as a group of 200, with multiple teachers in the room (as Khan recommends in his *The One World Schoolhouse*). At the end of the year, the ninth-graders scored in the 85th percentile for student growth according to the Northwest Evaluation Association's Measures of Academic Progress (MAP) exam (Khan & Slavitt, 2013, p. 30). This exam is, incidentally, the same one my colleagues and I used in 2012-14 for our research.

Criticism of Khan Academy. As with any educational paradigm shift, the implementation of Khan Academy in schools has met some criticism. In an interview with Wired Digital magazine, educational consultant and technology advocate Gary Stager claimed that "Khan Academy isn't innovative at all. The videos and software modules are just a high tech version of that most hoary of teaching techniques – lecturing and drilling. Schools have become 'joyless test-prep factories'" (Thompson, 2011, p. 5). Sylvia Martinez, the president of Generation YES

– a non-profit group that helps to implement classroom technologies – agrees with Stager, arguing that Khan Academy is simple rote learning. Critics' arguments are understandable; computerized education may teach a procedure well, but little opportunity is presented for truly innovative thought. It is important to recognize, though, that Salman Khan does not promote a classroom that is completely computer based. Rather, only one fifth of the day in Khan's (2012) ideal schoolhouse would normally be dedicated to computerized lessons. The remaining four-fifths would be composed of lessons, projects, labs, etc., at which students could creatively express themselves and learn through experimentation.

Other critics of Khan Academy mention the inertia that pushes against such large change to instructional methodology. Rather than preparing a single lecture and accompanying worksheet, teachers have to pour over data coming in from Khan Academy and generate personalized plans for students accordingly. Khan and Slavitt admit "at first, it was jarring for the teachers to have students working on different content in one classroom. After all, as opposed to the approach of Summit San Jose in which a team of several teachers work with 200 students, at Eastside College Preparatory School there was still just one teacher in a room full of students. It was challenging to preplan lessons when students were working at different levels" (Khan & Slavitt, 2013, p. 30). The solo teachers at Eastside found it difficult to address the needs of all their students. Even the successful Los Altos teachers acknowledge that they felt (at first) they had less control over what their students had learned (Thompson, 2011). Additionally, researchers in a 2011-13 study of 20 United States schools criticized Khan Academy, claiming the website changed too frequently for teachers to become comfortable with the format (Murphey, Gallagher, Krumm, Mislevy, & Hafter, 2014). For Khan Academy to be a more widely-accepted technology in the classroom, Khan, along with teacher training groups, will need to address these perceived shortcomings of the software.

Khanclusion

Clearly additional research is needed to identify a set of "best integration practices" as Khan Academy is incorporated more and more into the standard school setting. Even Khan (2012) admits in his book's conclusion: "Is Khan Academy, along with the intuitions and ideas that underpin it, our best chance to move toward a better educational future? That's not for me to say" (p. 253). Khan does not know if his work will revolutionize education; his hope is that educational institutions will try the software and judge for themselves. Additionally, work needs to be done to educate educators on integrating technology (specifically Khan Academy) in the math classroom. The educational paradigm shift is large and overwhelming for many teachers.

Despite initial apprehension and various criticisms of Khan Academy, though, Los Altos teachers and their counterparts around the world were able to adapt their teaching styles, and their fears about the program were alleviated when they saw dramatic results in student performance. Khan Academy has been implemented in different ways in a variety of settings, both as a primary instruction device and as a supplemental tool in a variety of settings, and it has proven to be a positive experience for teachers and students alike. Critics like Murphy et al. (2014) do agree that using Khan Academy as a supplemental resource is an effective way to practice procedural aspects of mathematics, and they admit that it has been shown to boost test scores. Moreover, it accelerates the learning of basic skills so that students have more time to work on advanced material. The next section examines how technologies (i.e. Khan Academy) can affect student motivation and critical thinking.

Technology, Student Motivation, and Critical Thinking

The Khan Academy platform is still fairly new, and its full potential as an academic resource is yet to be fully uncovered. In the following sections I examine the large question of how technology in general affects student motivation and critical thinking skills. I also look at teachers' experiences incorporating various technologies in the classroom, their feelings towards technology, and what road-blocks hold back the popularization of tech-centered classrooms.

Technology and Student Motivation

When implementing a new technology, teachers tend to be cautious about its effects on their students – will students be more motivated to learn, or simply more distracted? Like Khan, researchers An and Reigeluth (2012) support the notion that technology-enhanced, learner-centered classrooms increase opportunities for students to be active, and in doing so, promote self-regulation in students. As teachers utilize technology (i.e. Khan Academy or other platforms) they become "facilitators of knowledge, rather than transmitters of knowledge" (An & Reigeluth, 2012, p. 55). Teachers gave responsibility and some control over education to their students, and as a result, An and Reigeluth found that students felt empowered and motivated to take charge of their own educations.

In a study of the integration of the Geogebra software package into a geometry classroom, researchers Lyublinskaya and Funsch (2012) found that dynamic geometry software could have an effect on student motivation. In their experiment, they created several activities that students could go through to develop their knowledge of geometric proofs. Lyublinskaya and Funsch found that utilization of Geogebra helped students break large problems into smaller, tractable parts, and that students gained ownership of problems they were solving. Student motivation was increased as students fully realized their mathematical ability. Nepalese researchers Mainali and Key (2012) had similar findings, noting that students' enthusiasm for mathematics grew as technology like Geogebra was introduced to their otherwise non-technological classrooms. Students enjoyed the ability to manipulate figures, and in doing so were able to examine how changes in some properties of a geometric figure trigger changes in other properties.

Technology and Critical Thinking

In addition to student motivation, critical thinking is also promoted through use of technology in the classroom. Lyublinskaya and Funsch (2012) found that students who used Geogebra, TI-Nspire or Geometer's Sketch Pad software packages were more apt to identify patterns and develop geometric proofs than their counterparts who learned proofs through observing static images on paper. There was value, they argued, in teaching geometry using computer-aided proofs, since the computer-aided manipulatives often helped with students' inductive reasoning. "Proof by induction is an important and challenging topic. The ability to present it in a partially geometric context and to have the algebraic manipulation done automatically should have significant pedagogic benefits" (p. 454). Students who are given the electronic means to manipulate geometric figures and related algebraic equations, Lyublinskaya and Funsch (2012) argued, are liable to learn proof by induction more readily. Lyublinskaya and Funsch (2012) also found that complex proofs were more accessible to students when presented in a dynamic way using, computer-driven geometric representations.

It is important when teaching mathematics to allow students to identify patterns, and then to question why those patterns exist. An example I use in my math class relates to the number of vertices in an n-dimensional cube - as students develop multi-dimensional cubes, they begin to realize that the number of vertices goes from 1 to 2, and then to 4, 8, 16, 32, 64, etc. – they recognize that the number doubles each time. Similar patterns emerge for the number of edges and faces of n-dimensional cubes. Though students can draw these objects, they are best visualized through a software package like Geogebra or Geometer's Sketch Pad. Professors Arzarello, Ferrara, and Robutti (2011) of the University of Turin agree, and see real benefit to allowing students to explore geometry through use of electronic manipulatives before making conjectures: "the use of dynamic representations in modelling situations enhances the dialectic between the empirical side and the theoretical side of the mathematical objects" (p. 21). Through the assistance of computers students are able to identify patterns, and then they are required to think critically about why the particular patterns exist.

Teachers' experiences with implementing technology in the classroom

As evidenced in the previous two sections, technology, when incorporated into a classroom correctly, can improve student motivation and critical thinking skills. However, not all teachers embrace the use of educational software packages in their classrooms. What road-blocks prohibit teachers from moving forward with classroom technology integration?

Through a survey of 126 K-12 teachers, An and Reigeluth (2012) found that many teachers support the use of technology with an average rating of support of 4.83 on a 5-point scale, but they felt uncomfortable or ill-informed when implementing technological changes in the classroom. Close observations on a Likert scale and survey indicate that seminars on classroom technology use are too fast-paced and cover too much in a short amount of time. Teachers who are not familiar with technology already feel overwhelmed at seminars. The results indicate that teachers need more training on learner-centered instruction, and that developing a sense of community around integration of technology could greatly impact teacher perceptions of technology use in a positive way. An and Reigeluth conclude that for large paradigm shifts in education to occur, a great deal of time would need to be invested in teacher training and in changing school structure and environment.

Wright and Wilson (2011) also examined teachers' perceptions of technology integration and use in their classrooms. Through interviews of 10 fifth-year teachers, they found that younger teachers could demonstrate technical knowledge of technology integration through their electronic portfolios as soon as they graduated. These teachers were tracked over five years and assessed on their *phase* of technology usage (familiarization, utilization, integration, reorientation, and evolution). Wright and Wilson found that though many teachers were proficient users of technology, only one was on the fifth phase (evolution, continuing to evolve and adapt technology). Three were on the fourth, five on the third, and one on the second phase. This further supports the idea that professional development opportunities are critical to encouraging teachers to adapt to new technologies: even younger teachers are not likely to do it on their own.

Two large issues are cited by teachers reticent to incorporate technology in their classrooms. First, they feel underprepared (An & Reigeluth, 2012). They feel that instructional sessions for teachers are too fast-paced and cover too much material too quickly. Teachers are not afforded the time necessary to use the technology and to reflect upon it. Teachers need a greater amount of time to become accustomed to software, as well as time to discover how they can incorporate it into their lessons. Second, many teachers do not have easy access to technology (Wright & Wilson, 2011). Teachers complained about a range of issues from not having WiFi in the classroom to having only two outlets to power three devices (computer, projector, and printer). All participants continued to seek professional development, but technological barriers prohibited many participants from reaching the fifth phase of technology integration.

Eristi, Kurt and Dindar (2012) studied issues in incorporating technology into the classroom. They interviewed 21 teachers and collected data via focus groups. They used thematic analysis to group participant responses. The most prevalent groups of responses centered around failure to keep up with current technologies, lack of computers and internet in the classroom, and technical faults caused by incorrect use of technology (i.e. programs "not working," etc.). These authors' conclusions were similar to An and Wrights' conclusions: staff need better technological support and access to technology, as well as time to implement new ideas. All found that when technology was implemented properly teacher satisfaction and student achievement increased, and both teachers and students became more interested in the subject matter.

Finally, Mainali and Key (2012), two educational researchers in Nepal, examined the implementation of the Geogebra software package in developing countries, particularly in Nepal. The purpose of the study was to examine if, with training and internet access, teachers of mathematics could use the tool to illustrate geometric concepts to students. Professional development was available for teachers in the form of workshops where teachers had instruction and time available to experiment with the software. Mainali and Key found that participants learned how to use the software very quickly and enthusiasm for the software grew as teachers experimented with it. In addition, student enthusiasm for mathematics increased and teachers reported that students appeared more confident in their mathematical abilities as they used Geogebra in their math classrooms. This study further supports the idea that the availability of suitable technology in the classroom, combined with the proper training of its users, can result in very positive impacts on education.

In this section methods of teacher education and training were examined. The next section examines the various ways in which technology can be incorporated into the classroom for students.

Charter Schools and the Blended Learning Model

Salman Khan's notions of an ideal school are radical, and they require significant alteration of the status quo. Fortunately, not all of his ideas are new, and many other educators have implemented similar projects successfully. The Blended Learning model, which encourages presenting material to students in a variety of formats (including digitally), closely resembles the fantasy school system Khan wants to build. In the following sections I make a case for Blended Learning and look at different Blended Learning models. I then examine various situations in which Blended Learning has been implemented and tested.

The need for newer learning models. It is no secret that brick-and-mortar schools with lecture-and-test lessons are often drab and unengaging. The Prussian Model described in chapter one was successful in creating a literate and compliant generation of citizens, but it has done a poor job at tying subjects together or creating critical thinkers. Additionally, owing to strict time constraints, the Prussian Model leaves holes in students' understanding and ability to apply what they learn in school, and it fails to equip students with the twenty-first century skills they need to be successful.

Khan proposes an environment in which basic facts are learned by rote memorization quickly and wholly (no Swiss Cheese Learning), then reviewed with minimal time and effort just often enough to be maintained (mastery learning). This procedure allows students more time to learn about more complex topics in an active way. As Khan (2012) says:

> I hope it is clear by now, it was never my vision that watching computer videos and working out problems should comprise a kid's entire education. Quite the contrary. My hope was to make education more efficient, to help kids master basic concepts in fewer hours so that more time would be left for *other* kinds of learning. Learning by doing. Learning by having productive, mind-expanding fun. (p. 149)

In Khan's ideal world, which he tested successfully in a summer program (Khan, 2012), students would spend some amount of time working on rote skills through Khan Academy, but much of the time at school would be devoted to educational, critical-thought-provoking games. Students could learn about physics principles like torque or traction by building robots, or about psychological principles through a board game Khan calls "Paranoia Risk." Students in Khan's summer program were excited to discuss economics, and they dove into very deep topics about human inclinations and behavior after playing a stock market simulation game with one another. (Khan, 2012) These experiences allowed students in Khan's summer camp to break out of the drudgery of listen-and-regurgitate learning, and allowed them to think independently and innovatively.

It is this kind of mindset that educational researchers from the Wisconsin Policy Research Institute are trying to bring into United States public schools. Researchers Michael Horn and Meg Evans lament that our students are surrounded by new technologies and innovation every day, but the "American School system has continued to rely on an anachronistic factory-based model" (Horn & Evans, 2013, p. 16). They, like Khan, point out that "The systems in place in urban school districts around the country were created in the early 1900s to serve a different time with different needs" (p. 2). But according to Khan, "Among the world's children starting grade school this year, 65 percent will end up doing jobs that haven't been invented yet" (Khan, 2012). We must prepare students not just with modern skills, but with the ability to adapt to new situations, think critically, and create innovative solutions to problems. Students need time and opportunity to create and innovate, but they are not afforded them in the current educational models. This opportunity can be afforded to students through a variety of learning models.

Various models of Blended Learning. *Blended Learning* is not well defined – at least, not all school systems subscribe to the same model when talking about Blended Learning – but the central idea for each Blended Learning model is the same: some portion of instruction should be delivered digitally, and students should have some control over the pace and nature of their learning. Christensen, Horn, and Staker (2013) of the Clayton Christenson Institute for Disruptive Innovation find that four basic models of Blended Learning are seen in newer charter schools around the United States: Rotation Models, Flex Models, A La Carte Models, and Enriched Virtual Models. All incorporate new technology and teach critical thinking skills, but implement them in different ways.

Rotation Models of Blended Learning involve students rotating between several learning activities, at least one of which is an online activity. This model is considered a *hybrid* model because it can be incorporated into a traditional learning environment without great difficulty, and it retains many characteristics of a traditional classroom. Christensen et al. (2013) break the Rotation Model into four sub-models, all of which share similar characteristics. In a Station Rotation Model, students rotate between in-class learning activities. In a Lab Rotation model, students flip between their classroom and an online learning lab. These first two models are similar to what Salman Khan describes in *The One World Schoolhouse*, though they do not provide individualized instruction. In a flipped classroom, on the other hand, stereotypical in-class work and homework are interchanged, and online lessons are watched at home, while practice, group projects, etc., are completed in the classroom under a teacher's guidance. Finally, an Individual Rotation Model is similar to the others, but with an individualized component. Here, a student may rotate to only a select subset of stations based on need and ability.

Unlike the various Rotation Models, which are hybrid models, the other three models that Christenson et al. (2013) define are more *disruptive*. That is, they require a complete reworking of the classroom. Technology is not just incorporated into the classroom – it becomes the central focus.

In a Flex Model students complete all of their work digitally, and at their own pace. They continue to complete their work at school, and they are observed by an on-site teacher who can intervene as necessary. The Los Altos experiment falls into this category.

The final two models, A La Carte and Enriched Virtual, each involve a component of off-site online coursework. In an A La Carte model students take some courses completely online and others completely in a brick-and-mortar building. In an Enriched Virtual environment on the other hand, each course is broken into on-site/face-to-face and off-site/digital components (Christenson et al, 2013).

Case studies in Blended Learning. Some of the Blended Learning models described by Christenson et al. (2013) are still in their infant stages, though most show great promise. The flex model, which was implemented at Los Altos schools under the supervision of Salman Khan helped to bring low-performing, low-socioeconomic status students to or beyond the ability level of their affluent peers (Khan, 2012; Thompson, 2011). While it was hard at first for teachers to adapt to this disruptive model, with support they eventually became comfortable with taking on the role of a coach, rather than a direct instructor. This experiment gave validity both to Khan Academy and to the Flex Model for Blended Learning.

What about the individualized, Rotation Model-based classroom that Khan promotes in his book? A classroom very similar to Khan's has been tried, with great results (Horn & Maas, 2013). Rocketship Education Charter Schools in Palo Alto, California utilize a Blended Learning model where students rotate between a more traditional classroom structure and online learning. The online learning "is delivered in a learning lab in two-hour blocks and monitored by instructional aides rather than delivered by classroom teachers" (Horn & Maas, 2013, pp. 3-4), and covers both math and reading. Similar to Khan's ideal school, Rocketship relies on the computer lessons to "hone basic skills so that teachers in the traditional classes can focus on higher order thinking skills." Rocketship has seen promising results: 75% of their students are English Language Learners (ELL's), and 90% are eligible for free or reduced lunch. In spite of these potential disadvantages, Rocketship boasts 90% proficiency in math, and 83% proficiency in English – this is far above other schools in the same district that have similar populations of students.

Horn (2012) examined another school system that is beginning to use Blended Learning in a different, though effective way. In New Orleans, two fulltime state-wide charter schools have opened with a goal of offering academic credits to populations that otherwise struggle to get them: homeschooled students, students who are seeking advanced courses, and students who failed a course, and are looking for remediation. This model falls under the A La Carte model described by Christensen et al (2013). Horn claims that the online offerings currently available, as well as those that are in the works, allow students to work at their own pace and provide personalized attention that students may not otherwise get in a set-paced traditional classroom. Horn notes that much work needs to be done, but supportive legislation from the state is making it possible to make learning accessible to students who would otherwise not have the opportunity. Preliminary results are promising: students enrolled in an online Algebra 1 course in Louisiana outscored the statewide average on a statewide end-of-year exam. However, sample sizes are small, and results are not statistically significant (O'Dwyer, Carey & Kleiman, 2007).

Implementation of Blended Learning. Disrupting the status quo is no simple task. Educational institutions that attempt to implement a disruptive Blended Learning model for education often receive push-back from students, teachers, parents, and administration alike. It is hard to let go of our tried-and-true Prussian education model in favor of one that may look and feel different and chaotic. However, students today need more individualized attention, and they need more opportunities to develop higher order critical thinking skills, and that is something our Prussian system fails to do (Khan, 2012).

Fortunately, it only takes a single teacher to start a trend. Through *sustaining* (non-disruptive) Rotation models, teachers can show that technology integration is effective in their classroom. They can flip classrooms, utilize a Station Model, or create a Lab Rotation Model without much push-back from invested parties (Christenson, Horn, & Staker, 2013). They can use data from these experiments to demonstrate the benefits of Blended Learning.

In order to further the use of the Blended Learning Model, though, Christenson et al (2013) note that buy-in needs to occur at a district level. They recommend that schools create a team that works autonomously from the traditional classrooms, and that they use that team first of all to target high-risk students who are in desperate need of individualized instruction. As they find success they can begin to target the general population. This is a point at which family support is necessary. Throughout the development of individualized Blended Learning Models in a school, Christenson et al. recommend that top administrators support and "ruthlessly defend" the project.

Educational paradigm shifts are never easily made, and issues often come up at the state legislative level. In order to overcome these issues, Horn and Evans (2013) suggest that radical change needs to occur. Educational institutions will be met with opposition without proper state support. Unfortunately, educators are consistently met with roadblocks. In an examination of Milwaukee public schools

Horn and Evans cite a heavily bureaucratic school leadership group, along with lack of funds and lack of technology standing between students and opportunities for innovative instruction. In a different study, Horn (2012) found that radical changes in Louisiana were the direct result of legislative encouragement and action. Clearly much work and tremendous buy-in needs to occur at the classroom, school, district, and state levels to make Blended Learning models commonplace.

CHAPTER III: METHOD

Introduction

This action research project was completed at a Midwest performing arts charter high school in an urban setting, henceforth referred to as "Arts High School" (AHS). The goal of the project was to compare student performance in AHS math classrooms that did, and did not, incorporate Khan Academy software. The mission of AHS was to provide pre-college and pre-conservatory training to high school students, at the same time allowing them time away from school to work with local performance groups. Students were allowed, provided they maintained strong academic performance, to take time away from school to work as an apprentice with a local theatre or dance studio. In addition to four arts courses, students took standard academic courses (Math, Science, English, Social Studies, etc.). Students at AHS come from 80 different cities, both urban and rural. The student body is approximately 70% female and 30% male, with approximately 27% students of color (16% Black, 5% Asian, and 6% Hispanic). The total population at AHS was approximately 600 students in 2014, when this study was implemented.

The student body was diverse, both in socioeconomic status and in academic ability. Traditional school systems have the luxury of standardizing continuous curriculum across junior high school and high school. AHS did not have that luxury; students came from 80 different junior high school settings, having experienced a variety of curriculums. In order to place students into math courses appropriately, incoming students took the Northwest Evaluation Association (NWEA) "Measures Academic Progress" (MAP) exam. The NWEA provides statistical information on student performance per grade level on the MAP test; that information was used to place students. Students were placed into math courses based on a combination of previous courses taken, and MAP scores. For example, a student with Algebra experience and a score between 235 and 245, which equates roughly to "9th grade ability level", would be placed in a geometry course. Students who scored higher were placed in Advanced Geometry or Algebra II, whereas students who scored lower (than a 9th grade equivalency) required remediation.

Khan Academy software was implemented during the 2013-2014 school year, both as a central remediation tool in the remedial Math Skills classroom, and as an enrichment resource in the Geometry classroom, and data from both courses was collected. Both course offerings are described in more detail below.

The Geometry Classroom

I taught the geometry course at AHS each year between 2010 and 2014. The first year that I taught the course it was clear to me that students were not placed appropriately. Many students failed the course due to under-preparation, and many others complained of boredom – they felt the class went too slowly. After looking at MAP data I found a strong correlation between MAP score and the grade that students earned in geometry. Students with scores above 245 tended to earn an "A". Students with scores of 240 to 245 tended to earn a "B". Those with scores of 235 to 240 tended to earn "B" or "C" grades, and half of students with scores of 230-235 failed the course. No student with a score below 230 passed the course. It was clear to me that students who scored below 235 suffered from what Khan referred to as Swiss Cheese Learning. They were deficient in basic arithmetic and algebra, and so had trouble grasping more advanced material. To combat issues that arose with misplacement an Advanced Geometry course was created for students with scores above 245 and students who scored below 235 were placed in remedial math courses (described below).

The curriculum that I used in geometry changed drastically between my first and third years teaching the course, but was kept relatively static between my third (2012-13) and fourth (2013-14) years. The one main aspect of the geometry course that changed between those two years was the inclusion of Khan Academy in 2013-14.

I used Khan Academy it two ways in the geometry course. First, I used it as a review tool for recently learned material. Before taking a unit exam (approximately one in every 10 days) my students worked on Khan Academy exercises in the computer lab. Students would be assigned Khan Academy exercises to complete related to the unit's material. I would choose these exercises based on formative assessments the students had taken throughout the unit. If a student exhibited understanding of computing the perimeter of a regular polygon, but struggled to find the area, they were encouraged to review area material. Second, I used Khan Academy as a remediation and extension tool. Students who exhibited full understanding of material on formative assessments were encouraged to work on more advanced material. For example, students who mastered basic trigonometry were encouraged to work though exercises related to the Law of Sines. By the same token, students who struggled with trigonometry because they lacked mastery of the arithmetic of fractions were encouraged to work on elementary fraction exercises. I was able to monitor student activity through the Khan Academy teacher interface, and intervened when I found students who were struggling.

Beyond our "Khan Days" students were offered extra credit for earning mastery status on Khan Academy lessons of their choosing. Many students took advantage of this offer. This helped particularly with students who suffered from Swiss Cheese Learning. The students and I were able to identify their deficiencies in Algebra or arithmetic, and I recommend Khan Academy lessons accordingly.

It is important to note that in the geometry classroom Khan Academy was used as a supplemental tool, and not as primary instruction. Students continued to learn in a traditional manor, with lectures, activities, and practice exercises, and used Khan Academy to remediate and extend lessons.

The Math Skills Classroom

The Math Skills course was a new course offering as of the 2013-14 school year at AHS. Students placed in Math Skills were those who were not prepared for a 9^{th} grade math curriculum as determined by the NWEA MAP test. Student ability ranged from MAP scores of 170 (approximately 1^{st} grade ability level) to 235 (approximately 8^{th} grade ability level).

In prior years many things had been tried to address the needs of low-performing students. Courses like Intermediate Algebra, or Geometry Basics, or Algebra I with Math Lab components were attempted with little success. Students in these courses made little progress (see Chapter 4, figure 5), and were not prepared for the 9^{th} grade geometry course the next year. Forty percent of students who took a remedial course did not pass 9^{th} grade geometry in the subsequent year, and few earned higher than passing marks. One teacher of the remedial courses identified the same issue that Khan (2012) had: “These students are simply not ready for Algebra or geometry. How can they pass either of those courses when they don’t have basic arithmetic skills or number sense?” (S. Kemp, personal communication, January 8, 2014). Though students were passing their respective remedial courses, they still lacked the basic skills necessary for more advanced courses like geometry.

In 2013 our math department at AHS decided to break the vicious cycle of “remediate, fail, further remediate,” with a goal of identifying individual academic weaknesses in students and preparing them properly for high school math courses. Khan Academy was chosen as a primary instruction tool for the Math Skills course, and we developed a Flex Model-style course modeled after Khan’s experiments with the Peninsula Bridge Camp, and Los Altos school district. Like Khan’s students, our Math Skills students began with basic arithmetic and worked towards more advanced skills. After earning mastery-level recognition on Khan Academy at each grade level (1st, 2nd grade, etc.), students were given short assessments to verify their understanding.

Minimal amounts of group-work and lecture were used in the Math Skills courses. Students were all at very different ability levels, and struggled with different things. Similar to the teachers at Los Altos, though, my colleagues and I were able to identify students who were struggling in our course, group students by the topic with which they struggled, and offer small remedial lessons accordingly. Per Khan’s (2012) recommendation, seniors at AHS periodically tutored in the classroom. As Khan predicted, this resulted in Math Skills students behaving more maturely and both parties benefiting from direct one-on-one instruction.

Assessments

Two metrics were used in order to judge the success or failure of the incorporation of Khan Academy in the geometry classroom. First, data from the NWEA MAP exam were collected, both in the 2012-13 school year, and in the 2013-14 school year from geometry students. The changes in student scores, or growth of the student, from the fall to the spring were noted and compared. Second, geometry semester final exams, which remained identical between school years, were used to assess student understanding of geometry-specific material and data were recorded for these exams both years.

The NWEA MAP exam was used to assess the effectiveness of the Math Skills course as well. The change in NWEA MAP score of Math Skills students from the fall to the spring was recorded, and compared to score differences in students who in previous years had taken alternative remedial math courses. Anecdotal evidence from my colleagues who also taught the Math Skills course was also collected.

CHAPTER IV: RESULTS

Introduction

This research study examined what effects (if any) the introduction of Khan Academy would have on math students in an urban charter school. The research took place during the 2013-14 school year. Students in a geometry classroom, as well as those in a remedial math classroom, utilized Khan Academy as a supplemental learning tool and primary learning tool respectively. Scores from exams, final exams in geometry and NWEA/MAP exams in both courses, were collected, and scores of 2013-14 students were compared with scores of similar students from 2012-13 who had not utilized Khan Academy.

Geometry Results

Final Exam

Students in the 2013-14 geometry class took semester final exams that were identical to those taken in 2012-13. With the exception of the inclusion of Khan Academy, students experienced almost identical curriculums both years. However, students who utilized Khan Academy as a supplemental resource tended to perform better on their final exams (see figures 1 and 2). The median score on both the semester one and semester two final exams rose more than five percent ($p=0.168$ and $p=0.0802$ respectively, two-tailed t-test).

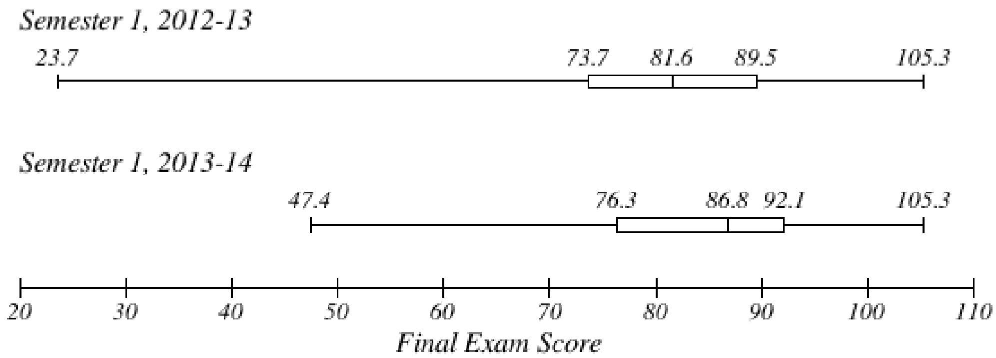

Figure 1. The range of scores on the semester 1 final exam each year.

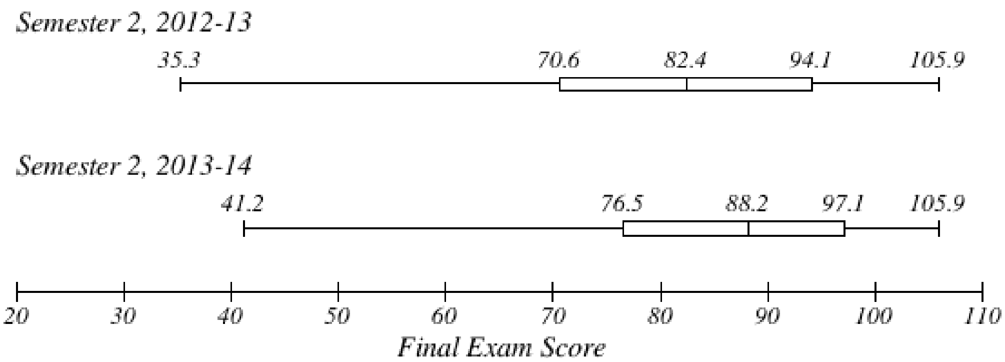

Figure 2. The range of scores on the semester 1 final exam each year.

NWEA/MAP Exams

Geometry students also took the Northwest Evaluation Association's "Measures Academic Progress" (MAP) exam at the beginning and end of the course. Growth in each student, measured by subtracting their Fall score from their Spring score, was tabulated. Some outliers existed for either extreme (growth or loss in score), but students' scores increased more, on average, in the 2013-14 school year with Khan Academy. In 2012-13, the middle half of students increased their scores by between zero and six points, with a median growth of two points, whereas the middle half of students in 2013-14 had score increases between one and 8.75 points, with a median growth of four points (see Figure 3).

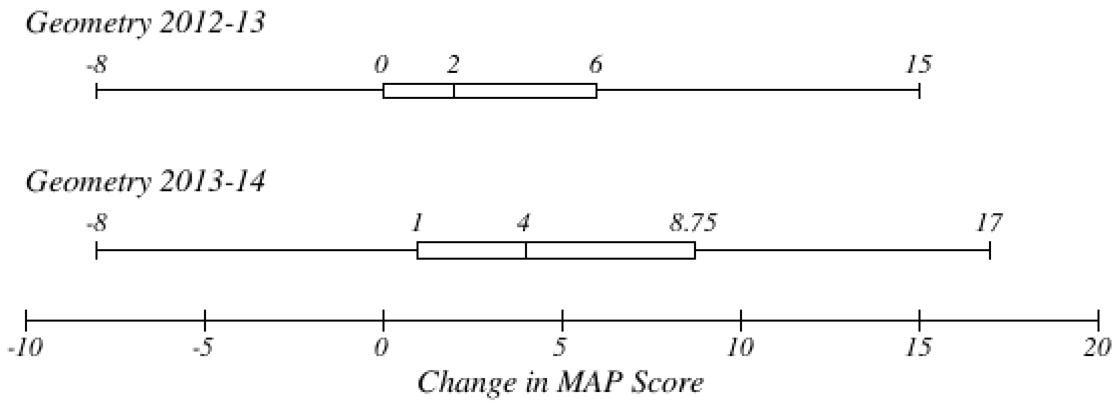

Figure 3. The change in MAP score, computed by subtracting the Fall score from the Spring score.

According to the NWEA, average students in high school are expected to show about two points of growth in a given year (Thum & Hauser, 2012). The 2012-13 geometry students followed that statistic, whereas the 2013-14 geometry students doubled it. The amount that students increased their MAP scores in 2013-14 was greater than the amount that students in 2012-13 increased their scores, and is shown to be statistically significant through a two-tailed unpaired t-test with $p=0.0013$.

Student activity information was gathered from the Khan Academy website. An extremely weak (not statistically-significant) positive correlation was found between the number of Khan Academy mastery skills students earned, and the amount by which their MAP score changed (see Figure 4).

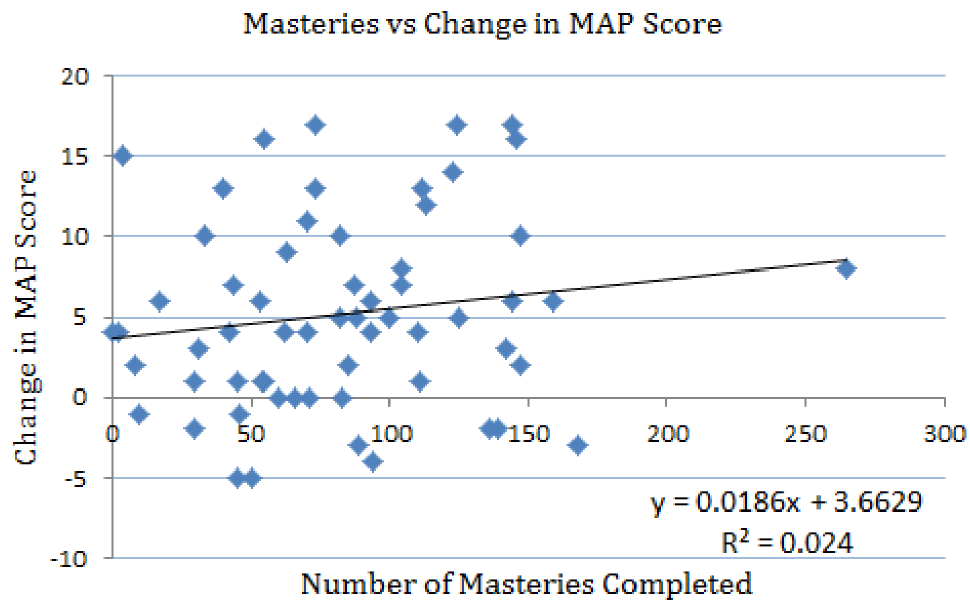

Figure 4. A comparison of change in map score against the number of *mastery-level* statuses attained.

Students who attained mastery-level status on more Khan Academy exercises tended to show greater growth in MAP score, though the correlation coefficient (r=0.155) indicates little correlation, between number of masteries completed and change in MAP score. By statistical convention, the weak positive correlation observed could be anomalous.

Math Skills Results

NWEA/MAP Exams

Similar to geometry students, remedial Math Skills students' scores were compared to the scores of students who had taken a more traditional remedial course the year before – one that did not use technology, and focused on arithmetic, and basic algebra and geometry skills.

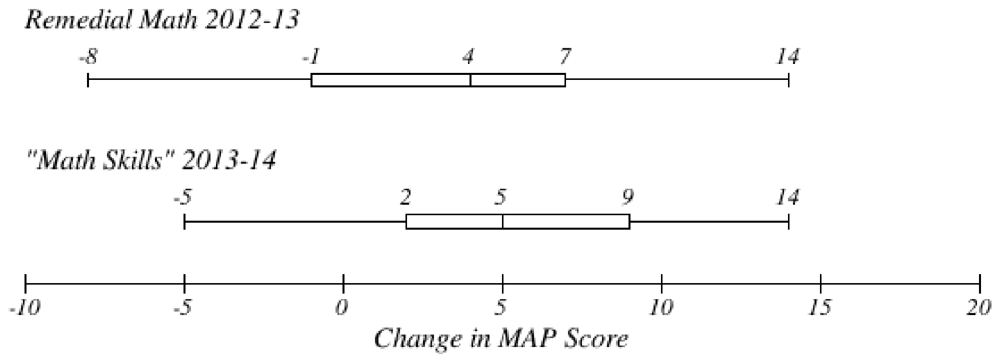

Figure 5. The change in MAP score, computed by subtracting the Fall score from the Spring score.

Though the results were less stark in Math Skills than in geometry, increases in change in MAP score were laudable. Students in the 2012-13 remedial course were more apt to show negative growth than students in the Khan Academy-based course (See Figure 5). Twenty-seven percent of 2012-13 students regressed in math ability, per the MAP test, whereas only 15% percent of 2013-14 students regressed. Students in Math Skills tended to increase their MAP score by one or two points more than their 2012-13 counterparts. The amount that Math Skills students increased their MAP scores in 2013-14 was greater than the amount that students in 2012-13 increased their scores, and is shown to be statistically significant through a two-tailed unpaired t-test with p=0. 0121.

Teacher Experience

Despite the growth seen in change in MAP scores when comparing 2012-13 and 2013-14 data, my colleagues recommended against offering a fully Khan Academy-driven course again in the future (N. Strenge & S. Kemp, personal communication, August 21, 2014). Several issues were cited, including technical difficulties (the internet, particularly first semester, worked inconsistently) and perceived student apathy towards the course. It was also difficult to teach higher-order thinking through Khan Academy. My colleagues and I agreed that Khan Academy was an effective resource for teaching basic math skills, but projects and group-work are better suited to teach more complex topics in mathematics.

Student Attitudes

Prior to taking the MAP test in the spring, teachers of Math Skills convened and subjectively classified students as 'highly-motivated', 'average', or 'apathetic' with regards to the student's attitude towards Khan Academy and Math Skills. *Highly-motivated* students were described as those who came to class each day, eager to learn, and who used their time in class appropriately. *Apathetic* students were those who became easily disengaged, or who openly refused to complete work in class. Data show that highly-motivated students increased their MAP scores more than their apathetic counterparts (see figure 6). On average, highly-motivated students increased their MAP score by eight points (approximately three or four grade levels). Apathetic students, on the other hand, remained stagnant. Their change in MAP score centered around zero, and score changes could be attributed to natural variance in exam score.

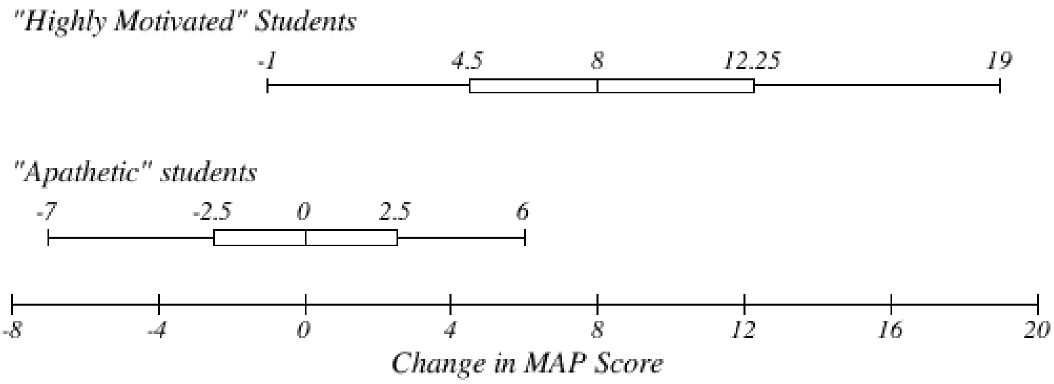

Figure 6. A comparison of the change in map score between students perceived as hard-working, and those perceived as apathetic ($p < 0.0002$ through a two-tailed unpaired t-test).

As with the geometry course, there was an extremely weak, not statistically significant (r=0.2298) positive correlation found when comparing the number of mastery skills completed to change in MAP score. No conclusion can be made due to the correlation coefficient, however.

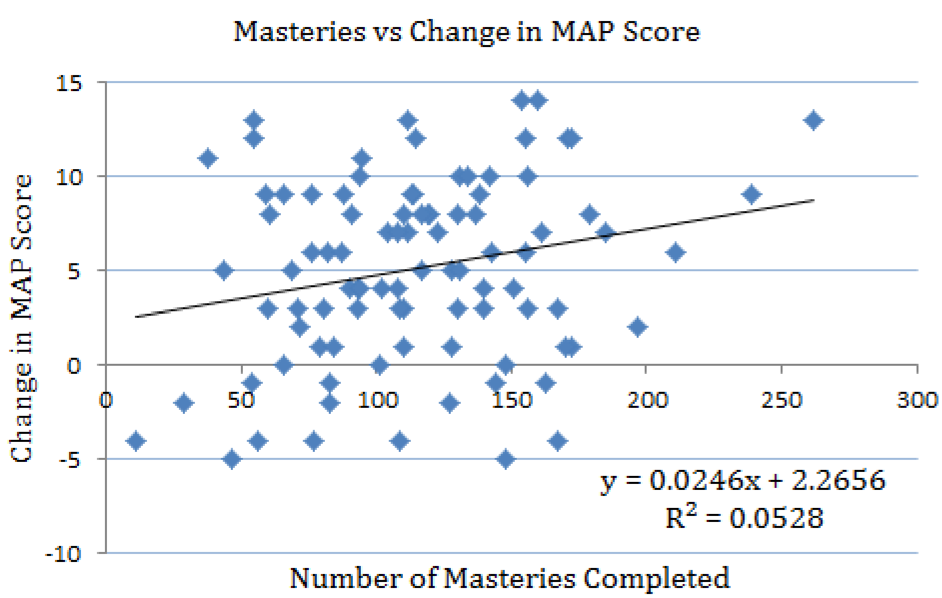

Figure 7. A comparison of change in map score against the number of *mastery-level* statuses attained.

CHAPTER V: DISCUSSION AND CONCLUSION

Summary

The goal of this thesis project was to assess the effectiveness of Khan Academy and other Blended Learning Models in the math classroom. Students in the 21st century require different skill sets than those in previous generations (Khan, 2012). They need learning environments in which basic skills can be mastered quickly and completely to allow time for opportunities to develop problem-solving and critical-thinking skills. Salman Khan believes that software like Khan Academy can help in that goal (Khan, 2012). Khan Academy can furnish students with mastery-level skills in mathematics ranging from basic arithmetic to advanced calculus in a thorough manner, addressing every student at his or her ability level. Khan Academy addresses issues like Swiss Cheese Learning by making sure students have complete understanding of a skill before moving on to the next. He also addresses the issue of pacing: students learn at different speeds, and Khan Academy addresses students' needs at a pace that will not leave the student behind, nor hinder them.

Khan Academy and similar technologies have been implemented by following a variety of Blended Learning models. Some schools like Menzi High School simply screened the Khan Academy videos, but retained most other aspects of their learning model (Barman, 2013). Los Altos teachers, on the other hand, followed a Flex Model and used Khan Academy as a central learning tool in middle school classrooms (Khan, 2012; Thompson, 2011). Chilean schools found a middle-ground with a Rotation Model, and utilized Khan Academy as a supplemental resource to develop procedural fluency, but also utilized direct instruction and group activities (Light & Pierson, 2014). Rocketship Schools also implemented a Rotation Model with Khan Academy, where online learning was delivered in two-hour blocks, and other time blocks were dedicated to creative and critical thought (Horn & Maas, 2013). Rocketship's implementation was the most similar to the ideal school Khan had envisioned in *The One World Schoolhouse.* Despite these implementation differences, results from these case studies were all positive: students tended to perform better than their peers when subjected to Khan Academy.

Professional Application

Results of this thesis' experiment were similar to those found by the Chilean schools, Los Altos, Rocketship, etc. Students at AHS who were subjected to Khan Academy during the 2013-14 school year tended to perform better on the NWEA/MAP exam than students who had taken geometry and remedial math the previous year. This indicates that a complete overhaul of a school system is not necessary to take advantage of Khan Academy; the software can be used as a supplemental tool and can be incorporated into current classrooms today. Unfortunately, no statistically significant correlation could be made relating the number of Khan Academy exercises a student had completed and their increase in MAP score. Additional research would need to be completed to identify what correlation (if any) exists.

Khan Academy in the AHS Geometry Classroom

Throughout the school year geometry students were brought to the computer lab, often before the end of a unit, to review the unit material. I used the software to assign Khan Academy modules to students based on formative assessments taken throughout the unit. Students reported through questionnaires that this strategy to be tremendously helpful. Students who had done poorly on the formative assessments were able to ask questions of me and their peers, and would generally fill their gaps in understanding by the end of a review session. Students who had performed well on the formative assessments were given extension assignments. For example, students who had done well with basic trigonometry ratios were assigned algebra II level work related to trigonometric identities. I found that the resources available on Khan Academy (videos, examples, etc.) were generally sufficient to guide the "quick-learners" through the more advanced material.

Towards the end of the school year I began utilizing Khan Academy at the start of a new unit, in addition to using it as a review resource. For example, during the unit on area and perimeter, students were brought to the computer lab to work through problems on area and perimeter of triangles, quadrilaterals, and regular polygons. In previous years three days would have been dedicated to these topics, but it had always been clear that students had seen this material previously, and some students seemed bored. When I approached the area and perimeter unit through Khan Academy, only a single additional day was needed to cement the material – students caught on quickly through active learning via Khan Academy on the first day, and needed only minimal review and additional explanation before feeling comfortable with the material.

Unfortunately, not all Khan Academy experiences in the geometry course were like this. During a unit on geometric proofs I allowed students to explore proof-based lessons on Khan Academy before they had a formal lesson on proofs. Though students knew basic terminology and theorems, they struggled with putting theorems together into coherent proofs in the format that Khan Academy requires. They learned to do proofs much more readily by doing a few as a class, and through a group activity on proofs. These experiences indicate that Khan Academy is useful for teaching basic introductory concepts quickly and thoroughly before jumping in to more advanced material in a unit, but may not be suitable for teaching material that requires strenuous critical thought, or material that is completely foreign to the student. I strongly recommend the use of Khan Academy as a review resource, and as a resource for teaching basic, rote knowledge, but recommend against using it to teach higher-order thinking.

Khan Academy in the AHS Remedial Math Classroom

The data gleaned from the NWEA/MAP exam is significant, and suggests that the incorporation of Khan Academy aided many remedial math students in a quest to fill gaps in knowledge gaps (see Chapter IV). While data gathered from the experiment at AHS is encouraging, it is important to look beyond the raw scores when assessing the success of the program. The data indicate that students with strong work ethics tended to perform very well and showed tremendous growth, but many other students found Khan Academy tedious and were obstinate. Students who disengaged readily plateaued, or even regressed in math ability. Additionally, as found in geometry, Math Skills teachers observed that students were able to learn basic arithmetic, algebra, and geometry, but struggled to learn advanced, critical-thinking skills from the software (N. Strenge & S. Kemp, personal conversation, August 21, 2014).

My colleagues and I agreed that remedial math courses should be taught in a hybrid manner. Some portion of lessons could be done via Khan Academy, especially for students whose gaps in learning center around fundamental arithmetic and algebraic concepts. Fundamental concepts are learned readily via Khan Academy. Higher-order thinking skills and problem solving, though, is better taught via group activities, projects and, on occasion, a classical Prussian-style lesson.

Limitations and Future Research

The data collected on students in 2012-13 and 2013-14 spanned only two years, and many factors including slightly smaller class sizes in 2013-14, an increase in the teaching experience of teachers in 2013-14, and access to better facilities (a new building) in 2013-14 could have contributed to the changes in data that were observed. Additionally, only weak, non-statistically significant correlations were found when comparing time spent, or number of mastery skills earned to change in MAP score. In order to validate the findings of this thesis project, further study over several years would need to be conducted wherein students are randomly separated into two groups: those who utilize Khan Academy in class and those who do not.

One of my colleagues, S. Kemp, began such an experiment in the 2014-15 school year at a new school. Students at Kemp's school were distributed randomly between teachers for an intermediate algebra course. Mr. Kemp's students utilized

Khan Academy in a similar way to how I used it in geometry; other teachers did not use Khan Academy. Preliminary data show that on common assessments, Mr. Kemp's students had mean scores that were consistently higher than their peers (see Figure 8).

	Ch 1 Test	Ch 2A Test	Ch 2B Test	Ch 3 Test	Final(Q1)	Ch 4 Test
Mr. Kemp (n=93)	86.21%	83.20%	85.18%	77.47%	87.49%	75.45%
Teacher 1 (n=30)	71.29%	77.24%	75.24%	72.26%	84.56%	73.22%
Teacher 2 (n=68)	80.36%	79.10%	81.76%	69.26%	85.21%	68.19%
Teacher 3 (n=60)	77.78%	75.04%	79.25%	73.10%	85.28%	73.53%
Teacher 4 (n=118)	79.56%	80.15%	77.15%	75.01%	86.90%	74.80%

Figure 8. Assessment data from Mr. Kemp and his colleagues' intermediate algebra students.

Khanclusion

For this thesis project I set out to identify the issues in today's Prussian-based school system, to measure the effects of incorporating Khan Academy in the classroom, and to identify a set of best practices for a Blended Learning classroom. I found that the task of incorporating Khan Academy in a math classroom was non-trivial, but worthwhile. Data indicate that use of Khan Academy aids in a student's ability to perform well on standardized exams, though anecdotal evidence shows that Khan Academy best teaches rote knowledge and higher-order thinking is best taught through other means (N. Strenge & S. Kemp, August 21, 2014). Other factors, like student attitude, have an effect on the success of Khan Academy integration, but if teachers can foster a positive classroom environment, utilization of Khan Academy as a supplemental resource can have a significant impact on student achievement.

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