ANALYSIS OF WEB-BASED ASSIGNMENT DATA REVEALS STUDYING HABITS

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This study uses qualitative and quantitative data from classroom surveys and web-based assessment to investigate the effects of the use of math-specific online content and applications by students in higher education. The data analysis highlights two principal tendencies among learners enrolled in a first-year Algebra course to complete asynchronous assignments: using Internet content as a crutch (parroting) and using math-specific applications (outsourcing). The study further discusses the impact of the tendencies with respect to learning and achievement.

1   INTRODUCTION

Technology is quickly reshaping the educational environment across the world. The image of students sitting at library tables scribbling on paper and pounding calculator keys, while surrounded by stacks of books, is being replaced by learners sitting in front of their laptops performing an assignment, while using a smartphone as calculator and a tablet as personal library collection. Best practices in pedagogy and curriculum development are also adapting to this new technological landscape. In mathematics, content and learning aids are readily and abundantly available on the Internet (Raines & Clark, 2013). Additionally, e-assessment (also known as web-assessment and computer aided assessment) has become ubiquitous and is publicly encouraged (Lewis & Tucker, 2009). We couple the analysis of e-assessment data from two semesters of an Introductory Algebra course (Table 1) with data from student surveys to address how Internet content shapes student learning with respect to time spent and outcome.

Computer technology has established itself as playing an integral role in teaching mathematics (Engelbrecht & Harding 2004) and most of the literature has focused on analyzing its benefits and pitfalls. Among the benefits of using e-assessment in the mathematics classroom are its value and efficiency (Kodippili & Senaratne, 2008). There is no need to wait for instructor feedback to find out about the accuracy of the homework. Completed problems and their solutions are automatically graded by the web-based homework system immediately upon submission (Leong & Alexander, 2014). The e-assessment platform can provide valuable time-on-task data since it allows for the instructor to monitor the time students spend practicing outside of the class and to anlyze the quality of their work (Stillson & Nag, 2009). Additionally, the majority of e-assessment platforms are able to generate focused practice material using a set of similar questions from a particular topic from large database of questions (Leong & Alexander, 2014). Web-based assessment in mathematics also appears to be influential in student academic success. In Ninguin & Horron's (2012) mathematics assessment study, it was discovered that there is a strong positive correlation between math computer lab hours and final exam scores. Other studies have shown that the e-assessment does not provide a statistically significant advantage over paper-and-pencil (Hannah, James & Williams, 2014).

Disadvantages associated with web-based assessment include learner's background discrepancy, disorientation, over-rich information and ineffective user-interface (Loong, 2010). Smith et al, recognized that online instructors feel that there are more channels of information in the web-based environment which causes more room for students to become confused (Smith, Furguson & Caris, 2003). Another disadvantage of using e-assessment is that students may find it difficult to enter responses in a particular format, the concern being that student frustration with using technology may have more to do with the technology itself than the mastering of the concepts (Leong & Alexander, 2014). There are also concerns about whether valuable skills such as the development of a mathematical argument or the exposition of a problem solution, normally conducted on paper, will be forfeited by using web-based assignments (Engelbrecht & Harding, 2004).

The overall conclusion from our literature review is that e-assessment is an established practice in mathematics for higher education, especially for beginner courses, and it is here to stay since its benefits far outweigh its disadvantages.

E-assessment is usually paired with a textbook for the course that is used on, but it is also indirectly connected with the myriad of learning tools that are available on the Internet. We aim to study the connection between e-assessment and these learning tools, but the literature on the subject is rather scarce. An interesting study by Raines and Clark (2014) analyzed the correlation between scores and learning aids for one of the major e-assessment platform. The results were based on student surveys about the use of learning aids. Their results were inconclusive on whether the learning aids had an impact on student learning (Raines & Clark, 2014). In addition to the learning tools provided by the e-assessment publisher, there are thousands of other options that are just an Internet search away. One of the most probable outcomes to such a search is a link to a Khan Academy video or tutorial, one of the most popular math websites (Thompson, 2011). These searches are often successful, allowing students to find a very similar problem to the one they are trying to solve, leading to parroting as a

result (Thompson, 2004). Other popular resources to further mudding the waters of mathematical education are what we will refer to as Math Apps (MA). These are advanced problem solvers that can be accessed through a web browser or by downloading an app to a personal device such a phone or a tablet. MA capabilities are almost limitless. For example, once the user masters how to query the system of choice, the answer to a difficult factoring problem takes a few second using Mathway (www.mathway.com), or the user can cut and paste a word problem to find its answer using Tiger Algebra (www.tiger-algebra.com). For those who have paper-and-pencil assignments, there is PhotoMath (www.photomath.net) that allows users to take a picture of a math problem that the app will promptly solve. The king of these applications is Wolfram Alpha (www.wolframalpha.com) a computational engine that can solve most, if not all, assignments from algebra to differential equations. There is no existing literature on the connection between learning and the use of math applications, although some of the issues are similar to the ones faced by educators during the advent of graphing calculators (Smith & Shotsberger, 1997). Our goal and intent is that this article will initiate a dialogue that will assist educators and curriculum designers to harness the positive learning characteristics of these new technologies and eliminate the negatives.

2 METHODOLOGY

2.1 Background

The study looks at two semesters of data (Fall 2014 and Spring 2015) from a first year Algebra course (MAT134) whose topics and assignment structure are depicted in Table 1. The course is a general education requirement for all majors, but students can opt-out of the course by earning a satisfactory score on a placement exam that is taken on-line by each incoming student during the summer previous to enrolment. The course uses (Lial, Hornsby & McGinnis, 2011) as textbook and its companion MyMathLab (Pearson, 2011) as e-assessment platform. The Fall 2014 (F14) dataset contains entries from 9 sections of MAT134 and it includes 667 students. The demographics of the F14 datasets are characterized by 86% freshmen, 67% female, 37% minorities and 25% commuters. Conversely, the Spring 2015 (S15) dataset contains entries from 8 sections of MAT134 and it includes 545 students. The learners in the Spring 2015 dataset are mostly freshmen (86%) who took a more basic algebra course during the Fall 2014 semester or students who failed to pass the course in the previous semester. The demographic breakdown from Spring 2015 is very similar to the breakdown from Fall 2014, with the lonely exception being the percentage of minority students that reaches 57% in the Spring 2015. In general, the Spring 2015 student population has a less robust mathematical background and, for this reason, we decided to analyze each dataset separately.

All of the assessment for the course is done online using MyMathLab (MML). During the 15-week duration of the course, there are three proctored summative assessments labelled Unit Exams (Table 1). Each Unit Exam week is preceded by a four week cycle. During each week of this four week cycle, the students have to complete homework (no time limit, unlimited attempts), a quiz (1hr time limit, unlimited attempts) and an exam (1hr time limit, one attempt). All problems in these

assignments use MML's random number generator so that no student receives the same exact assignment. Additionally, questions in the Quizzes, Exams, and Unit Exams are randomly scrambled and pooled. The e-assessment platform also provides tools to help students with their work. These tools are only available for the Homework portion and can be accessed within each homework exercise. The tools that are used the most are called "Help me solve this" and "Show me an example". With "Help me solve this", the system dynamically shows the student all of the steps to solve the problem at hand (same numbers). To move from one step to the next, the student will have to perform the correct calculations. At the end of the process, the numbers in the student's exercise are changed and the student can attempt the problem for credit. After clicking on "Show me an example", the student is shown the procedure to solve a similar problem with different numbers. A preliminary study of the effectiveness of these tools showed that the majority of learners felt more motivated to complete the assignments (Hodge, Richardson & York, 2009).

Table 1. Course topics and assignment distribution.

Topics	Coverage (weeks)	Take-Home Assessment	Proctored Assessment
Basic Algebra Review	1	Weekly Homework, Quiz and Exam	Unit Exam 1
Polynomials	1	Weekly Homework, Quiz and Exam	
Rational Expressions & Functions	2	Weekly Homework, Quiz and Exam	Unit Exam 2
Radical Equations & Functions	2	Weekly Homework, Quiz and Exam	
Quadratic Equations & Inequalities	2	Weekly Homework, Quiz and Exam	
Graphing	2	Weekly Homework, Quiz and Exam	Unit Exam 3
Exponential & Logarithms	2	Weekly Homework, Quiz and Exam	

2.2 Data Collection and Processing

We were able to collect quantitative data from all of the sections in the study and also some qualitative data from three sections in the Fall 2014 semester (N=172) and one section in the Spring 2015 semester (N=59). The quantitative data was obtained from MyMathLab and consists of assignment scores (Homework, Quizzes, Exams and Unit Exams), time spent on each assignment, and the last date that each assignment was attempted. Demographic data was pulled from the Institution's Learning Management System (LMS). The qualitative data was part of the in-class polls that one of the instructors regularly uses to gather immediate feedback from the classroom during a lecture. The polls were administered using PollEverywhere (www.pollev.com) a web based polling tool that allowed students to answer the poll in real time using their

personal devices, such as laptops and cell phones. We used the data from two polls from the Fall 2014 semester and two polls from the Spring 2015 semester. Each poll addresses the use of on-line learning tools and Math Applications.

The raw data was processed using Microsoft Excel to convert all times spent on assignment to minutes. We also converted to numerical values all dates representing the last time each assignment was worked. These numerical values are more easily handled than dates by different statistical packages. In addition, we removed from the raw dataset all entries that had zero scores on all assignments past the Week 3 withdrawal deadline. As a result the total number of entries for this study is 1205 students, 660 for Fall 2014 and 535 for Spring 2015.

2.3 Data Analysis

The qualitative data was used to identify the Math Applications and Learning Tools that were being used by students as well as the frequency of use. The same multiple-choice poll was given to students in Fall 2014 (November 9th) and Spring 2015 (February 10th) and its results are displayed on Table 2. The other poll from Fall 2014 (October 22nd) asked the students about their use of Mathway. A total of 172 students answered the poll: 34% said that they were not aware of Mathway, 19% said that they never used it, 42% said that they only used it to check their answer and 5% said that they always use it. The second poll, given in Spring 2015 (February 24th), was open-ended and asked the students about their approach to completing the assignments: 100% of the students used the learning tools and 35% also used Mathway.

Table 2. Results from lecture polls offered on Fall 2014 and Spring 2015. The Poll asked: "What Learning Tool Helps you the Most?"

Semester	Mathway	Show Me an Example	Help Me Solve This	Other
Fall 2014	17%	66%	17%	0%
Spring 2015	3%	76%	14%	7%

The quantitative data consists of 39 assignments and their temporal data. To reduce the number of variables we used the statistical package R to do a correlation analysis of the assignment grades. The quiz and exam scores had a Pearson correlation coefficient of 0.949. We decided to keep the exam score for the analysis and discard quiz scores thus reducing the number of assignments to 27.

The dataset shows that there are many cases where students spend a large amount of time on the homework assignments. In such cases, the homework is often last accessed after both the quiz and the exam have been completed. To analyze this behavior, we added 10 columns to our dataset, one for each of the homework. These columns contained a 1 if the homework was last accessed within ten minutes of completion of the exam, 0 otherwise.

In the effort of looking for study trends, we conducted (using R) many different statistical analyses including hierarchical clustering, k-means clustering and PCA analysis (Legendre & Legendre, 1999). We also created a different dataset in which all the time-on-task data was transformed into binary form by replacing the times with a 1 if the time spent on the assignment was on the top 50th percentile for the assignment, or a 0 if it was in the bottom 50th percentile. By rearranging the time-on-task data in this fashion, we were able to further separate students into different groups. To assess the efficacy of the studying pattern represented by each group, we compared the exam and unit exam performances.

3   RESULTS

The data from the classroom polls shows that most students are using the tools that accompany the e-assessment software, and at least one third of them are using the math application Mathway. Interestingly, only 3% of the Spring students mention Mathway as useful compared to 17% in the Fall. However, 35% of the Spring and 47% of the Fall students mention regular Mathway use to (at least) check their answers. This discrepancy can be interpreted as an acknowledgement by the students that math applications are a shortcut to get the work done in time, however do not promote better understanding. In addition to checking their answers, some students mentioned a more extensive use of Mathway while working on the assignments. We labelled these students as "Outsourcers" and we looked at their data for the ones we could identify from the polls. Intuition suggests that heavy use of math applications would lead to high grades and short times on the homework and exams, and considerably lower grades on the proctored unit exams. This is indeed what we observed in some cases such as the case shown on Table 3 with the label "Outsourcer 1". This student was able to complete the weekly homework (40-60 problems) and exam (15-20 problems) with almost perfect scores, but the performance drops drastically during the in-class exams. The student labelled as "Outsourcer 2" from Table 3 is instead able to maintain his performance during the unit exams as well. This second case suggests that some students are able to use math application to optimize the time spent on the material without sacrificing learning outcomes.

A second trend that surfaced from the polls was the heavy use of the "Show me an example" tool and little use of the "Help me solve this". Student that over-rely on "Show me an example" are constantly parroting the steps shown on the tool leading to high grades as well as high times spent on the asynchronous assignments. We labeled these students as "Parrots" and the data for two such students are shown in the last two row of Table 3. Analogously to what we observed for the Outsourcers, parroting can have a beneficial effect toward learning the material as well. This is the case for the last row in Table 3.

To validate the ideas developed through the analysis of the poll data, we applied hierarchical and k-means clustering to the full dataset for each semester. We ran multiple iterations of these two clustering methods using different setups as well as raw, scaled (using averages and max values) and standardized version of the data. Both methods did not return a meaningful partition of the data except for consistently identifying the group of learners with most difficulties in the course. We labeled this group as "Stranded" and found that a common characteristic of this group is to have a

few missing assignments.

Table 3. Typical performance of Parrot and Outsourcers highlighting that within both groups learning can occur.

Groups	Homework Avg Score	Avg Time	Exam Avg Score	Avg Time	Unit Exam Avg Score	Avg Time
Outsourcer1	99%	74 min	95%	10 min	20%	31 min
Outsourcer2	100%	90 min	96%	20 min	95%	22 min
Parrot 1	100%	270 min	91%	23 min	74%	44 min
Parrot 2	100%	296 min	88%	34 min	94%	33 min

The next step after clustering was to use Principal Component Analysis (PCA) to extract and interpret some ordination of the data. For both datasets, PCA showed that 65% of the variance is captured by the first two principal components. One of the two main principal components captured the scoring variables, and the other captured the temporal variables with no obvious trend emerging from the distribution of the data points in the principal components plane.

After unsuccessfully trying to extract trends from the raw data, we applied data-driven heuristics to manipulate the data and quantify the trends that emerged from the poll data. A common trend for the Parrots identified via the poll data was the use of the "Show me an Example" tool during while taking an exam. This learning tool is only available while working on homework problems, so the student would need to have the homework and the exam open at the same time to be able of using "Show me an example". To quantify this occurrence we generated 12 columns comparing when homework and exam were accessed last. Each column would contain a zero if the homework was closed at least 10 minutes before the exam, 1 otherwise. In addition, we transformed the temporal data into binary form (as discussed in the previous section) to create a better separation between students who are consistently spending more/less time on their assignments. We then clustered the students using the following criteria:

- **Parrots**: students whose times are on the top 50th percentile for all asynchronous assignments and for the time differences between homework and exam access (meaning that a learner was performing Quiz/Exam work with the Homework open to be able to access the learning tools).

- **Outsourcers**: students whose times are on the bottom 50th percentile for all asynchronous assignments.

- **Stranded**: students with a score of zero on at least one of the unit exams.

- **Traditionalists**: students who did not fit the previous categories.

This heuristic clustering approach captured the poll data, placing students who admitted to always using Mathway in the Outsourcers category, and assigning to the Parrots category the students who admitted to extensive use of the learning tools with all assignments. The Stranded category comprises students who would eventually fail

the course. We looked at trends within this category and it appears that students who start out as Outsourcers are more likely to become stranded than students who start out as Parrots. We labelled the last category as "Traditionalists" because it appears to represent students who approach the assignments traditionally by completing the homework and then attempting the exams. The stringent constraints of the group assignment criteria make Parrots and Stranded as completely distinct group from Traditionalists. The separation between Outsourcers and Traditionalists is not as obvious, but further analysis, including t-test scores of 3.0E-09 For Fall and 0.001 for Spring, confirms that the two groups are distinct.

A summary of some relevant group statistics for the four groups is displayed in Table 4. According to the values of Pearson's correlation coefficient for the different groups, Traditionalists have the best ability to retain their knowledge for the in-class exams, while Parrots have the least. This is an expected result since traditionalists attempt their exams using an approach that is the most similar to the in-class exams (no online learning tools or math applications).

Table 4. Summary of relevant statistics for heuristic clustering: r(E,UE) represents Pearson's correlation coefficient between the average exam score and the average unit exam score. Δ(UE,E) represents the mean difference between the average score in the unit exam and the average score in the exam.

Group	Fall 14			Spring 15		
	Splits	r(E,UE)	Δ(UE,E)	Splits	r(E,UE)	Δ(UE,E)
Parrots	26%	0.56	-0.11	22%	0.46	-0.14
Outsourcers	14%	0.46	-0.08	15%	0.4	-0.16
Stranded	7%	0.59	-0.49	13%	0.52	-0.45
Traditionalists	53%	0.6	-0.05	50%	0.73	-0.19

Figure 1 shows scatter plot and regression lines comparing average exam and unit exam scores for Parrots and Outsourcers. The scatter plots show more variability for Outsourcer than Parrots and also between Spring and Fall semesters. These visual impressions are confirmed by the regression analysis data. The R-squared coefficients for Parrots are 0.32 and 0.21 for Fall and Spring, for Outsourcers they are 0.21 and 0.16 respectively. For all groups the regression analysis shows a strong linear relationship with p < 0.001 and residual plots that are evenly distributed and absent of any significant bias.

4   CONCLUSIONS

Through various statistical methods we have been able to partition the participants in this study into four different groups: Parrots, Outsourcers, Stranded and Traditionalists. The first two groups are of particular educational interest since they represent two different and somewhat unwanted (by educator and curriculum developers), applications of technology to math courses. Parrots represent students who are using the seemingly limitless content available on the Internet as a crutch to

get through the mathematics curriculum. Outsourcers represent tech savvy students who are willing to spend a few hours to become familiar with a mathematics application and then use such application to facilitate their coursework. Both of these
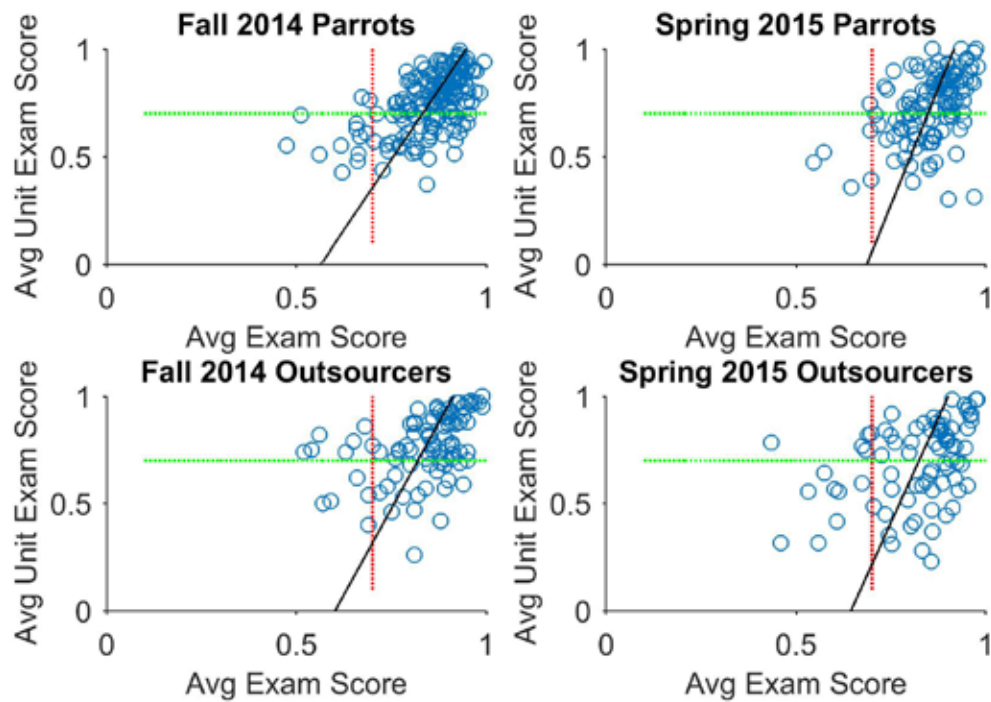

Figure 1. Scatter Plots for the Parrots and Outsources groups: each plot includes a regression line. The dashed vertical line represents the passing score (70%) threshold for the exams. The dashed horizontal line represents the passing score threshold for the unit exams.

tendencies are basically impossible to capture by using assignment scores, but most e-assessment platforms provide time-on-task data that can be used to analyze learner's studying tendencies. This data becomes important for curriculum developers so that they can design assessment tools that are more appropriate for the current technological environment. Instructors can also use this data to determine appropriate interventions with their learners. Being able to precisely and confidently suggest to students how to change their studying habits can have a powerful impact on their ability to successfully complete the coursework.

The combination of assignment scores, temporal data, and the unpredictability of college students leads to datasets that are very cumbersome to analyse. We were able to extract our groups only after combining the e-assessment with heuristic suggested by the survey data. It would be important to expand this study to minimize heuristics and maximize the robustness of data analysis. This goal could be achieved by adding more variables to the dataset. Possible candidates include quiz attempts (Hannah et al., 2014), attitudinal test scores (Mathai & Olsen, 2013) and high-school GPA. Another approach could consist of analysing and comparing student performance within each assignment. Most e-assessment platforms provide educators with the ability to extract performance data for each problem within an assignment and

therefore it could be possible to extract further differences between groups. For example, Outsourcers could perform worse than Parrots on word-problems, but outperform them on complicated factoring exercises.

The study focused on identifying learners with certain studying patterns and assessing how these patterns affect learning within the course. The results suggest that Parrots retain the material better than Outsourcers, but do not provide any insight with regard to how students perform on future courses. We are currently collecting data to conduct a study that focuses on the evolution of these groups through the mathematics curriculum at our Institution, but more qualitative and quantitative studies are needed to produce best practices for educators on how to handle internet content and math application and also to keep pace with our tech savvy learners.

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REFERENCES

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

Hannah, J., James, A., & Williams, P. (2014). Does computer-aided formative assessment improve learning outcomes? *International Journal of Mathematical Education in Science and Technology*, *45*(2), 269-281.

Hodge, A., Richardson, J., & York, C. (2009). The impact of a web-based homework tool in university algebra courses on student learning strategies. *Journal of Online Learning and Teaching*, *5*(4), 618-628.

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

Legendre. P., & Legendre, L. (2012). *Numerical Ecology*. Elsevier.

Leong, K., & Alexander, N. (2014). College students attitude and mathematics achievement using web based homework. *Eurasia Journal of Mathematics, Science & Technology Education*, *10*(6), 609-615.

Lewis, J., & Tucker, A. (2009). Report of the AMS first-year task force. *Notices American Mathematical Society*, *56*(6), 754-760.

Lial, M., Hornsby, J., & McGinnis, T. (2011). *Algebra for college students, seventh edition*. Addison Wesley Publishing Company.

Loong, E.Y.K. (2010). Web-based mathematics: student perspectives. *Mathematics Education Research Group of Australasia*.

Mathai, E., & Olsen, D. (2013). Studying the effectiveness of online homework for different skill levels in a college algebra course. *PRIMUS*, *23*(8), 671-682.

Ningjun, Y., & Herron, S. (2010). A correlation between hours spent in the math computer lab and final exam scores among computer-based college algebra students. *Review of Higher Education & Self-Learning*, *5*(16), 26-30.

Pearson. (2011). *MyMathLab*, Pearson Mastering Lab, retrieved from http://www.pearsonmylabandmastering.com/northamerica/mymathlab/.

Raines, J., & Clark, L. (2009). Analyzing the effectiveness of tutorial learning aids in a course management system. *Journal of Studies in Education*, *3*(3), 120-136.

Smith, G., & Ferguson, D. (2004). Diagrams and math notation in e-learning: growing pains of a new generation. *International Journal of Mathematical Education in Science and Technology*, *35*(5), 681-695.

Smith, G., Ferguson, D., & Caris, M. (2003). The web versus the classroom: instructor experiences in discussion-based and mathematics-based disciplines. *Journal of Educational Computing Research*, *29*(1), 29-59.

Smith, K., & Shotsberger, P. (1997). Assessing the use of graphing calculators in college algebra: Reflecting on dimensions of teaching and learning. *School Science and Mathematics*, *97*(7), 368-376.

Stillson, H., & Nag, P. (2009). ALEKS and MATHXL: using online interactive systems to enhance a remedial algebra course. *Mathematics & Computer Education*, *43*(3), 239-247.

Thompson, C. (2011). How Khan Academy is changing the rules of education. *Wired Magazine*, *126*.