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Student Perceptions on Teaching and Learning using Open Educational Resources in College Calculus

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Student perceptions on teaching and learning are investigated in a side-to-side comparison between traditional (closed, CER) non-free course materials and free open educational resources (OER). The primary resources being compared are textbook and automatically-graded web-based homework systems. The results are based on a 32 item survey given to 103 Calculus students using either the closed (52 students) or open (51 students) materials. The survey is designed to assess student attitudes and perceptions in five areas: mathematics, learning style, effort, cost and OER. We conclude from our study that students believe they learn best from active or tactile activities (hands-on work in class, homework and tutoring) and least from passive or conceptual resources (textbook, lectures and notes). Secondly, the results show students perceive OER just as effective as CER, and would take free OER classes if given the opportunity, and the OER group more strongly held this belief. However, while students appreciate the cost-saving aspect of OER, cost of course materials is not a hardship and would not affect class choice or progress. A third aspect detected from the survey is that students who used the proprietary homework system (CER group) had a better experience and expended less time than those using the open homework system (OER group), in part due to the interactive help and support with the proprietary system. This is consistent with homework scores, which were higher in the CER group than OER group. We conclude from this study that students would prefer an OER course, and more strongly if they have previously taken an OER course, while care should be taken using OER to ensure an equally effective ex-

perience as CER. We hypothesize that a teaching style which focuses on active (tactile) learning is more effective than a focus on passive (conceptual) learning, and recommend OER be developed with this in mind.

Keywords: open educational resources, mathematics, calculus, web-based homework, on-line homework, WeBWorK, perceptions, surveys

INTRODUCTION

Open educational resources (OER) are free-to-use course materials copyrighted under an open license which allows for sharing and remixing, in contrast to traditional closed (proprietary) educational resources (CER), which are not free to use and published under traditional copyright. The main appeal of OER for most of us is the free and easy access to the materials, as well as flexibility in developing our courses. The main appeal for students is cost. However, the cost-saving feature is not the only important aspect of OER. Successful adoption of OER in higher education depends on the quality and effectiveness of the resources. Effectiveness and successful adoption of OER course materials are gauged not only by student performance but also by student attitudes and perceptions on the effectiveness of the resources and on choosing materials that best support student learning. Hence, it is important to understand students attitudes and learning styles in effectively developing and adopting OER materials.

In this paper, we investigate student attitudes and perceptions on learning and using OER in College Calculus, as a follow-up to the study in (Kersey, 2019) which investigated student performance using OER. The study is based on four sections of Calculus I during the Fall of 2017 taught by myself (the author of this paper). The four sections were split into two groups of two sections (70 students) each, the CER group using a traditional proprietary textbook and web-based homework system, and the OER group using an open textbook and open homework system. To carry out our analysis, we developed and implemented a 32-question survey to understand students attitudes and perceptions of mathematics, learning, effort, cost and OER. The survey was given at the end of the semester to 52 students in the CER group and 51 students in the OER group. Our particular aim is to understand student perceptions on learning and OER, in order to determine what kinds of OER materials should be developed to best support student learning.

In the next section of this paper, we review literature relevant to this study in the following areas: studies that include student surveys on attitudes and perceptions in science, results of surveys on open educational resources, research on web-based instruction, and studies describing OER transformations. Following the literature section, we describe our methodology used in this study, including course materials, course design, and our student survey. In the main part of this paper, we analyze and summarize our statistical results to determine trends and significant differences between the CER and OER groups. The survey questions and raw data are included in the appendix, and our findings are summarized in the conclusion section of this paper.

Literature Review

Development of OER courses typically involves replacing traditional textbooks with open textbooks and online resources. Several studies have shown that such a transformation does not significantly affect student performance and learning or progression, such as (Allen, Guzman-Alvarez, Smith, Gamage, Molinaro, & Larsen, 2015), (Weller, de los Arcos, Farrow, Pitt, & McAndrew, 2015), (Hilton, Gaudet, Clark, Robinson, & Wiley, 2013) and the papers reviewed in (Hilton, 2016). Some studies indicated an improvement in performance and retention using OER, such as the open psychology implementation in (Hilton, & Laman, 2012), and the secondary level science study in (Robinson, Fischer, Wiley, & Hilton, 2014) which was based on end-of-the-year state standardized tests.

Typically, studies show that student attitudes and perceptions using OER compared to CER are about the same. These include (Allen, Guzman-Alvarez, Smith, Gamage, Molinaro, & Larsen, 2015), (Bliss, T. J., Robinson, T. J., Hilton, J., & Wiley, D. A., 2013), (Weller, de los Arcos, Farrow, Pitt, & McAndrew, 2015) and the papers in (Hilton, 2016). In (Martin, Belikov, Hilton, Wiley, & Fischer, 2017), student and faculty perceptions on textbook costs show that 66% of students have not purchased a textbook due to cost and that 91% of the faculty would be willing to adopt OER as an alternative to CER textbooks.

Some studies have been developed to understand the degree to which student perceptions can predict student success in Physics, the survey (CLASS) was developed in (Adams, Perkins, Podolefsky, Dubson, Finkelstein, & Wieman, 2006). The survey is based on a 5-point Likert scale, like in our work, to determine the level of agreement on 42 statements designed

to measure novice to expert perceptions in Physics. Their survey has been adapted to Biology in (Semsar, Knight, Birol, & Smith, 2011), computer science in (Dorn, & Tew, 2015), Chemistry in (Barbera, Perkins, Adams, & Wieman, 2008), Chemistry in (Allen, Guzman-Alvarez, Smith, Gamage, Molinaro, & Larsen, 2015) and Earth and Ocean Science in (Jolley, Lane, Kennedy, & Frappe-Seneclauze, 2012). A similar survey (MAPS) was developed in (Code, Merchant, Maciejewski, Thomas, & Lo, 2016) to study student attitudes and perceptions on mathematics, and implemented to a large sample of 3411 students. Their results show that higher perceptions and attitudes correlated with higher course grades.

The primary tool for web-based instruction in mathematics is an online web-based homework system that automatically grades and randomizes problems. There are several good packages. The proprietary (CER) homework used at our university is MyMathLab, by Pearson publishing. In (Buzzetto-More, & Ukoha, 2009) MathXL is used in a remedial mathematics class. A widely used open web-based homework system is WeBWorK, which is under an open license and can be downloaded and installed for free. Good references on using WeBWorK include the reports (Carpenter & Camp, 2008), (Denny & Yackel, 2005) and (Gage & Pizer, 1999), and papers on effectiveness WeBWorK include (Hauk, Powers, Safer & Segalla) and (Swanbom, Moller, Evans & Reeves, 2016). WeBWorK plays a primary role in our study.

Regarding performance measures using web-based homework compared to traditional, some studies favor web-based, such as (Brewer, & Becker, 2010), (Dufresne, Mestre, Hart, & Rath, 2002), (Kodippili, & Senaratne, 2008), (Smolira, 2008); some studies favor traditional, such as (Williams, 2012); and some studies indicate no difference, such as (Bonham, Deardorff, & Beichner, 2003), (Carpenter, & Camp., 2008), (Demirci, 2007), (Hauk, Powers, Safer, & Segalla, 2014), (Nguyen, Hsieh & Allen, 2006) and (Palocsay, & Stevens, 2008). There are various reasons for these results, such as the amount of feedback and deadlines, which make these studies perhaps more about homework design rather than the mode (web-based or traditional). Additionally, the withdrawal rate improved using web-based homework in (Buzzetto-More, & Ukoha, 2009).

In terms of perception, most studies favor web-based homework, such as (Buzzetto-More, & Ukoha, 2009), (Smolira, 2008) and (Nguyen, Hsieh, & Allen, 2006). While, just one study we looked at, (Demirci, 2007), reported no difference in perception. Instant feedback and drilling/practice are reported as advantages of web-based homework over traditional in (Nguyen, Hsieh & Allen, 2006) and (Williams, 2012).

The only side-by-side comparisons of CER and OER using web-based homework that we could find were reported in (Kassis, & Lopez, 2008) and (Kersey, 2019). In (Kassis, & Lopez, 2008), their study included student perceptions and performance using an online textbook with integrated homework system in economics. Four sections (two using OER and two using traditional) were compared. Results showed that online had a negative (but insignificant) impact on performance. In their study, 58% of the students disliked the online textbook while 64% felt the web-based homework took more time than paper-based homework. Our study is similar. The performance aspect of our study was reported in (Kersey, 2019). In that paper, we showed that students using OER were able to access important course materials earlier in the semester, leading to better performance on their first exams than CER, while later in the semester the students using the OER web-based homework performed better due in part to the level help offered with the CER system. In our present work, we will investigate the impact of perceptions.

Methodology of Study

The primary goal of this study is to compare open educational resources (OER) with closed (traditional) resources (CER) in teaching college level Calculus. The usual approach to transforming a traditional course to an open course is to adopt an open textbook. Typically, this is the primary resource. However, often in mathematics, homework is the dominant resource for students, and in recent years many of us use web-based online homework. Hence, in our study, we will be adopting both an open textbook and web-based homework system as a replacement for the traditional resources.

The course instruction was carried out during the Fall 2017 semester, with two sections of Calculus I using CER (70 students total) and two sections using OER (70 students). To reduce variability, the author this paper taught all sections. The same lecture notes and exam reviews were used, as well as similar homework problems and exams. Students had no prior knowledge to opt-in to either group and were of similar demographics. As well, based on a pre-test, student knowledge entering the course was almost identical, on average.

The traditional textbook used for the CER group in our study is Thomas' Calculus I published by Pearson publishing and is bundled with the online homework system MyMathLab. For the OER group, OpenStax Calculus I was adopted for the textbook and WeBWorK as the online homework

system. In WeBWorK, there is a large problem library to choose from, and additional were written for the OpenStax Calculus I textbook (available in GitHub). Comparing the two homework systems, MyMathLab and WeBWorK, they both provide automatic grading, an interface to learning management systems and basic help, such as "email instructor." The main differences are that MyMathLab has more problem help and integration with the textbook, while WebWorK has more problems to choose from and the ability to create questions. To be sure students had adequate opportunity to solve problems, they had unlimited attempts on each homework set until the due date, and were given the opportunity to make up work at the end of the semester. Allowing unlimited attempts (or at least several attempts) is highly recommended in online mathematics homework due to issues concerning entering data or calculation mistakes. In this way, the homework is considered more a learning tool than a grading tool.

At the end of the semester, a 32 question perception survey was administered to 103 students, 52 from the CER group and 51 from the OER group. Survey questions are based on a 5-point Likert scale: 2=strongly agree, 1=agree, 0=neutral, -1=disagree and -2=strongly disagree. The survey items are grouped in five main categories: Mathematics Attitudes (Items 1-7), Learning Style (Items 8-14), Effort (Items 15-22), Cost Impact (Items23-26) and OER Attitudes (Items 27-32). For each survey question, the mean is reported among all students, CER students only, and OER students only, and a ranking is based on means, high to low. The survey and results of the survey are included in the appendix.

To analyze the data, we ranked the means of the student responses on each question and compared differences between the CER and OER groups using a Wilcoxon Rank-Sum test (equivalently: the Mann-Whitney U-test) and the T-test. There is much disagreement in the literature concerning appropriate tests for survey data like ours (which is on a 5 points ordinal scale), with concerns being sample size and lack of normality. However, it has been shown in (de Winter, J., & Dodou, D., 2010) that both of these tests are effective in analyzing surveys on a Likert scale. We remark that the null hypothesis for the T-test is "the means are the same," and the null hypothesis for the U-test is "the medians are the same." The p-value of the U-Test and T-Test listed in the table represents the probability that the means for the U-Test (respectively, medians for the T-test) between the two groups are the same. Hence, the closer to one, the more likely the groups are similar. For p-values around .05 (5%) or less, the difference between the CER and OER groups are statistically significant.

Results of Study

The results of this study are based primarily on the survey administered to students at the end of the semester. The survey questions are data are given in the appendix, and summarized below.

Category	Ranked Survey Items
Learning style (from questions 8-14)	14, 11, 12, 13, 8, 9, 10
Highest ranked questions	27, 14, 5, 31, 6, 29, 28, 30, 11, 1, 12, 13
Lowest ranked questions	10, 32, 24, 26, 16, 25, 20, 23
Highest Agreement between CER and OER	22, 10, 20, 16, 25, 12, 7, 26, 11 (T-Test)
	16, 15, 20, 7, 11, 10, 25, 26, 22 (U-Test)
Highest Disagreement, Significant Differences	29, 1, 6, 2, 28, 31, 3, 23, 17 (T-Test)
	29, 28, 1, 6, 2, 30, 17, 23, 31 (U-Test)

The learning style of students is quantified in questions 8-14 on the survey. These are ranked according to means of student responses, and a rank is assigned. The results are summarized in the table below.

Learning Style Ranked among all students (high to low)		
14	II	I learn best from hands-on work in class
11	II	I learn best from homework
12	II	I learn best from tutoring
13	II	I learn best from on-line materials and videos
8	II	I learn best from lectures
9	II	I learn best from course notes
10	II	I learn best from reading the textbook

Based on these results, we conclude that students feel in-class work provides the best learning opportunities (question 14). This question is the second highest rated question on the survey, with a mean of 1.44. Note that lecturing and course notes are rated much lower (.68 and .56), indicating that time in class is perhaps better spent allowing students to work together or by themselves solving problems. According to the table, solving homework (question 11) is the second best learning approach. It is ranked 9th among all questions, with a mean score of .96, closely followed by tutoring (question 12) and learning from on-line materials (question 13). Taken together, this shows that active (or tactile) learning (hands on work in class work, homework, work with a tutor) is more useful to students than inactive

(conceptual) learning (lectures, course notes, textbook). According to the survey, the least effective learning style (which is also ranked last in the survey) is learning from the textbook (question 10). This is the only negative mean score of the learning style questions on the survey (at -0.55). Hence, students view the textbook in our study as the least effective mode of instruction.

The next table lists the highest ranked (strongest agreement) items on the survey.

Highest ranked survey items among all students (highest first)		
27	V	If given the opportunity, I would take courses with free course materials
14	II	I learn best from hands-on work in class
5	I	Mathematics is important for my education
31	V	I would rather take a class with free course materials
6	I	Mathematics is important for my career
29	V	The free textbook is as good as non-free textbooks
28	V	Free materials are as good as non-free course materials for this class
30	V	The free homework system is as good as non-free homework systems
11	II	I learn best from homework
1	I	I like mathematics
12	II	I learn best from tutoring
13	II	I learn best from on-line materials and videos

The highest ranked questions are 27, “If given the opportunity, I would take courses with free course materials,” and 14, “I learn best from hands-on work in class”. Among the top eight, five of the questions (27, 31, 29, 28, 30) indicate a strong preference or agreement with OER. Hence, category V (Free OER), ranked the highest of the five categories, showing that students would prefer OER classes, and believe the free OER course materials are as good as non-free materials. Also among the top twelve highest rated questions, four of the questions (14,11,12,13) indicate strong agreement with category II (Learning Style). Hence, second to category V in importance among all students is category II. The third category that shows support among students in the top ten is category I (mathematics attitudes and aptitude). This includes question 5, “Mathematics is important for my education”, question 6, “mathematics is important for my career,” and question 1, “I like mathematics.” This leaves categories III (Effort) and IV (Cost importance), as the lowest rated of the five categories.

The lowest ratings among all questions are listed in the next table.

Lowest ranked survey items among all students (lowest first)		
10	II	I learn best from reading the textbook
32	V	I would rather take a class with non-free (traditional) course materials
24	IV	The cost of course materials affects which classes I choose
26	IV	The cost of course materials affects my progress
16	III	I spend most of my time studying the lecture and course materials
25	IV	The cost of course materials is a hardship
20	III	Videos helped me learn best
23	IV	The cost of course materials is an important consideration for my classes

The lowest ranked question among all students is 10, "I learn best from reading the textbook," with a negative rating. This negative rating is likely in part due to the emphasis on this particular course on online homework and class work, and in part reflects students reticence to read and learn on their own. The second lowest ranked question is 32, "I would rather take a class with non-free (traditional) course materials," again with a negative average score. This is consistent with student attitudes that they would prefer free course materials and they believe free materials are as good as non-free. The third and fourth lowest ranked questions are 24, "The cost of course materials affects which classes I choose," and 26, "The cost of course materials affects my progress," both with negative ratings. As well, two more survey items, 25 and 23, concern costs and are in the lowest eight of all survey questions. These results were surprising. What this shows, is that while students do appreciate the OER, the cost of materials will not change their long-term plans. This result may depend on the institution and student demographics.

The next table lists the survey items which had the greatest level of agreement between the CER and OER groups based on the U-Test (the T-Test gives similar results).

Agreement between CER and OER based on U-Test (highest first)		
16	III	I spend most of my time studying the lecture and course materials
15	III	I spend many hours a week preparing for this class
20	III	Videos helped me learn best
7	I	I'm doing well in this course
11	II	I learn best from homework
10	II	I learn best from reading the textbook
25	IV	The cost of course materials is a hardship
26	IV	The cost of course materials affects my progress
22	III	On-line homework is easy to use

From the table, five of the first six questions (16, 15, 20, 11, 10) of nine listed indicate that students in the two groups have a similar perception on learning styles. The fourth (7) indicates that students between the two groups feel they are doing about the same in the class. The seventh (25) and eighth (26) indicate that cost factors are viewed about the same between the two groups, and the ninth (22) indicates that students feel about the same concerning the difficulty level of the homework.

The next table lists the survey items which had the greatest level of disagreement between the CER and OER groups based on the U-Test. Note that p-values less than around .05 indicate statistical differences between the two groups.

Disagreement between CER and OER based on U-Test (lowest first) (Statistically Significant Differences)		
29	V	The free textbook is as good as non-free textbooks
28	V	Free materials are as good as non-free course materials for this class
1	I	I like mathematics
6	I	Mathematics is important for my career
2	I	I'm good at mathematics
30	V	The free homework system is as good as non-free homework systems
17	III	I spend most of my time doing homework
23	IV	The cost of course materials is an important consideration for my classes
31	V	I would rather take a class with free course materials

From the table, the first two lowest p-values, and also four of the top nine listed, show that the CER and OER group differ on the effectiveness of OER course materials. For all these items, the experimental (OER) group viewed OER materials as more effective than the control (CER) group. There are perhaps a couple of reasons for this. One possibility is that students using the OER materials were happy with the materials. A second possibility is that students may "buy-in" to whatever resource they are provided. The 3rd through 5th most significant differences between the two groups concern attitudes toward mathematics and ability in mathematics. Again, students in the OER group had a higher perception. The remaining items of significance concern time spent on solving homework and the importance of cost. Again, the OER group had a higher perception in these areas.

On the survey, students were encouraged to provide their opinion on course materials and on-line homework in particular. Regarding the free OER materials, a typical comment was:

"This was my 1st free course materials class, and I was so thankful!"

Regarding the experience using the online homework systems, students felt the proprietary CER homework provided more help than the OER. Typical comments that reflect this attitude include the following:

"The online homework (MyMathLab) was very helpful because it gave instant feedback, and it provided examples, help for the problem, and reference to the textbook."

"If online homework (WeBWorK) had similar questions with the problem-solving steps would be helpful for more difficult problems."

The experience with homework systems is consistent with overall homework scores at the end of the semester, which on average were 81.63 for the CER group and 72.35 for the OER group.

Conclusions

In this paper, we investigated student perceptions on OER and learning in college calculus. Our study was based on a side-by-side comparison of classes using open to those using closed textbooks and homework systems. Based on our study, we were able to conclude a few results. It was shown

that students would prefer to take a free OER class if given the opportunity. Moreover, students believe the quality of OER are as good as CER, while the OER group more strongly held this opinion. Somewhat surprisingly, we found that, while students appreciate saving money, the cost of their course materials is not a significant hardship, nor affect class choices or progress. It was shown that the students in this study learn best from active, hands-on work (such as in-class work or homework), and least from passive resources (such as the textbook). Hence, we suggest that OER be developed with this in mind. In analyzing the survey data based on a 5-point Likert scale, we showed that both the Wilcoxon Rank-Sum test (U-Test) and T-Test gave similar results. Finally, from student comments, we were able to determine that the proprietary CER homework provided a better overall experience than the OER homework system due in part to the level of online support. Based on this study and other studies cited in this work, OER materials are a viable alternative to CER materials in terms of student perceptions and attitudes on learning. Hence, we recommend developing OER with student learning in mind, and in particular focus on resources that support active learning.

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APPENDIX

2=strongly agree, 1=agree, 0=neutral, -1=disagree, -2=strongly disagree			ALL		CER		OER		T-Test	U-Test
			Mean	Rank	Mean	Rank	Mean	Rank	p-value	p-value
1	I	I like mathematics	0.87	10	0.51	18	1.24	9	0.00221	0.00536
2	I	I'm good at mathematics	0.69	14	0.38	22	1.00	10	0.00513	0.01228
3	I	Mathematics is fun and enjoyable	0.62	19	0.37	24	0.88	12	0.03452	0.10435
4	I	Mathematics is stressful and frustrating	0.67	16	0.85	9	0.49	23	0.10273	0.06734
5	I	Mathematics is important for my education	1.37	3	1.17	3	1.57	1	0.66638	0.47640
6	I	Mathematics is important for my career	1.17	5	1.08	5	1.25	8	0.00348	0.00978
7	I	I'm doing well in this course	0.65	18	0.62	17	0.69	19	0.73979	0.86003
8	II	I learn best from lectures	0.68	15	0.83	11	0.53	22	0.18655	0.14800
9	II	I learn best from course notes	0.56	20	0.65	15	0.47	24	0.43550	0.31622
10	II	I learn best from reading the textbook	-0.55	32	-0.54	32	-0.57	31	0.89353	0.82815
11	II	I learn best from homework	0.96	9	0.92	6	1.00	10	0.69810	0.84035
12	II	I learn best from tutoring	0.87	10	0.90	8	0.84	15	0.77391	0.69466
13	II	I learn best from on-line materials and videos	0.76	12	0.65	15	0.86	13	0.36283	0.60465
14	II	I learn best from hands-on work in class	1.44	2	1.48	1	1.39	5	0.56460	0.41092
15	III	I spend many hours a week preparing for this class	0.50	23	0.42	20	0.57	20	0.48314	0.89770
16	III	I spend most of my time studying the lecture and course materials	0.21	28	0.23	27	0.18	28	0.81886	0.95027
17	III	I spend most of my time doing homework	0.54	22	0.33	25	0.76	16	0.05102	0.05654
18	III	Lectures helped me learn best	0.55	21	0.71	13	0.39	26	0.16687	0.17061
19	III	Course notes helped me learn best	0.47	24	0.38	22	0.55	21	0.45852	0.62798

2=strongly agree, 1=agree, 0=neutral, -1=disagree, -2=strongly disagree			ALL		CER		OER		T-Test	U-Test
			Mean	Rank	Mean	Rank	Mean	Rank	p-value	p-value
20	III	Videos helped me learn best	0.45	26	0.42	20	0.47	24	0.83548	0.89441
21	III	On-line homework helped me learn best	0.66	17	0.47	19	0.84	14	0.09091	0.14213
22	III	On-line homework is easy to use	0.72	13	0.71	13	0.73	17	0.95422	0.71573
23	IV	The cost of course materials is an important consideration for my classes	0.46	25	0.21	28	0.72	18	0.04165	0.06150
24	IV	The cost of course materials affects which classes I choose	-0.12	30	-0.29	30	0.06	29	0.16909	0.19360
25	IV	The cost of course materials is a hardship	0.30	27	0.27	26	0.33	27	0.80777	0.74533
26	IV	The cost of course materials affects my progress	-0.11	29	-0.16	29	-0.06	30	0.71409	0.72551
27	V	If given the opportunity, I would take courses with free course materials	1.44	1	1.33	2	1.55	2	0.20829	0.25455
28	V	Free materials are as good as non-free course materials for this class	1.10	7	0.83	11	1.37	6	0.00733	0.00451
29	V	The free textbook is as good as non-free textbooks	1.16	6	0.85	9	1.47	4	0.00073	0.00144
30	V	The free homework system is as good as non-free homework systems	1.10	7	0.92	6	1.27	7	0.09900	0.04217
31	V	I would rather take a class with free course materials	1.34	4	1.13	4	1.55	2	0.01761	0.06333
32	V	I would rather take a class with non-free (traditional) course materials	-0.44	31	-0.31	31	-0.57	31	0.30065	0.28064