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Open Educational Resources in the Undergraduate Engineering Curriculum: A Materials Science Case Study

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Open Educational Resources in the Undergraduate Engineering Curriculum: A Materials Science Case Study

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Abstract

Open Educational Resources (OER) are freely accessible, open licensed materials that can include text, media, or other digital formats and are created for teaching, learning, and supporting research. One of the obvious benefits to OER is a reduced cost to students. The skyrocketing cost of tuition and textbooks makes attending college more difficult. OER has see more wide-spread adoption in the Humanities and Social Sciences due to the need for incorporating current topics or the use of classical works of fiction that are in the public domain. Science, Technology, Engineering, and Mathematics (STEM) fields have seen a much lower rate of adoption. Part of this lower adoption rate can be attributed to the dependence on the peer review process and the tradition of lecturing from a known and standard textbook. This study is a first attempt at incorporating OER into an engineering course, specifically in a Sophomore level Materials Science course in the Mechanical and Aerospace Engineering program at Utah State University. In a comparison across multiple sections with the use of both OER and a traditional textbook, the results show the same or improved student educational outcomes. The results also show higher student satisfaction and course quality through the significant cost savings and exposure to more resources that are relevant and more applicable to their future courses and expected roles in their future careers.

Introduction

Open Educational Resources (OER) are freely accessible, open licensed materials that can include text, media, or other digital formats and are created for teaching, learning, and supporting research [1–4]. OER and Massive Open Online Courses (MOOCs) are changing the ways in which people learn all over the world [5, 6]. These new approaches to education are a response to the lack of access to and the increasing cost of education throughout the developing and developed world. Overcoming the disparity in educational access worldwide, and even just within the United States, is a long-term goal of OER and MOOCs, but to be successful will require the support of governments and agencies that regulate education [7]. Another benefit to OER is a reduced cost to students, also making education more accessible. The skyrocketing cost of tuition and textbooks makes attending a university more difficult [8]. Beyond the direct societal benefits of OER through improved access to education, other benefits to education include tailored material to the course

topics and multiple perspectives. The most common approach to incorporating OER into the college classroom is through the replacement of the traditional textbook, with the motivation being to save students money and therefore reduce the financial burden of attending college [4]. This form of OER has see more wide-spread adoption in the Humanities and Social Sciences due to the need for incorporating current topics or the use of classical works of fiction that are in the public domain.

Science, Technology, Engineering, and Mathematics (STEM) fields have seen a much lower rate of adoption of this form of OER, but have been significant parts of MOOCs like Carnegie Mellon University's Open Learning Initiative and the MIT OpenCourseWare [9, 10]. Interestingly, these forms of OER provide lecture notes, videos, assignments, and other course material, but often still utilize a traditional textbook that an Open Learner would be required to have in order to be successful in the course. Although these forms of OER are critical to worldwide access to education, more emphasis should be given to ensure all of the educational materials in use are fully open. Within the field of engineering this can be more challenging as OER is not always available. The current lack of engineering OER will be less of a burden as more Open Education Publishers publish books in specialized areas like engineering.

This study is a first attempt at incorporating an OER substitute for a traditional textbook in an engineering course, specifically in a Sophomore level Materials Science course in the Mechanical and Aerospace Engineering program at Utah State University. In a comparison across multiple sections taught by the same instructor with the use of both OER and a traditional textbook, the results show the same or improved student educational outcomes. The results also show higher student satisfaction and course quality. Students benefited from the significant cost savings and also from the exposure to resources that were more relevant and applicable to their future courses and expected roles in their future careers.

Approach

In this case study, student reported progress on outcomes and learning objectives and their perspectives of using a traditional textbook and OER are compared. The course in which the case study is conducted is a Sophomore level Introduction to Material Science and Engineering course in an ABET accredited Mechanical Engineering Bachelors Degree Program. The study compares student reported progress on outcomes and learning objectives from ABET [11] and IDEA [12]. This study also includes student perspectives in the form of comments and opinions from a section that utilized OER. The study is conducted over four semesters from 2014 to 2017 where each section is taught by the same instructor. Three sections were taught using the traditional textbook while one section was taught using OER.

As an introductory course in Mechanical Engineering, the learning objectives focus on gaining and applying fundamental knowledge. Specifically, the ABET student outcomes fall under outcome (a), which is an ability to apply knowledge of mathematics, science and engineering and more specifically fall into the following subcategories of outcome (a):

- ABET 3a1: Students apply scientific and engineering principles to formulate a mathematical model of a system or process, which is appropriate for the required accuracy.
- ABET 3a2: Students apply mathematical principles to obtain an analytical or numerical solution to model equations.

Similarly, the IDEA learning objectives are tabulated from student responses of the following IDEA learning objectives:

- IDEA Objective 1: Gaining factual knowledge (terminology, classifications, methods, and trends).
- IDEA Objective 2: Learning fundamental principles, generalizations, and theories.
- IDEA Objective 3: Learning to apply course material.
- IDEA Objective 4: Developing specific skills, competencies and points of view needed by professionals in the field most closely related to this course.
- IDEA Objective 9: Learning how to find and use resources for answering questions or solving problems.

This study uses both the ABET 3a1 and 3a2 student outcome and the IDEA Objectives 1-4 and 9 as metrics to quantify progress on student learning objectives within this course. The students are asked to respond to these statements based on their experience in the course using a 5-point Likert scale, where a rating of 1 would indicate that they strongly disagree that they met that specific outcome or objective and a rating of 5 would indicate that they strongly agree that they met that specific outcome or objective. The students are asked to respond to these questions during the end of the semester online anonymous survey along with other questions about the course and instructor. Students are also encouraged to provide comments relating to aspects of the course they liked, disliked, and how they think it could be improved.

Traditional Textbook

Three sections were taught from 2014-2016 using a traditional textbook. The textbook was a commonly used resource in introductory materials science courses, W. D. Callister and D. G. Rethwisch, *Materials Science and Engineering: An Introduction* [13]. In the Spring of 2014 and 2015, students were required to use the Eighth and Ninth editions, respectively. In the Spring of 2016, students were allowed to use any edition of the text in an attempt to save students money.

Open Educational Resources

One section was taught in 2017 using OER. The course material is not truly OER as the resources are not openly available to the general public. The resources used for this course are a mixture of OER and resources available to students at Utah State University through the Merrill-Cazier Library subscriptions, and thus have no additional cost to the students. Future efforts will be made to make this course and others offered by this instructor and in this department fully OER. The primary motivation of adopting OER in this course was to eliminate the cost of the tradition textbook used in previous offerings of the course [13]. In order to do so the instructor explored OER textbooks, but found limited resources for the topics covered in the undergraduate materials science course. The topics covered in the course are given in Table 1.

To provide coverage of all of these topics, multiple resources were required, some of which were not truly OER as they required access to the Utah State University Library. The resources

Table 1: List of topics on the ABET syllabus for the Introductory Materials Science Course.

Bonding	Crystalline Structures	Solid Imperfections
Diffusion	Mechanical Properties	Strengthening Mechanisms
Material Failure	Phase Diagrams	Phase Transformations
Thermal Processing of Metals	Metal Alloys	Polymers
Composites	Ceramics	Optical and Magnetic Properties
Thermal Properties	Electrical Properties	Corrosion

included in the OER section of the course were references [14–21]. All of these materials were available at no charge to the students and could be accessed online through the Utah State University library website. Direct links to the resources were provided on a digital copy of the course syllabus and on the course website to make access easy. Additionally, students had the ability to print these resources if they preferred hard copies. The number of resources is large, but needed to provide complete coverage of the topics and multiple perspectives to the students in the heavily conceptual course.

Results

Table 2 shows the details of the sections in which the study was conducted. The student reported progress on ABET and IDEA outcomes and learning objectives are shown in Figures 1 and 2. These quantitative results were collected during an end-of-the-semester online survey with voluntary participation by the students. The ABET student outcomes and IDEA learning objectives mentioned previously were presented and students were asked to respond based on their experience using a 5-point Likert scale. The responses of the students for each semester were then averaged and presented in Figures 1 and 2. Table 2 includes information about whether OER was used, student enrollment, survey response percentage, and the overall course and teacher ratings for comparison between the semesters. These results of the student responses to these outcomes and learning objectives in Figures 1 and 2 show a slight increase in both ABET student outcomes and IDEA learning objectives when using OER (2017) when compared to the traditional textbook (2014-2016), though not statistically significant. These results do not necessarily show an improvement in student learning, but they clearly show that student perceptions of their own learning is not negatively impacted through the use of OER. This suggests that the use of OER, at least in this course, did not adversely affect the student outcomes or learning objectives based on student responses.

Table 2: Details of the semesters included in the study and information about the response rate and overall teacher and course ratings. (Teacher and course rating are based on a 5-point Likert scale)

Year	OER	Enroll.	Resp. Rate (%)	Teach. Rating	Course Rating
2014	No	158	67	4.3	3.9
2015	No	179	94	4.1	3.7
2016	No	168	92	4.0	3.8
2017	Yes	108	87	4.2	4.0

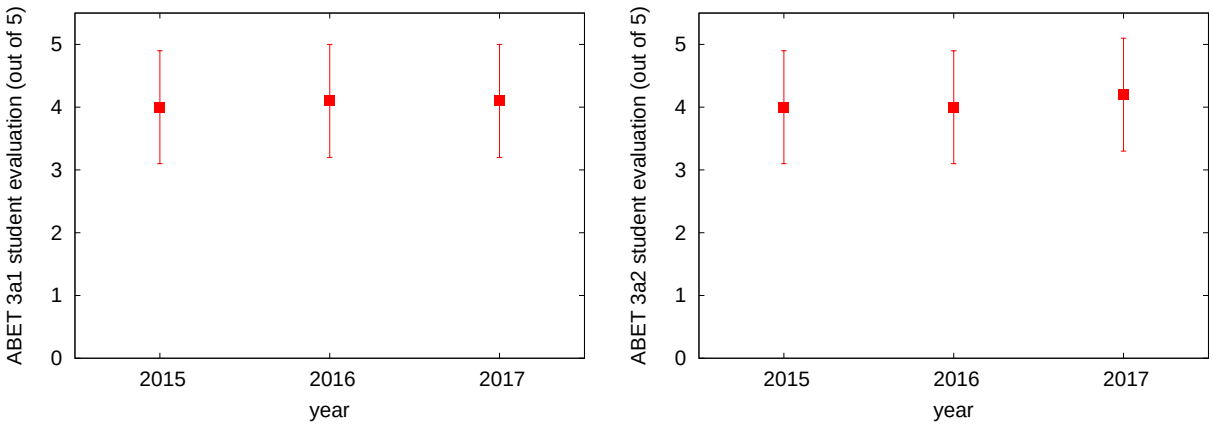

Figure 1: Plot of the student reported progress on ABET outcomes. (left) 3a1. (right) 3a2.

Student Comments Relating to OER

In addition to the student reported progress on outcomes and learning objectives, we also present here some comments that highlight some of the advantages and disadvantages that students identified based on their experience in this course with the use of OER. This section provides a summary of the comments with some direct quotes from student comments on the final course survey and our interpretation of what they mean for students in general.

- Many students appreciated not having to purchase a textbook - these are likely students that find the cost of attending college to be a financial burden: "I liked that we didnt have to purchase a textbook for the course."
- Some students appreciated the numerous resources that were available to them, providing multiple perspectives - these students seemed to like having more than just a single source of information: "I like that he gave us several resources to use to learn the material."
- Some students like that the resources were accessible via the internet - presumably students liked being able to access material without having to carry a hard copy of the book around, this allowed them continuous access to resource material: "All of the information taught in class was easily accessible and there was plenty of different resources to find more material on the subject matter."
- Some students commented that the use of multiple resources caused confusion and would prefer a single textbook (even if it needed to be purchased) - these students did not want to look at the syllabus to figure out which resource they should be looking through based on a given topic: "I did not like that there was not a required text book. I like classes that follow the flow of a text book so its really easy to know what we need to know and read for next class. I think the 10 or so links that have the information in the book is a pain and a huge time waster. I would much rather have a book that has everything I need."
- Some students did not like the online form of the resources - these students would prefer a hard copy: "I dont like not having a textbook hard to study electronic textbooks"

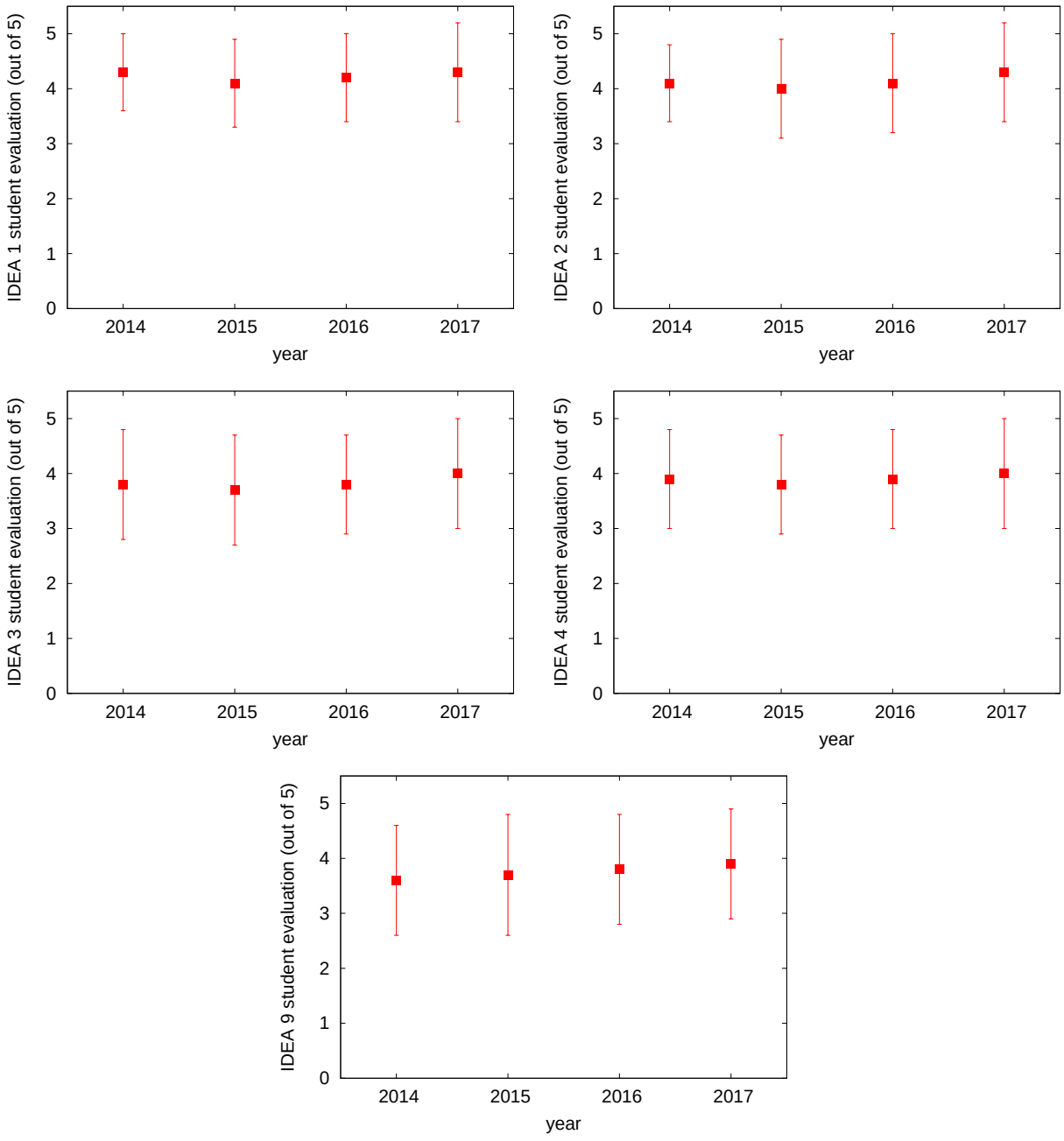

Figure 2: Plot of the student reported progress on IDEA learning objectives.

The student comments provided a better picture for how students felt about OER and how the OER were used in the course. In general, students appreciated not having to purchase a textbook for the course and liked having access to the course material (OER and lecture notes). Some students commented on liking the resources while others felt the number, access method, and location of the resources were less convenient when compared to courses with a traditional textbook. The themes identified from the negative comments listed above are not an issue with OER in this case, but rather an issue with the implementation of OER in this course. From these comments, we have been able to identify some potential best practices based on the student perceptions in this study which are aimed at having a successful experience when adopting OER or just trying to reduce cost and increase access to education materials.

1. Limit the number of resources used in a course that is traditionally taught from a single textbook. Providing multiple perspectives is good, but the 10 resources used in this case was overwhelming and burdensome for some students.

2. Provide multiple ways to access the resources. In this case, links were provided in two locations, but could have also been incorporated into weekly announcements about course assignments and topics being covered.

3. Provide options for electronic usage and print form to satisfy both types of students.

4. If a good resources is not available at no cost, consider replacing the current material with a lower cost option.

Conclusions

The combined results show that the use of OER in the introductory materials science course had no negative impact on the student reported outcomes and learning objectives and overall that students appreciated not having to purchase another expensive textbook. One of the primary motivations of adopting OER in this case was to reduce the cost of education, thus making it more accessible to students who are already financially burdened from attending college, and removing the cost of the textbook is a step in that direction. An assumption being that it is not being made more accessible and less of a financial burden is that there are not negative impacts to the education of the student, which has been demonstrated here based on the knowledge students feel that have gained in the process of taking this course. Some students did not like this implementation of OER due primarily to the number of resources and the online or electronic access, which are complaints that could be address while still using OER. The main conclusion of this pilot case study of using OER in an engineering course is that students did not feel significantly different about their progress towards outcomes and learning objectives and experienced the benefit of a reduced financial burden. Future studies by this research team and the Mechanical and Aerospace Engineering Department at Utah State University will look to address the issues identified here and undertake a more detailed pedagogical study of the adoption of OER in this and other engineering courses. Continued work in this area will lead to lower cost, more accessible, and more relevant engineering education.

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