



Current Usage Patterns of Open Educational Resources in the Engineering Mechanics Classroom and Barriers to Adoption

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Abstract

Open Educational Resources (OER) represent a small but growing portion of the educational resources market, but the use of OER in engineering is limited. This study seeks to identify the current adoption patterns of OER in engineering mechanics courses and barriers to adoption. Research questions are examined through the lens of Rogers' Diffusion of Innovation model. A survey of mechanics instructors across the United States, combined with publicly available data from college and university websites, were used to identify instructor practices and opinions regarding OER. During the 2017-2018 academic year, widespread OER usage was found at only a handful of institutions. However, knowledge of OER among mechanics instructors was high, and many instructors reported an interest in OER for their courses. A lack of quality OER content for engineering mechanics courses seems to be the primary barrier to more widespread adoption.

Background and Introduction

This study aims to explore the current state of Open Educational Resources (OER) use in introductory engineering mechanics courses. According to the William and Flora Hewlett Foundation:

Open Educational Resources (OER) are teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use and repurposing by others. OER include full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials, or techniques used to support access to knowledge ([2019](#)).

While an increasing amount of data exists on the use of OER in higher education, there is very little research on the use of OER in engineering specifically. This study examines the current use of OER in engineering education and identifies barriers to adoption in the engineering curriculum through a survey of mechanics instructors and analysis of publicly available data from college and university websites.

Using OER in the Classroom

When used in place of traditionally published commercial content, OER can have several advantages. First, OER are free to use. In a study of five large institutions pushing to utilize more OER in their classes, researchers found that OER saved students an average of \$128 per class ([Senack 2015](#)). With the College Board ([2017](#)) advising students to budget between \$1,220 and \$1,420 a year for textbooks and other supplies, it becomes clear that OER has a huge potential for lowering the cost of college. In fact, the increase in the cost of textbooks far exceeds the rate of inflation ([Popken 2015](#)), and everyone from educators ([Tovar & Piedra 2014](#)) to non-profits ([William and Flora Hewlett Foundation 2019](#)) to legislators ([Polis et al. 2017](#)) are seeking to rein in costs. Rapidly increasing textbook costs go beyond an inconvenience to an issue of access. Up to 65% of students declined to buy or rent a textbook due to cost, even though 94% of those same students thought it hurt their grades in that course ([Senack 2015](#)).

Beyond being free to students, the licensing agreements on open resources also make them fundamentally more adaptable for instructors. This allows instructors to mix and match resources, add self-authored content as they see fit, and contribute to the evolution of the resources that they employ for teaching. While this authoring and adaptation may take extra time on the part of the instructor, past research has shown that instructors overwhelmingly tend to adapt educational innovations to their setting, rather than adopting them verbatim ([Henderson & Dancy 2007](#)). The ethos of creative commons and public domain licenses play into the tendency, giving instructors more control.

When examining the effect of OER on student learning, the results are generally positive. Most direct comparisons of traditionally published materials and OER show no advantage one way or the other in terms of student learning outcomes ([Allen et al. 2015](#); [Winitzky-Stephens & Pickavance 2017](#)). Some smaller studies found learning gains associated with OER ([Ackovska & Ristov 2014](#); [Llamas-Nistal & Mikic-Fonte 2014](#); [QingHua et al. 2014](#)), but in many of these cases there was a significant shift in content delivery methods beyond simply opening up the content. There are other studies, however, where significant impacts on student learning were observed due to increases in access and affordability. Researchers at the University of Georgia in a multi-year university-wide study found significant drops in DFW grades (i.e., students receiving D grades, F grades, or withdrawing from the course) along with corresponding increases in the B+ and higher grades when courses implemented OER into their classrooms ([Colvard et al. 2018](#)). This positive impact was concentrated in low income students, as indicated by Pell Grant eligibility. There is nothing about the structure of OER that makes it a better learning resource than traditionally published content for students when everyone has equal access, but access is not equal. OER improves the learning environment by making access to learning resources more equitable.

Despite the above considerations, OER represented a relatively small share (9%) of the overall textbook market in higher education for the 2016-2017 academic year ([Seaman & Seaman 2017](#)). This was a significant rise over the 5% recorded in 2015-2016, but still far from a majority. Seaman & Seaman ([2017](#)) found large, introductory, multi-section courses such as calculus, chemistry, and physics had the highest rates of adoption (16.5%) and that the OpenStax

textbooks series (<https://openstax.org/>) represented the dominant provider of open content in the population studied.

OER in Engineering Education

When examining the effects of OER in engineering education specifically, we find more limited research and resources. As librarians seeking to increase the use of OERs at two western US institutions, Anderson et al. (2017) found that "few resources existed for specialized upper-division engineering courses." In a survey of engineering faculty reported in the same study, the authors observed that 59% of the faculty interviewed had little or no familiarity with OER. Others acknowledged possible benefits (reduced costs and customization), but also reported concerns about quality and difficulty finding engineering OER. Further responses from faculty indicated that some used OER to supplement commercial texts rather than replace them, which would increase awareness and discussion even if high textbook costs remain an issue. As the authors note, "one size does not fit all when it comes to open education," and strategies to increase the use of open resources may vary from one class to the next.

Some engineering OER textbooks and resources do exist and can be found in repositories such as MERLOT (<http://merlot.org/merlot/index.htm>) or the Open Textbook Library (<https://open.umn.edu/opentextbooks>), but options are more limited than with "general education" subjects such as chemistry, economics, math, physics, etc. Additionally, it can be noted that OpenStax, the predominant OER publisher in higher education (Seaman & Seaman 2017), does not currently offer any OER for engineering subjects, further speaking to the limited availability of these resources in engineering.

Tovar and Piedra (2014) provide a review of OER related to computer and electrical engineering specifically, but no such reviews seem to be available for other engineering subjects. Overall, OERs seems to be limited in engineering, along with limited reviews of OER materials, and limited research within the context of engineering education.

The Adoption of Other Innovations in Engineering Education

Because of limited OER adoption in engineering subjects and limited research on OER adoption in engineering education, the authors also sought to examine the adoption patterns of other educational innovations in engineering education to help shed light on how OER might be adopted in the community.

The spread of innovations such as problem-based learning, instant-feedback system (clickers), just-in-time teaching, think-pair-share, as well as several other innovations have been more thoroughly examined than the spread of OER. In particular, Borrego and colleagues (Borrego et al. 2010; Borrego et al. 2013; Borrego & Henderson 2014) have done a lot of work in the area of the spread of innovations in engineering education.

Borrego noted extensive research surrounding the effectiveness of the learning innovations in her study, though adoption rates of these innovations remain low. Simply proving the worth of an educational innovation through research does not lead to widespread adoption within the engineering education community, highlighting the importance of understanding the spread of the innovation. This conclusion mirrors work done in physics education, where research found that adoption of pedagogical innovations remains limited even if awareness of these innovations and motivations to implement them are high (Henderson & Dancy 2007; Dancy & Henderson 2010).

Rogers Diffusion of Innovation Model

Following the lead of Borrego and colleagues ([Borrego et al. 2010](#); [Borrego et al. 2013](#)), the authors chose to use Rogers' Diffusion of Innovation model ([2003](#)) as a guide to understand the spread of an innovation. This model is a framework for understanding how ideas or tools spread through a social system. Since its introduction in the early 1960s, the model has become a staple of social science and was used in this study as a framework through which we can examine the adoption of OER as an innovation. Rogers' model proposes that the four main elements that impact the spread of a new idea: the nature of the innovation itself, the communication channels, time, and the social system in which the innovation is being adopted. Each of these elements, along with the characteristics of OER adopters, will be addressed in the Results and Discussion section. Along with the four key elements, Rogers' model also includes a sequential five stage innovation-decision process that an individual moves through when deciding to adopt an innovation (Table 1). These stages of the innovation-decision process, along with the four main elements described in the Diffusion of Innovation model will be used as a guide to understand the current landscape of OER adoption in engineering education.

Table 1. Five stages of Rogers' innovation-decision process.

Stage	Description
Knowledge	The individual is first exposed to the innovation but lacks information and has not yet been inspired to learn more.
Persuasion	The individual is interested in the innovation and actively seeks out more information and details.
Decision	The individual weighs the advantages and disadvantages of the change and decides whether to adopt or reject the innovation.
Implementation	The individual employs the innovation to a varying degree and continues to gather information and judge the innovation's usefulness
Confirmation	The individual finalizes their decision to continue using the innovation, thus accepting the innovation into the normal order of things or reverting back to previous methods

Scope of the Study

In examining OER within engineering, the authors chose to focus on engineering mechanics courses for three key reasons. First, these are large, often multi-section, introductory courses where the introduction of a single OER tool could have a big impact for both students and instructors. Second, these are courses where engineering departments have control over curricular decisions, unlike introductory math or science courses. Third, unlike engineering design or programming courses that can vary significantly from one institution to the next, the content taught in the introductory mechanics courses is reasonably stable and consistent from one institution to the next and from one year to the next. Because of these reasons, it is believed that engineering mechanics courses would be the logical and most likely place to start for engineering instructors interested in adopting or authoring OER. The fact that OpenStax content has focused on similar courses outside of engineering ([Seaman & Seaman 2017](#)) lends additional credence to the idea that mechanics courses will serve as the entry point for OER diffusion into engineering. More specifically, this exploratory study seeks to address the following research questions: (RQ1) *What are the current OER adoption patterns in engineering mechanics courses?* and (RQ2) *What barriers exist to the adoption of open resources in engineering courses, and how might these barriers be overcome?*

Methods

The authors developed a two-pronged data collection strategy to address the research questions. The first data source was publicly available online records of required and recommended course materials across a sample of engineering programs. The second data source was a survey distributed to engineering mechanics instructors at the randomly selected institutions, as well as instructors in the Mechanics Division of the American Society for Engineering Education. OER innovators and adopters are likely overrepresented in this second data set due to self-selection biases; however, the survey allows for insight into the adoption process and motivations that are simply not available from online public records. With these two complimentary data sources, the authors sought to draw insights that either source alone would not be able to provide.

Gathering Data from Publicly Available Online Records

All colleges and universities have some way of communicating the instructors' required and recommended course materials to students, and much of the time this information is publicly accessible to those outside of the institution. The authors reviewed a sample of these publicly available records in a methodical way in order to gain insight into the course materials being assigned for mechanics classes.

The authors began by developing a stratified random sample of institutions with engineering programs to ensure a diversity of learning environments. This approach was used to ensure that large public institutions did not dominate the sampled data and that community colleges, many of which act as leaders in OER adoption, were not underrepresented. Table 2 outlines the four institution types in the study, with twenty randomly selected institutions from each institution type, and a total of 80 institutions overall. Specific institutions to be evaluated were randomly chosen from a list of institutions with ABET accredited programs (<https://amspub.abet.org/aps/category-search>) using a random number generator.

Table 2. Institution categories and definitions.

Category	Definition	Number of Institutions
Two-Year Colleges	Institutions that offer no accredited four-year engineering or engineering technology degrees	20
Undergraduate Only College or University	Institutions that offer no graduate programs in engineering or engineering technology (accredited or otherwise) but do offer accredited four-year undergraduate degrees	20
Public Research Universities	Public institutions that offer at least one graduate program in engineering or engineering technology.	20
Private Research Universities	Private institutions that offer at least one graduate program in engineering or engineering technology.	20

These classifications were broadly based on the Carnegie System, though some classifications were merged to simplify analysis. Additionally, institutions with distinct campuses or separate colleges or universities in the same system were categorized individually, meaning that programs were grouped by the highest degree offered at that given location.

The authors identified the introductory mechanics courses covering statics, dynamics, strengths of materials or some combination of these topics for the 80 institutions. Publicly available academic plans and course descriptions were used as a starting point, as course titles varied from

one institution to the next. As someone who teaches each of these courses, the first author served as the authority as to which courses counted as "introductory mechanics" courses.

The authors then used publicly available class search functions on institutional websites to identify any sections of the courses offered during the 2017-2018 academic year, as well as course instructors and required course materials. Though not all institutions make this data publicly available online through course catalogs or campus bookstores, information was available at a majority of the institutions.

Survey Instrument Development and Implementation

To complement publicly available data, the authors distributed a survey to mechanics instructors designed to identify the extent of OER adoption efforts as well as barriers to OER adoption. Course instructors identified through the data collection process described above received an invitation to complete the survey. In addition, a survey invitation was sent to the American Society for Engineering Education Mechanics Division mailing list to widen the net for potential participants. The overall structure of the survey was developed around the five stages of the innovation-decision process discussed in Rogers' Diffusion of Innovation model (2003). The survey was developed and administered in Qualtrics using conditional branching so that only relevant questions would be asked of the survey responders. A guide to the critical questions mapped to each stage of adoption is presented in Table 3.

Table 3. Survey questions mapped to the innovation-decision process.

Stage of Adoption	Survey Question	Answer Interpretation
Knowledge	How would you describe your level of awareness of Open Educational Resources (OER)?	Instructors reporting "I had never heard of them before this survey" were marked as having no knowledge, while all other responses indicated knowledge of OER.
Persuasion	Have you ever evaluated or reviewed any open educational resources with the intention of replacing existing course materials in your mechanics course(s)?	Instructors answering "Yes" to this question were marked as moving on to the persuasion stage of adoption.
Decision (Accept or Reject)	Have you ever evaluated or reviewed any open educational resources with the intention of replacing existing course materials in your mechanics course(s)? <i>with</i> Have you ever used an open textbook in an engineering course you were teaching?	Instructors answering "Yes" to the first question and "No" to the second question indicated advancement to the Decision process with a reject decision. Instructors answering "Yes" to the first question and "Yes" to the second question indicated advancement to the Decision process with an accept decision.
Implementation	Have you ever used an open textbook in an engineering course you were teaching?	Answering yes indicated that the instructor had advanced to the implementation stage.
Confirmation	How would you describe your experience using open educational resources (OER)?	Instructors who reported "Poor, didn't work, not impressed" were considered to have not moved to the confirmation stage, while all other responses were considered confirmation.

Beyond the key branch point questions, the survey asked for demographic and institutional information, relevant barriers to the next stage of adoption, opinions regarding the innovation itself (OER), the communication channels, and the social system of engineering education. Realizing that OER is one potential solution in controlling textbook costs, the authors also solicited information on other efforts to control course material costs.

Question development was informed by Fowler and Cosenza's work (2009), to ensure that (1) questions are consistently understood, (2) respondents have access to the information required to answer the question, (3) the way in which respondents are asked to answer the question provides an appropriate way to report what they have to say, and (4) respondents are willing to provide the answers called for in the question. A copy of the survey instrument can be found at the Penn State ScholarSphere (<https://doi.org/10.26207/yrk-2g66>).

To ensure that questions adhered to the above criteria, a preliminary version of the survey was sent to two experienced mechanics instructors outside of the project for review. Each of these reviewers was asked to take the survey multiple times (in order to fully explore the branching survey structure) and were asked to identify any areas of confusion or any options that may not have been taken into account with the multiple-choice responses. Feedback from these reviewers was addressed before sending out the official survey to recipients. The survey instrument and data management plan were also reviewed by the Penn State IRB (STUDY00008500). The request to complete the survey was then distributed, and a follow-up email was sent two weeks after the initial request in order to improve the response rate.

Results and Discussion

The discussion of the results begins with an analysis of data gathered from publicly available sources, followed by an analysis of the data gathered from the survey instrument.

OER Usage - Collection of Data from Institution Websites

There were 192 mechanics courses identified at the 80 selected institutions. Each course represents a single course designation, no matter how many sections of that course were offered during the 2017-2018 academic year. This was done because multiple sections of the same course at each institution were often treated as a single entry in listing required and recommended course materials. Of the 192 courses, the authors identified the required and recommended course materials for 158 of these courses. For the remaining 34 courses, course materials and other details were either inaccessible without a login or they were otherwise not publicly listed on the institution website. For the 158 courses with information, notable findings and observations include:

- Almost no OER was listed in the course materials from the observed institutions. The one clear example of OER being used was the "Freeform Lecturebook" (Rhoads et al. 2014) being used across three mechanics courses at a single large public research institution.
- Outside of OER, it was noticed that one institution included textbook costs as part of tuition and another course listed the textbook as optional (presumably with the instructor providing the necessary resources for those who choose not to buy the textbook).
- All other courses appeared to be using traditionally published textbooks. Based on the institutions that also listed the price of these resources (usually through the campus bookstore website), the median cost of a new print version of the required textbook was \$218.75. Used materials, rental options, and electronic versions of the materials in some cases brought these costs down, but the availability of these resources was inconsistent.

- Two sets of commercial books (the Hibbeler mechanics textbooks and the Beer & Johnston mechanics textbooks) appear to dominate the market of commercially available texts in engineering mechanics. The widespread adoption of just a few textbooks does speak to the uniformity of the content being taught from one institution to the next, which in turn shows the market for any one OER could be quite large.
- Finally, in 26 instances access codes for supplemental materials were required. Though this is not a majority of the observed courses, it does represent a substantive proportion. OER has the potential to not only replace course textbooks, but open tools could also potentially replace commercial supplemental content as well.

In addition to the overall median cost of the required materials, the authors examined the median prices in each type of course (statics, dynamics, strength of materials) and in each type of institution for patterns. In this examination, median prices were found to vary some, but there was no observable pattern overall. This indicates that in general no one course, or type of institution was more cost-conscious than the others. More information on these results can be found in Moore and Reinsfelder ([2018](#)).

Perceptions and Barriers - Survey of Engineering Mechanics Instructors

After gathering the survey results, removing incomplete responses, and removing anyone who did not report teaching an introductory mechanics course during the 2017-2018 academic year, the authors were left with 56 completed surveys. With such a niche population being surveyed (engineering instructors teaching specific mechanics courses) one could argue that this serves as a reasonably representative sample. As seen in Table 4, the survey respondents also represented a variety of institution types, as well as a range of experience in mechanics education.

Table 4. Survey respondents by institution type and years of experience.

Institution Type	Years of Teaching Experience				Total
	Less than 2 Years	2-5 Years	6-10 Years	More than 10 Years	
Two-Year College	0	3	5	2	10
Undergraduate Only College or University	1	7	3	4	15
Public Research Institution	3	8	6	5	22
Private Research Institution	1	1	1	5	8
Other	0	0	1	0	1
Total	5	19	16	16	56

Overview Survey Respondents in the Diffusion of Innovation Pipeline

Discussion of the survey responses will be broadly organized around the five stages of the innovation-decision process from Rogers' Diffusion of Innovation model ([2003](#)). Overall, engineering mechanics instructors implementing OER in their classrooms are still in the minority. Open textbooks were implemented in the classrooms of less than 10% of the instructors surveyed. When OER supplemental materials are included, this still represents less than a third of the classrooms. Though implementation could be higher, it was encouraging that significant portions of instructors were observed to have knowledge of OER or and have even spent time searching for resources in their classes. An overview of the stage of adoption that survey respondents were at, according to the guidelines set out in Table 3, is provided in Figure 1. A more detailed analysis of the usage patterns, perceptions, and observed barriers to adoption for each stage is provided in the sections below.

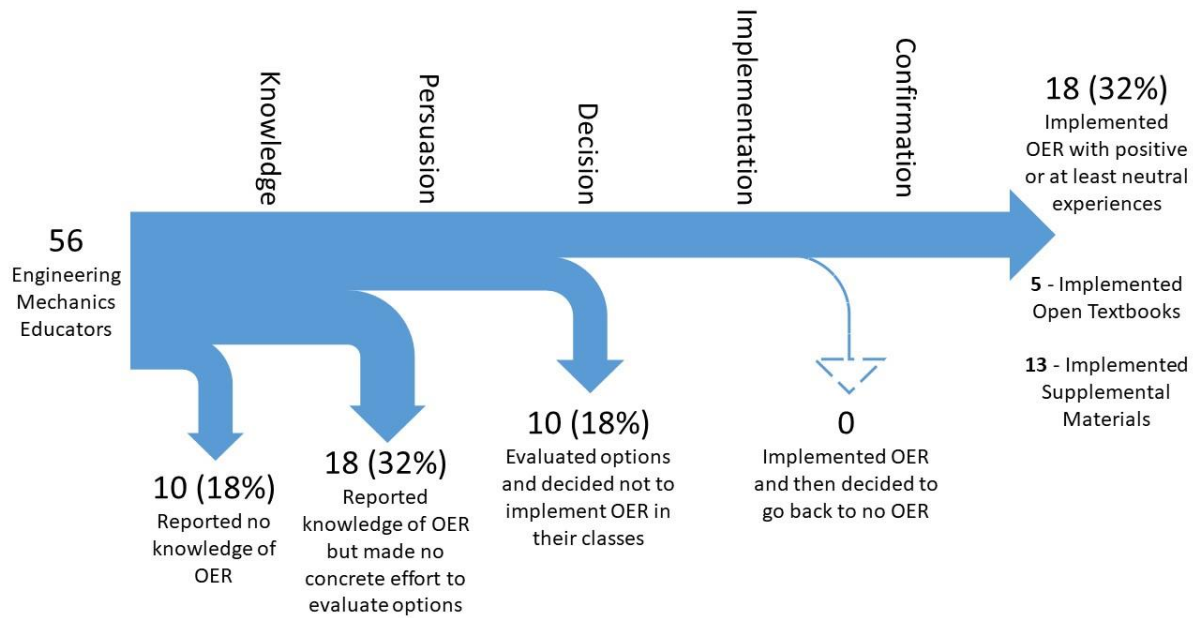


Figure 1. OER adoption according to the innovation-decision process.

Knowledge of OER

Of the 56 survey respondents, only 10 reported no previous knowledge of the term "Open Educational Resources." This indicates that the term is generally part of the vocabulary understood by mechanics educators and indicates a fairly high level of "knowledge" in the community as defined in the innovation-decision process of the Diffusion of Innovation model (Rogers 2003). This is also much higher than the 41% awareness reported by Anderson et al. (2017) for engineering faculty in general. While it is hard to provide definitive answers as to why this difference may exist, it could be due to the lack of OER resources in higher level courses causing lower awareness in higher level subjects, or that the faculty teaching introductory mechanics courses are more cognizant of OER since these courses are taught alongside courses such as math, chemistry, and physics where OER is most prevalent.

When asked to identify sources of information on OER, colleagues and personal connections were by far the most common. These personal connections served as the primary communication channel through which the innovation spread. Other possible channels for information were research publications, e-mail lists/blogs, and administrators, though these other items were rarely identified as a source of information on OER for the faculty members in this study. Despite the relative importance of personal connections in spreading the knowledge of OER, 43 of the 56 survey respondents reported knowing of no other faculty members at their institution using OER. This would seem to undercut the hypothesis that cognizance of OER is boosted because mechanics is taught alongside large introductory courses where OER is most prevalent. Knowing that personal connections are critical to the spread of knowledge, if the number of OER adopters were to rise, it seems likely that the communication between colleagues would push knowledge of OER to near 100%.

Seeking Information on OER

Persuasion, the next stage of the innovation-decision process, is where the instructor actively seeks more information on the innovation. In this case, the authors determined if someone was at the persuasion stage if they had either adopted some sort of OER tool or reported spending time searching for and evaluating open tools, even if they did not report adopting those tools. Based on these criteria, 28 of the 46 instructors with some knowledge of OER moved into the persuasion stage. This represents 50% of the original survey respondents, showing that serious consideration of OER adoption is present among mechanics instructors.

Instructors who reported knowledge of OER but had not spent time evaluating any specific resources (i.e., those who had not advanced to the persuasion stage) were asked an open-ended question on what would prompt them to evaluate OER for their classes. Responses to this question generally fit into two categories. The first was related to faculty who did not have control over the selection of course materials used, particularly the textbook. When individual faculty lack the control to choose, it is understandable that they do not sink time into finding and evaluating resources. This represents a fundamental barrier in the social system to the spread the innovation; however, it could also represent an opportunity should those that have control over course material selection decide to adopt OER for all course sections.

For respondents where control was not the issue, the lack of time required to find and evaluate new resources was most commonly cited as a reason. A lack of available time on the part of faculty is a common factor holding back the implementation of pedagogical innovations ([Dancy & Henderson 2010](#)). Administrative processes that reward faculty time spent finding and evaluating resources may help develop a social system where OER spreads more quickly. In fact, numerous institutions around the country are now offering financial incentives or grants to faculty who work to adopt, adapt, or create OER that will lower the cost of course materials for students ([Yano 2017](#)).

Deciding to Adopt or Not Adopt OER

After gathering information and evaluating available resources, instructors must decide if they are going to adopt OER for their classroom. This can obviously end with an affirmative decision, where they move on to implementation, or a negative decision, where they continue with the tools currently in use. Of the 28 instructors that reported evaluating OER, 18 reported using some sort of OER in their classroom, moving these instructors on to the implementation phase. Five of the 18 instances of OER adoption were open textbooks used to replace traditionally published textbooks. The other 13 cases of OER adoption represented OER that was used to supplement class materials or class assignments, often in small ways. For supplemental materials, it is unlikely these resources would be listed as required resources on the institution websites. If we make this assumption, it brings the OER adoption patterns more in line with what was observed via online public records.

Instructors who evaluated OER in some capacity were asked about their experiences. Most found some resources available related to engineering mechanics, but they also consistently discussed the lack of quality resources and, more importantly, a lack of depth in the available resources. In particular, the smaller number of worked examples that were available in OER when compared to traditionally published textbooks seemed to be a big negative for many instructors. These results were mirrored in the more generally reported perceptions of OER, where a lack of suitable resources was cited as the second most common reason for not adopting OER (behind "Happy with current textbook/course materials. Not interested in changing"). In a similar

comparison, 19 of the 56 respondents felt that available OER was of lower quality than traditionally published resources whereas, only 3 respondents felt it was of higher quality. The remaining respondents indicated no observed difference or that quality varied from one comparison to the next. To increase adoption rates, a higher perceived quality in the innovation itself is required.

Implementation of OER

After an affirmative decision, the innovation-decision process moves on to the implementation phase, where adopters start using the innovation. This corresponds to deciding upon OER use in the classroom. Of the original 56 survey respondents, 18 reported using some sort of OER in their mechanics classrooms. Some of the specific resources being reported as replacements for traditionally published textbooks included the Open Learning Initiative Engineering Statics Course (<https://oli.cmu.edu/courses/engineering-statics-open-free/>) from Carnegie Mellon University, the Mechanics Map Statics Textbook (<http://mechanicsmap.psu.edu/>) by Jacob Moore, Multimedia Engineering Statics (www.ecourses.ou.edu/cgi-bin/eBook.cgi) by Kurt Gramoll, and Introduction to Statics and Dynamics (<http://ruina.tam.cornell.edu/Book/>) by Andy Ruina and Rudra Pratap. It should be noted that the Ruina and Pratap textbook is not technically OER because it relies on the traditional copyright status of "all rights reserved" and clearly states that the work may not be redistributed or copied without the written permission of the authors. However, the authors do freely distribute the full text on their website. This confusion between "free" and "open" is common among faculty ([Seaman & Seaman 2017](#)). Another respondent reported using OER they had developed themselves, but did not mention anything about when and where this tool was hosted.

In terms of the resources reported to supplement courses, multiple respondents mentioned Coursera modules (<https://www.coursera.org/>) and MecMovies (<http://web.mst.edu/~mecmovie/>) by Timothy Philpot. YouTube videos were also frequently mentioned, though specifics were not given. Quality, availability, and licensing in these cases may vary from one video to the next, with many YouTube videos being free but not open for revision and reuse similar to the previously discussed textbook.

One inherent strength of OER in this arena is its adaptability, or at least its potential adaptability when compared to traditionally published content. Researchers have found that innovations are modified or re-invented by instructors to fit the class in up to 70% of the instances where they are implemented ([Henderson & Dancy 2007](#); [Dancy & Henderson 2010](#)). Results here show a similar trend, where many of the adopters are integrating smaller resources into their course (videos, modules, interactive software tools) rather than using a wholesale textbook replacement. While this adapting and remixing is prohibited under most copyright terms, creative commons licenses can explicitly allow this adaptation.

The Continued Use of OER

The final stage of the innovation-decision process is confirmation. This is the process through which the adopter evaluates the implementation and decides if the innovation now moves on to be part of the standard order of things or if they move back to prior methods. To evaluate this stage, those who adopted OER were asked to indicate how they felt about the implementation. None of the respondents felt that the implementation went poorly, indicating a high level of confirmation. Though this is a positive, the majority of those who implemented OER in their classrooms reported that while the implementation was good, it required more work than using

traditionally published materials. Though not unexpected, this does represent a cost to implementation and continued use.

Suggestions for Reducing Barriers & Increasing OER Adoption

Instructors seem ready to use OER if institutions and individuals are ready to put the work into creating and maintaining quality resources for engineering mechanics courses. The specific suggestions below, related to each stage of the innovation-decision process, should help reduce barriers and increase the adoption of OER in engineering mechanics courses.

- *Knowledge:* OER is already widely understood as a term among engineering mechanics educators, and local colleagues, such as fellow faculty members, librarians, and instructional designers, seem to be the primary communication channels through which word spreads. OER adoption rates are low at colleges and universities, but as we see more supporters and adopters, it is likely that awareness will spread through existing communication channels.
- *Persuasion:* Though many instructors sought out and evaluated resources on their own, many others mentioned a lack of time as a reason they did not do the same. Administrative structures rewarding the time spent finding and evaluating these resources are one possible way to address this challenge. From the OER developers' side, better repositories that make resources easier to find may also help save faculty time. Librarians can also play an active role here by monitoring newly created OER content and helping faculty to identify potentially relevant OER for their courses. Further, faculty should be encouraged to provide reviews of OER to help other instructors evaluate the usefulness of content. The Open Textbook Library maintained by the University of Minnesota (<https://open.umn.edu/opentextbooks>) is one example where faculty reviews are provided for many OER titles.
- *Decision:* This is the single most important suggestion. Many instructors have sought out open resources for their engineering mechanics classes, but most felt there was a lack of quality OER available in their topic area. Instructors are ready for quality OER to be available; that quality content just needs to be developed. How to best encourage OER authorship and development is beyond the scope of this study, but there is certainly a ready audience. Other subjects, including biology, chemistry, physics, and math, have already seen substantial progress around the creation of OER. Engineering educators should look to replicate the success in these other areas to increase the availability of quality OER for engineering mechanics courses.
- *Implementation and Confirmation:* Finally, most instructors who implemented OER felt it was successful, but required more time on the part of the instructor. In addition to supporting the discovery and evaluation process, institutions should also work to support instructors as they implement OER in their classrooms. In many cases, support is available from local instructional designers and librarians. These professionals are often willing partners in the OER process, monitor many of the latest trends and developments around OER, and regularly work with faculty from all disciplines.

An abridged version of the above recommendations can be found in Table 5.

Table 5. An action plan for reducing barriers and increasing OER adoption in engineering mechanics.

Stage of the Adoption Process	Suggestions for Improving Adoption Rates of OER
Knowledge	<i>Individual Faculty & Librarians:</i> Knowledge is already generally high, but knowledge seems to spread primarily via local colleagues. If no engineering faculty are using OER at your institution, you can provide examples and talk to your local colleagues about the experience.
Persuasion	<i>Institutions:</i> Create administrative structures and incentives that reward time spent searching for and evaluating OER.
	<i>OER Developers:</i> Create better repositories with easily accessible reviews to make finding and evaluating OER easier for faculty members.
Decision	<i>OER Developers:</i> Work to create quality, peer-reviewed content with rich sets of worked example problems. ¹
Implementation and Confirmation	<i>Institutions:</i> Offer ongoing support for those faculty members who decide to implement OER in their classrooms. Librarians and instructional designers may be well positioned to help in this area.

¹The authors believe this item is the most critical in improving adoption rates.

Other Methods of Controlling Textbook Costs

When asked what was the greatest potential advantage of OER, the majority of instructors pointed to the cost savings for students. OER represents one solution to this problem, though the authors realize other methods could also be used to keep textbook costs down. Of the 56 mechanics instructors surveyed, 51 reported employing at least one method to keep costs down other than OER usage. Having students use an older version of the textbook was the most commonly employed method, though a variety of strategies were reported (Figure 2).

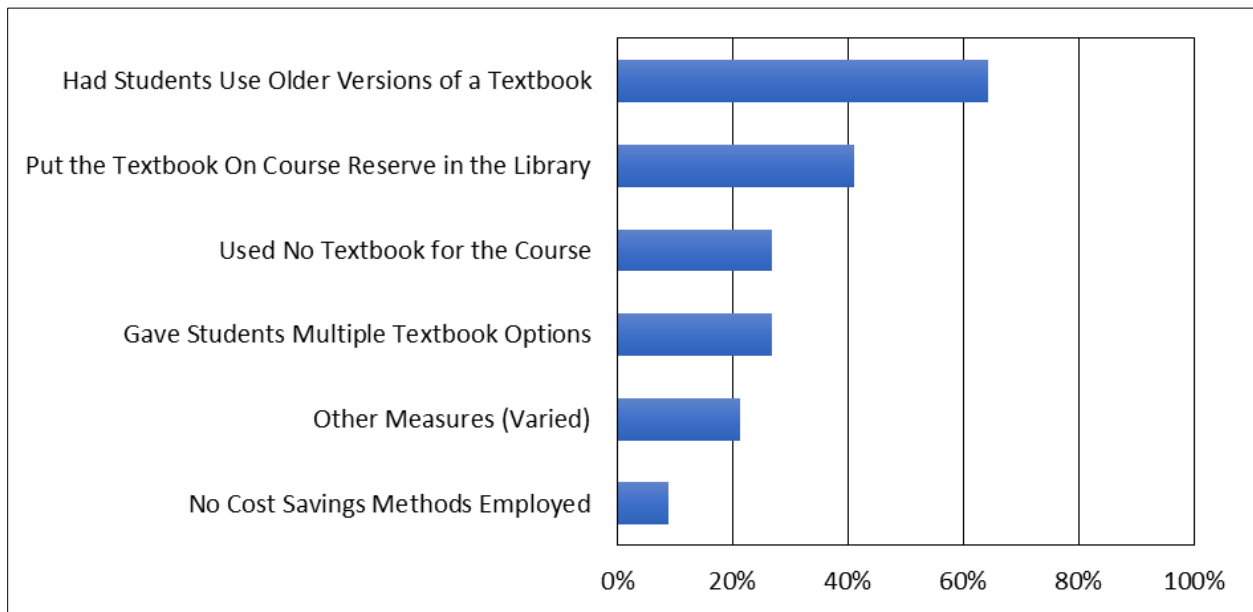


Figure 2. Other cost-saving measures employed by engineering mechanics instructors.

As a note on Figure 2, these cost-saving measures are not necessarily mutually exclusive, and many instructors reported employing multiple methods. As engineers, there is a clear problem to be solved in the rising price of course materials, but it is important to realize there are multiple possible solutions to any given problem.

While these other methods may seem sufficient, it should be noted that publishers have also worked to design their products to undercut or compete with these methods. Textbook rental, electronic textbooks, and access codes for supplemental materials are all in tension with many of the methods discussed above. While many instructors seek to use resources in a way that reduces the financial burden on students, for-profit publishers are seeking ways to remain profitable. Resources that are designed to be free and accessible would help reduce this tension.

Limitations

In terms of study limitations, the authors were only able to gather information from 56 engineering mechanics instructors. This is largely a result of the niche population of engineering instructors specifically teaching a small subset of courses. Though these instructors are reaching thousands of students, the low rates of OER adoption mean that only a handful of those instructors were in the later stages of the adoption model. This makes it difficult to generalize the characteristics of the adopters themselves. Should the population of adopters grow in the coming years, a follow-up study to identify the characteristics of the adopters would be useful to further our understanding.

Additionally, this research looked at engineering mechanics instruction from the instructors' perspective. An examination of OER in other areas of engineering, as well as an examination of OER from the student perspective also have merit and could provide a better understanding in this area. Furthermore, through examination of efficacy of different change strategies ([Borrego & Henderson 2014](#)) in spreading OER would be useful from the perspective of campus administrators.

Conclusion and Future Work

The use of OER in engineering mechanics courses remains the exception rather than the rule, but this research shows promise for the future of OER in engineering. Instructors are aware of the high cost of college textbooks and the vast majority of instructors in the survey reported using various methods to try to keep textbook costs down. Knowledge of the concept of OER is high among instructors, and a full 50% of the survey respondents reported investing time into evaluating OER relevant to their classes. Instructors have raised concerns about the quality of the resources available at this time, but they seem ready for quality tools to become available.

The single most important area for future research regarding OER in engineering education may be how to establish a robust ecosystem for supporting high quality OER development. Specifically, instructors wanted access to "quality" content, but what counts as quality content for engineering educators is still largely unanswered. Many instructors mentioned that robust sets of example problems were missing from current resources, but beyond that, the authors did not observe specifics on what instructors and students wanted in OER. This represents a useful follow-up to this study that could serve as a model for filling the need identified in this study.

In the end, the social system of mechanics educators seems primed for change. Communication channels between librarians and faculty have already led to high levels of awareness of OER, the availability of resources is limited but growing, and in time this will lead to an environment where learning resources are more equitably shared by learners.

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