Board 30: Applicability of Open Educational Resources (OER) in Construction Engineering

Dr. Michael Shenoda, Farmingdale State College

Michael Shenoda is currently an assistant professor in the Department of Architecture and Construction Management at Farmingdale State College in New York. He has previously served as a faculty member at other institutions, totaling over 10 years in civil and construction engineering education. Michael is a member of several professional organizations, including American Society of Civil Engineers (ASCE), Institute of Transportation Engineers (ITE), and American Society of Engineering Education (ASEE). He has also been inducted into Tau Beta Pi, the National Engineering Honor Society, and Chi Epsilon, the Civil Engineering National Honor Society. He has carried out research in several areas, including advanced traffic signal control, construction management, and sustainability in construction and civil engineering. Michael has also worked in the engineering industry for several years, as both a design engineer and construction inspector. He is a licensed professional engineer in New Jersey and Texas, and a LEED (Leadership in Energy and Environmental Design) Accredited Professional in Building Design and Construction.

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Abstract

Construction Engineering education makes use of a variety of resources, including copyrighted textbooks and proprietary software. The cost of such resources can limit access to educational programs in Construction Engineering. However, as construction engineering is practiced by a number of public agencies at all levels of government, it is possible that openly licensed content can be made available to students in such programs while maintaining an effective curriculum and meeting required student learning outcomes. As stated by OER Commons, though, the availability of such resources "is not just about cost savings and easy access to openly licensed content; it's about participation and co-creation." As such, the goal of using OER in construction engineering is to foster adaptation of the material to enhancing student learning and providing the most up-to-date information, through evaluation by faculty, students, and other stakeholders, like industry. As well as examining the current state of OER use and general applicability in Construction Engineering, this paper considers the development of a course offering in an undergraduate construction cost estimating course using OER. A framework for evaluating and improving the effectiveness of student outcomes in such a course is proposed. Future research is considered with completion of the first offering of this course and comparison to assessment results in a traditional course offering.

Background

The study of Construction Engineering involves courses in areas of construction practice such as estimation, scheduling, safety, project management, and plan reading and production. Such courses normally involve expenses for students in terms of textbooks, equipment, and software. The expenses for course textbooks and materials can be quite high. These include prices ranging to over $300 for individual textbooks in engineering [1], [2], to $700 per semester [3], to upwards of $1200 a year on average for civil engineering programs [4]. These costs also increase at an exorbitant rate, with textbook costs estimated to have been increasing 1500%, or nearly three times the overall rate of inflation, since 1970 [5].

These expenses can lead to negative consequences for students in a number of ways. Students will often avoid buying textbooks until later in the semester, or avoid buying them altogether [6]. They often choose course alternatives, or delay taking courses with high textbook costs [7]. This leads to delays in student graduation, increases in student attrition, and avoidance of majors (like engineering) with higher textbook costs [6]. Most importantly, within the courses themselves, students perceive, and faculty observe, lower performance with textbook access issues [8]. For lower-income students, for whom such textbook costs can take up 5% or more of total household income [3], this can lead to the need to take part-time jobs while taking classes, or making trade-

offs regarding housing, food, and transportation [9], which can indirectly affect their performance in classes.

There are a number of ways that students and faculty contend with the high and rising costs of textbooks and other course materials. Some of these may be considered undesirable, like illegal downloading and/or copying of materials [6], textbook sharing [8], or use of alternative materials that may not be pertinent to the course [7]. There are certainly a number of ways that have been thought out with the consideration of maintaining student performance and/or legal standing; these include:

- Second-hand (used) textbook markets, increasingly problematic due to greater use of CD software or online access codes (which usually cannot be repurchased) for supplemental materials like assignments, exams, etc. [10]
- Financial aid-based funding of textbook purchases; problematic because it may create a "prop-up" effect on textbook prices [11] and because it is increasingly less likely to cover textbook costs [7]
- Increased library purchases of textbooks for student lending [12]
- Textbook rentals [13]
- Electronic/online textbooks (e-textbooks) [14]
- Textbook republishing [2]
- "Lean" textbooks [1]

Clearly, there is great interest and creativity on the part of both students and faculty in finding ways to reduce the costs of course materials and the impact of those costs. The last tactic outlined, however, points towards the most extreme consideration: the concept of eliminating the cost of textbooks in courses altogether. This concept has been promulgated recently in the movement to Open Educational Resources, or OER. While these are often considered to be "free" materials, UNESCO defines OER in a more expository manner as "teaching, learning and research materials in any medium – digital or otherwise – that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions." [15] This definition is intended to speak more to the availability of materials rather than their quality; i.e. the goal is to find ways to widen the availability of high-quality educational materials in a variety of ways.

There has been much public consideration (e.g. [3], [10], [11]) that the textbook industry incentivizes the high cost of textbooks, which are often written by academics. As a possible result (although it is not the intention herein to explore the motivations behind this), OER efforts to date have been focused towards liberal arts, social sciences, mathematics, and the general sciences, as evidenced by a review of a number of directories and case study repositories (like the OER Center for California [16], California State University [17], Washington State University [18], OpenStax [19], and SUNY OER [20]). There is also a tendency towards the nature of resources being lesson plans, assignments, syllabi, or lectures (as noted in the cited directories and in OER creation tools provided by clearinghouses like OER Commons [21]).

This lack of availability of OER for Engineering, particularly with regard to textbooks, creates an opportunity in many disciplines of Engineering. This is especially true considering the relatively higher expense for Engineering course materials, as indicated earlier. There may be concerns with OER adoptions in Engineering for a number of reasons, including maintenance of academic rigor of programs, preoccupation of faculty with meeting the rigors of engineering research (both of which are examined by Campbell et. al. [22], or even preservation of inequities in engineering programs through rigor [23]. (Whether or not this preservation is intentional, this last point is something that can certainly be positively addressed in Engineering through OER.) These reasons will not be further explored herein, except to note that OER applications in Engineering are currently quite rare. A search through all of the previously referenced repositories yielded no examples of Engineering-specific OER implementations.

This is not to say that Engineering, as a discipline, has been completely neglected by OER efforts. Perhaps the best example of OER implementation in Engineering is Massachusetts Institute of Technology's MIT Open CourseWare repository [24]. (New Jersey Institute of Technology also maintains a smaller OER repository for Engineering courses [25].) Courses in nearly every discipline of Engineering are represented in MIT's repository. However, even therein, there is only one linked example of an open source textbook in the area of Construction Engineering (for the topic of project management).

Despite this, Construction Engineering is actually an area that is ripe for OER implementation. This is because construction projects are very often carried out, either directly as a builder or, more often, as a client, by governmental agencies. With this being the case, these agencies often put forth, for open access, a variety of resources for guidance in the execution of construction projects. A short list of some federal agencies from which such resources are available includes:

- General Services Administration, through its Office of Design and Construction [26]
- U.S. Army Corps of Engineers, through its Civil Works Cost Engineering and Agency Technical Review Mandatory Center of Expertise (MCX) [27]
- Marine Corps Publications Electronic Library [28]
- National Park Service, through its Denver Service Center [29]
- U.S. Government Accountability Office [30]

This is not a comprehensive list of federal agencies with such resources freely available, and there is a vast array of state and local agencies that provide them, as well. Clearly, the potential to source OER for Construction Engineering is great.

Development of an OER course in Construction Engineering

As stated at the beginning of the "Background" section, there are a number of topic areas taught in individual courses in Construction Engineering. When considering which course to develop for OER implementation in our program, we considered two main factors: (1) availability of high-quality open access materials for the topic in question, and (2) impact to cost of current

course materials. Based on these two factors, our cost estimating course, CON 357 – Quantity Surveying and Costing, was selected for OER implementation.

Considering the second factor first herein, the typical cost for materials for the course are shown in Table 1. It should be understood that there are a variety of course materials available for this course, as for all courses, and there will be variability in choices from one instructor or institution to the other. There are, indeed, lower cost textbook and software available, as a search at Amazon.com will uncover. These materials were selected (a) in consultation with our Industry Advisory Board as to the typical software and topics of concern in the practice and (b) without a consideration of cost (as a primary factor). This course material cost is comparable to the costs considered for engineering courses, as discussed in the "Background" section.

Table 1. Typical course material costs for CON 357 – Quantity Surveying and Costing.

Resource	Cost
Textbook	
Construction Estimating Using Excel, 3rd Edition by Steven Peterson	$164.48 (via Amazon.com [31])
Software (for electronic quantity takeoffs)	
Bluebeam Revu eXtreme 2018 Academic	$99.00 (via shop.bluebeam.com [32])
Cost data reference	
RS Means Online Cost Data Student Package	$45.00 (via rsmeans.com [33])
TOTAL	$308.48

To consider resources, it is helpful that nearly every governmental agency, including the ones referenced in the "Background" section, carries out projects, whether by capital investment, acquisition, or production, that require a cost estimate. This means that they provide ample and, usually, open guidance regarding the submission of estimates, from which sources can be drawn.

After reviewing the cost estimation guides available from a number of governmental agencies, the choices were narrowed down to three on the basis of (a) their relevance to estimation of capital construction projects, (b) their comprehensiveness in terms of covering all aspects of the construction estimation process (from conceptual/parametric estimation to construction phase cost adjustments), and (c) their utility in meeting the course objectives. The three choices are:

1. U.S. Army Corps of Engineers Technical Letter No. 1110-2-573: Construction Cost Estimating Guide for Civil Works [34]
2. U.S. Marine Corps MCRP 3-40D.12: Construction Estimating [35] (actually a multi-service handbook for construction estimating)
3. Department of Defense United Facilities Criteria (UFC) Handbook: Construction Cost Estimating [36]

Although all three of these handbooks have merit in all three areas, the one that was chosen for the first iteration of OER implementation was the U.S. Marine Corps document. Along with meeting the bases outlined above Its outline and format are very similar to the existing textbook for the course, listed in Table 1. Of course, the choice of open-source textbook is subject to

change as the OER implementation evaluation, as described in the "Framework for Evaluation" section to follow, is conducted.

Open resources for construction cost data are more limited. None of the federal agencies referenced above maintain open-source cost databases, and many local databases have been pooled into proprietary databases. (For example, many state DOTs have migrated their bid cost data to AASHTOWare [37].) There are a few open-source online construction cost databases, like Get-A-Quote [38], but these are relatively inaccurate and sparse. It is likely, for this course, that low- to no-cost options around the current RS Means database will be explored, including maintaining the student access requirement, or making print or online access available through departmental or library funding. (While not quite in the same spirit as OER, this will meet the quality and cost goals outlined at the beginning of this section.)

Software resources are more abundant, with nearly every agency providing some kind of cost estimation calculator, often intended to be used in conjunction with their estimation guidance. Most of these, however, are based on templates for the use of Microsoft Excel. Since the use of Excel is a desirable outcome (as seen in the "Framework for Evaluation" section), one of these templates will be used. To be determined is whether to use one of two options:

1) as is currently the case, to provide guidance for students to construct their own template in Excel (in which case, the National Park Service Cost Estimating Requirements Handbook [39] will be used)
2) to provide a pre-existing template, allowing students to focus more on other areas of the cost estimating process (in which case, the Smithsonian Institution Construction Cost Estimating Form [40] will be used)

Unfortunately, plan takeoff software such as the Bluebeam package typically considered for use in the course is unavailable directly on an open-source basis. While it would be ideal to include such a package would be helpful to the course, they are not essential, and their lack of availability can be mitigated through hand and/or CAD-based quantity takeoff procedures.

Even maintaining RS Means Online student access for the course, Table 2 shows that a significant cost reduction of over 85% can be achieved. Based on future considerations that can be made for cost data references, and for OER material adaptations (to be discussed in the "Further Considerations" section), this cost can potentially be reduced further or eliminated.

Table 2. OER course material costs for CON 357 – Quantity Surveying and Costing.

Resource	Cost
Textbook	
U.S. Marine Corps MCRP 3-40D.12: Construction Estimating	$0.00
Software (for electronic quantity takeoffs)	
Smithsonian Institution Construction Cost Estimating Form	$0.00
Cost data reference	
RS Means Online Cost Data Student Package	$45.00
Non-OER total (from Table 2)	$308.48
Cost reduction	-85.4%

Framework for evaluation

The Quantity Surveying and Costing course aims to meet four course objectives, which are outlined in Table 2. These were developed in consultation with our Industry Advisory Board and with consideration towards meeting student outcomes for Construction Engineering Technology programs as put forth by the Accreditation Board for Engineering and Technology (ABET). The course objectives are mapped to these ABET student outcomes for the 2018-2019 evaluation cycle [41] in Table 2, as well.

Table 3. Course objectives for CON 357 mapped to ABET program outcomes.

	ABET program outcomes								
Course objectives	a	b	c	d	e	f	g	h	i
1. *explain* the estimation process for construction projects, including bid preparation, project progress, and closeout	X								
2. *carry out* estimation procedures for the various aspects of a construction project		X				X	X		
3. *utilize* computer methods, including Excel, to carry out estimation.		X	X	X					
4. *prepare* a complete bid submission for a typical construction project		X			X	X		X	

ABET program outcomes
(a) utilize techniques that are appropriate to administer and evaluate construction contracts, documents, and codes;
(b) estimate costs, estimate quantities, and evaluate materials for construction projects;
(c) utilize measuring methods, hardware, and software that are appropriate for field, laboratory, and office processes related to construction;
(d) apply fundamental computational methods and elementary analytical techniques in sub-disciplines related to construction engineering.
In addition, graduates of baccalaureate degree programs will, to the extent required to meet the Program Educational Objectives:
(e) produce and utilize design, construction, and operations documents;
(f) perform economic analyses and cost estimates related to design, construction, and maintenance of systems associated with construction engineering;
(g) select appropriate construction materials and practices;
(h) apply appropriate principles of construction management, law, and ethics, and;
(i) perform standard analysis and design in at least one sub-discipline related to construction engineering.

I have taught this course, under different titles and at different institutions, but with the same course objectives, at least once per year from the 2013-2014 academic year to the (current) 2018-2019 academic year. I have tracked student levels of performance with each offering, with the aim of continuous quality improvement (CQI) for the course. Normally, I would have considered CQI initiatives in the areas of sequencing of topics, lesson plans, assessment tools (exams, exercises, and projects), and general teaching techniques. I have presented the tracking of this performance in Figure 1. With some variability to be considered based on some of the CQI applications, as well as changes in institutions, enrollment numbers, and ABET outcomes, there is still a general consistency to be seen for each objective, as well as at least adequate performance across all objectives.

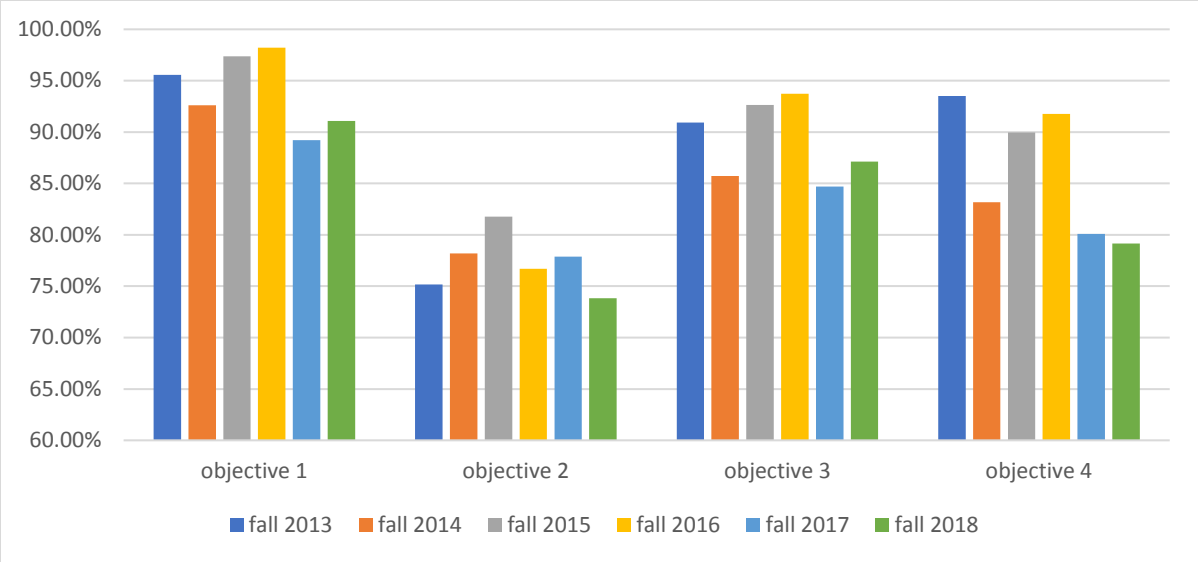

Figure 1. Tracking of student performance in course objectives for estimating course (CON 357)

While it is certainly appropriate to maintain this format of evaluation for the course in general through OER implementation, it is also prudent to consider other impacts to the course resulting from this action. It is one of the more drastic shifts an instructor can make to a course, and there is an implication, as considered in the "Background" section, that there may be a possible degradation in course quality with a shift to "free" (i.e. lesser by perception) materials. Thus, evaluation tools that consider course quality from a number of aspects should be utilized. Fortunately, this area of OER is relatively well-researched.

Lumen Learning has introduced the concept of an "Annual OER Report Card" [42] to evaluate OER implementations. Some of the areas of the report card are more program-based (rather than course-based) and some are course objective based (for which the current evaluation method will be retained), and are thus disregarded herein. Three main areas from which evaluation criteria can be drawn are: (1) Cost Savings Goals, (2) Faculty and Student Satisfaction Goals, and (3) Student Learning and Engagement Goals.

Another source of guidance for OER evaluation is the *Guidebook to Research on Open Educational Resources Adoption*, put forth by the Open Textbook Network [43]. Similar to Lumen Learning, there are areas of evaluation to be considered on the basis of cost, student and faculty use, and perceptions of OER (mainly to be focused on student perception). There is also a toolkit referenced in the Guidebook, which provides a number of several possible survey questions that can be provided to students to evaluate these three areas.

On the basis of these previous considerations, I will continue to evaluate the course with the same course outcomes, mapped to the same ABET outcomes (subject to changes made by ABET) and using the same assessment tools. This will allow an "apples-to-apples" comparison of course quality using measures that have been compiled on a regular basis and with a reasonable sample size. (It is understood, however, that inability to control for the variations seen

in Figure 1, as discussed earlier, will make it unlikely that a fully scientific study can be executed in this context.)

In addition, I will draw from questions in the survey provided through the Guidebook [x] to consider additional impacts of OER implementation. There are a number of questions that are meant to provide control variables for the survey sample; these will be omitted. The survey questions will thus be as outlined in Table 3. A baseline is necessary for comparison of responses to these survey questions from a non-OER offering of the course. This will be done once per academic year, either from a non-OER section of the course at the same institution or a non-OER offering of the same (or similar) course from a nearby institution.

Table 4. Survey questions for evaluation of impacts of OER implementation.

Q#	Question	Choices
1	In general, how often do you purchase the required texts for the courses you take?	❍ Never (1) ❍ Rarely (2) ❍ About Half the Time (3) ❍ Often (4) ❍ Always (5)
2	How much do you typically spend on texts each semester?	❍ Less than $100 (1) ❍ $101 - $200 (2) ❍ $201 - $300 (3) ❍ $301 - $400 (4) ❍ $401 - $500 (5) ❍ More than $500 (6)
3	On average, how many courses do you take each semester?	❍ 1 (1) ❍ 2 (2) ❍ 3 (3) ❍ 4 (4) ❍ 5 or more (5)
4	For a typical course, how often do you use the required texts?	❍ Never (1) ❍ 2-3 Times a Semester (2) ❍ 2-3 Times a Month (3) ❍ 2-3 Times a Week (4) ❍ Daily (5)
5	Did you purchase any texts for this course?	❍ Yes (1) ❍ No (2)
6	How much did you spend on texts for this course? (If yes to Q#5)	❍ Less than $20 (1) ❍ $21 - $40 (2) ❍ $41 - $60 (3) ❍ $61 - $80 (4) ❍ $81 - $100 (5) ❍ $101 - $120 (6) ❍ $121 - $140 (7) ❍ More than $140 (8)

7	Why did you not purchase the texts for this course? (select all that apply) (If no to Q#5)	❑ The texts were not available for purchase (1) ❑ The texts were available free of charge online (2) ❑ I simply didn't want to purchase texts for this course (3) ❑ I borrowed someone else's texts (4) ❑ I used library copies (5) ❑ I heard the instructor doesn't use texts for this course (6) ❑ I couldn't afford to purchase the texts (7) ❑ The texts were sold out (8) ❑ I rented the texts (9) ❑ Other reasons (10) _____
8	How often did you use the texts for this course during the semester?	❍ Never (1) ❍ 2-3 Times a Semester (2) ❍ 2-3 Times a Month (3) ❍ 2-3 Times a Week (4) ❍ Daily (5)
9	How would you rate the quality of the texts used for this course?	❍ WORSE than the quality of the texts in my other courses (1) ❍ About the SAME AS the quality of the texts in my other courses (2) ❍ BETTER than the quality of the texts in my other courses (3)
10	Imagine a future course you are required to take. If two different sections of this course were offered by the same instructor during equally desirable time slots, but one section used texts similar to those used in this course and the other used traditional published texts, which section would you prefer to enroll in?	❍ I would enroll in the section with TRADITIONAL PUBLISHED TEXTS (1) ❍ I would enroll in the section with TEXTS LIKE THOSE OFFERED IN THIS COURSE (2) ❍ I would have no preference (3)

Further considerations

The main goal of OER implementation, other than improvement of access to course materials, is the maintenance of course quality. Since this is most clearly demonstrated (certainly, for instance, for the purpose of ABET program evaluation) by the achievement of course objectives and program outcomes, maintenance of these along the levels of those seen in the tracking shown in Figure 1 will be a primary goal.

It is surely desirable to improve student performance in courses, and that will be a further aim of the OER implementation, as tracked through the course objectives seen in Table 3. However, it should be considered that, if such improvements are made after OER implementation, they can result from three main avenues:

1. standard CQI improvements, as outlined in the “Framework for Evaluation” section

2. CQI-type improvements in direct response to OER implementation (e.g. changing lesson plans or assessment tools to better align to open-source materials)
3. changes to the OER materials themselves

This last item should actually be seen as another goal of OER implementation. As stated by OER Commons, the use of OER is "about participation and co-creation." [21] This means that course materials should not be seen as static, or changing only on the basis of periodic updates or editions dictated by textbook publishers, for instance. They should be adapted based on instructor needs, student input, and other circumstances. In the end, OER materials should be unique to each course and each instructor as this adaptation takes place. Improvements to course quality overall based on these changes may not be evident from the evaluation of the course objectives alone, but in combination with changes to responses in the OER survey, as see in Table 4.

The first OER implementation to the CON 357 course is anticipated for an offering in either the Summer term or Fall semester of 2019. Thereafter, the course, with OER availability, will be offered at least once per academic year. Evaluations of course objectives and collection of the OER survey will be conducted in each of these offerings. Also, as stated in the "Framework of Evaluations" section, both evaluations will be conducted at least once per academic year to one non-OER offering of the course, either at the same institution or one nearby.

It is hoped that these results can be both positive and informative as to the applicability of OER to Construction Engineering within the first two offerings of the course with OER implementation. Dissemination of those results would be desired soon afterwards. This would lead to a consideration of wider implementation to other courses in our Construction Engineering curriculum, as well as through partnering and feeder institutions. This would, hopefully, allow greater access to our program as well as to the Construction field, at large.

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