



UTA CARES  
Open Educational Resources  
**Final Report**

Incorporating an Open Educational  
Resource into the Applied Fluid  
Mechanics Laboratory Course to  
Enhance Civil Engineering Education



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## Project Summary

In this project an open educational resource (OER) was developed and incorporated into the applied fluid mechanics laboratory course. The objectives of this OER were to: 1) provide students with adequate and consistent educational resources, 2) assess the benefits of utilizing free and open course material to enhance engineering students' technical skills and engagement, and 3) reduce the financial barriers to engineering education. The applied fluid mechanics laboratory course is an essential component of water resources engineering programs, but it is challenging to find standard course materials that help students comprehend and connect with experimental procedures. The OER allows all engineering students to benefit from free, perpetual access to the course content in the forms of customized lab manuals, educational videos, and an interactive lab report preparation toolkit, which eliminated the need for dedicated textbooks. A web-based multimedia e-book was created on Pressbooks, and it is publicly available to students and educators in other universities. The OER was implemented in fall 2018 at the University of Texas at Arlington. The students' learning experiences and the effectiveness of course materials were gauged by circulating survey forms to the students enrolled in the course at the end of 2018 spring (traditional lab) and fall 2018 (open educational resource) semesters. Data related to some control variables were collected for the purpose of performing a statistical analysis. Students' grades for lab reports, quizzes, and the final exam were also compared. The statistical analysis showed that the grades of the students who used the OER as reference material were higher than those of the students who had the same instructor the previous semester but were taught using traditional teaching materials. Teaching with OER also reduced the amount of time spent by students on the course, which indirectly reduced the cost of their education. The results of this study signify the effectiveness of the OER in enhancing engineering education.

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## 1. Introduction

Open educational resources (OER) is gaining popularity in engineering education due to advancements in science and technology. It is freely accessible, and contains openly licensed text, media, and other digital assets that are useful for teaching, learning, and research. However, OER is understood differently by various communities. In 2015, UNESCO defined OER as “*educational resources that are openly available for use by educators and students, without an accompanying need to pay royalties or license fees*” [1]. The OER movement is used in education primarily to counter the necessity for costly commercial products, typically textbooks and licensed publicly accessible content [2]. The inherent value of OER in the educational sector is its open access to materials that are fundamental elements of the scholastic curriculum [3]. Unlike other resources, OER incorporates a license, usually called the *Creative Common License*, which encourages the reuse of materials and potentially the adaptation of materials without first requesting and obtaining permission from the creator [1]. OER has proven to be valuable for students, as well as for instructors, who are able to improve their teaching methods by monitoring their own material and/or by comparing their methods with other instructors’ methods [4]. As a result, the overall scholastic community benefits from the development of the OER system.

In this project, an OER was developed and implemented to transform the traditional teaching methods of the *Applied Fluid Mechanics Laboratory*, a civil engineering (CE) junior level course. OER was introduced in this course to provide students with open-access and reliable material, reduce their cost of education, and enhance their chances for success. A web-based multimedia e-book is created on Pressbooks, and it now publicly available for students and educators in other universities.

The OER was developed by a faculty-student team comprised of the PI, Dr. Ahmari, one graduate student, and three undergraduate students who had taken the applied fluid mechanics lab course previously and had served as lab assistants for one semester. Thus, development of this OER is an excellent example of open pedagogy, where learners contribute to education.

Creation of this OER was funded by the UTA CARES Grant Program, which is sponsored by UTA Libraries.

This report presents the process of developing the OER and the results of implementing it in the applied fluid mechanics lab course. It also quantifies the effects of this teaching approach and depicts how it helped students overcome learning barriers and successfully complete the lab course. The OER provides a cost-effective alternative to traditional methods of teaching this course.

## 2. Motivation

Laboratory courses are considered as essential components of engineering programs. They are designed to consolidate a basic understanding of a subject (e.g. fluid mechanics, soil mechanics), to verify certain fundamental principles in engineering, and to give students the opportunity to gain

hands-on experience in relating theory to application. Since there are no standard textbooks available for such courses, the teaching materials are usually developed by either lab instructors (as handouts) or lab equipment manufacturers (as instruction manuals). Students rarely connect with these types of course materials because they are narratives, and it is very difficult for students to visualize experimental procedures by reading about them. Consequently, the lab instructors and/or their assistants traditionally demonstrate the procedures of the experiments at the beginning of each lab session. The effectiveness of this method largely depends on how rapidly the students can grasp the information given to them by the instructor in a few minutes of demonstration, how many students are in the class and in each lab group, the availability of lab equipment, etc. Some students record videos of the instructor demonstrating the experiment procedure for future reference. Since these demonstrations are not standardized, the level of information shared with the students might not be consistent throughout the semester, and it may vary from one semester to another. Some instructors go too far and literally run the entire experiment, while others provide too little instruction. In both cases, they defeat the objective of the lab course, which is to engage students in a hands-on learning experience. The lack of standard materials costs the students time and money, as they often resort to seeking help from textbooks and online resources for information relating to the lab demonstration and theoretical background of the experiments. Even though free internet resources (e.g. lab manuals, videos, lab reports) are increasingly available, they are, in most cases, inadequate and unreliable. To minimize the issues and complications associated with the fluid mechanics lab course, an OER was developed to house educational materials and instructions in a single location.

### 3. Objectives

The foremost objectives of this project were to provide students with adequate and consistent educational resources, assess the benefits of utilizing free and open course material to enhance engineering students' technical skill and engagement, and reduce the financial barriers to engineering education. Due to several aspect of the topic and some associative factors with work, the project focused of several specific tasks to meet the overall research objective:

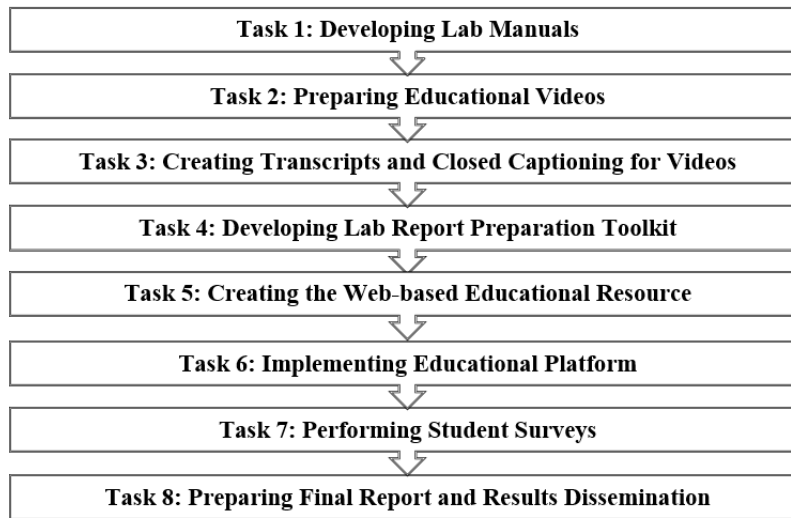
- Provide student with adequate and consistent educational resources,
- Assess the benefits of utilizing open course material to enhance engineering education,
- Develop and implement an OER to reduce the financial barriers, and
- Improve students' success in applied fluid mechanics course.

### 4. Methodology

The project included eight major tasks that are shown in Figure 1. The OER was developed through Tasks 1 to 5 and implemented by conducting Tasks 6 and 7. Task 8 was designed for disseminating the results.

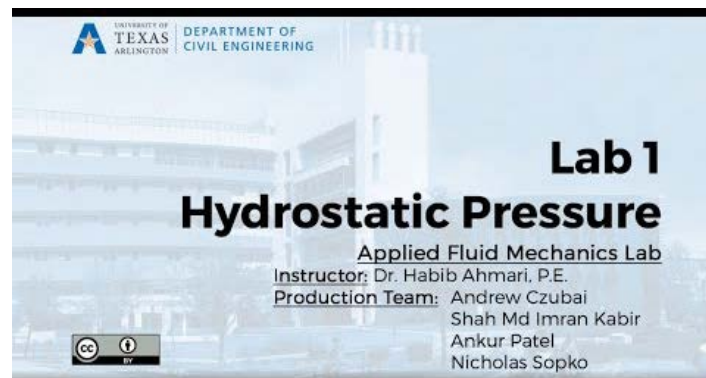
## 4.1 Development

**Developing lab manuals (Task 1)** – A customized lab manual was developed for each experiment. The laboratory apparatus, with appropriate images and figures; experimental procedures; and lab report preparation are explained thoroughly in these manuals. The manuals include the following sections: Introduction, Objective, Method, List of Equipment, Equipment Description, Theory, Experimental Procedure, Results and Calculations, and Report.



*Figure 1: Project Major Tasks*

**Preparing educational videos (Task 2)** – A short educational video was prepared for each experiment, as well as one video that demonstrates how to operate the lab’s hydraulics benches. Each video is limited to 4-6 minutes to keep the students focused on the subject [5]. Two trained undergraduate students collaborated to prepare the content of the videos, and one graduate and one undergraduate student oversaw the video production and editing. Video recording of the experiments was captured in standard video format, and video editing was done using professional software. The videos were reviewed carefully to check the quality and accuracy of the contents. The videos were uploaded into YouTube and are publicly available. The links to the videos are embedded in the e-book created on Pressbooks.



*Plate 1: Sample Educational Videos Developed in this Project*

**Creating transcripts and closed captioning for videos (Task 3)** – The transcripts and close captioning were prepared and added to the videos to provide the users with a complete set of information about each experiment.

**Developing report preparing toolkit (Task 4)** – An Excel-based toolkit was developed for recording raw data collected in the lab. This toolkit also provides students with automatically generated result tables and output graphs that are required for their lab reports. As shown in Figure 2, Excel workbook containing raw data, result table, and graphs tabs were prepared as a toolkit to support lab report preparation. To generate the result table and various plots of the results students are required to input raw data collected from the experiments during lab. The links to Excel workbooks corresponding to the laboratory experiments are embedded in the e-book created on Pressbooks.

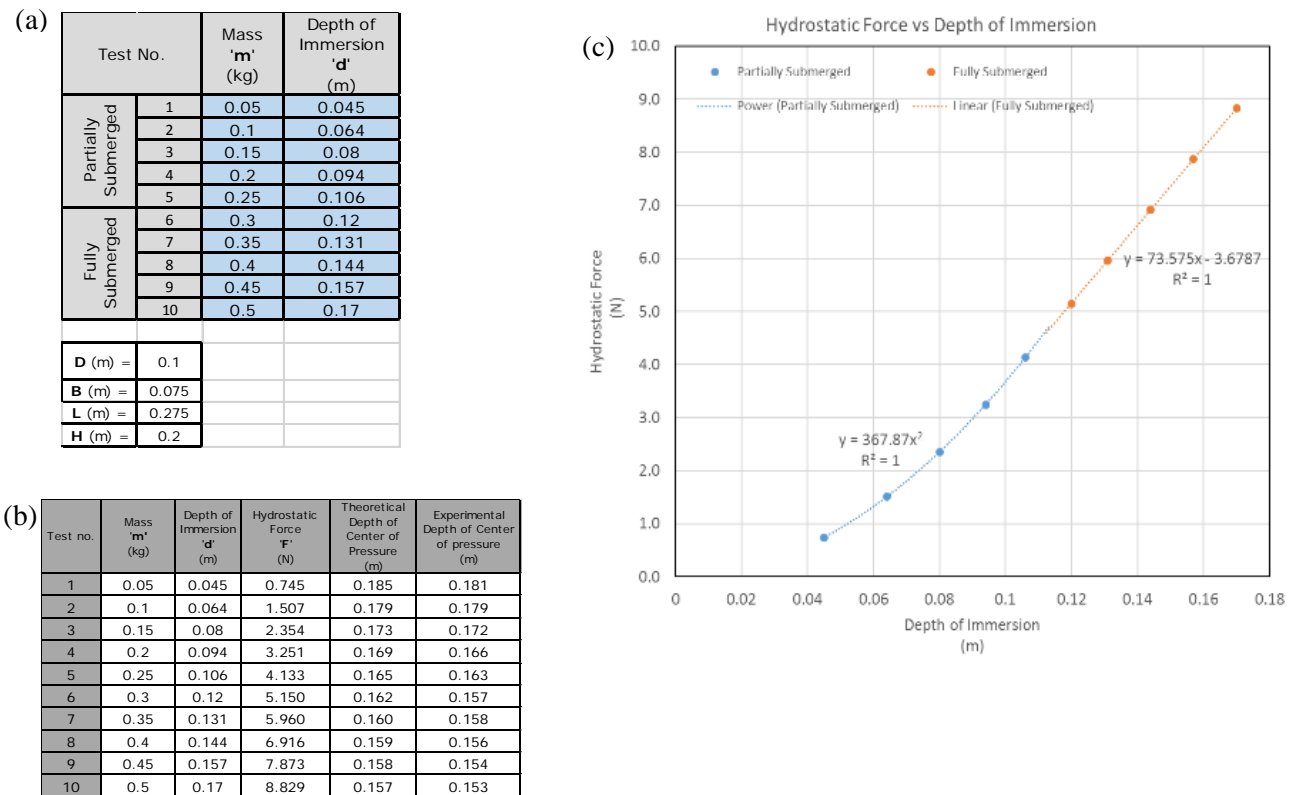


Figure 2: Sample Excel workbook tabs: a) raw data tables, b) result tables, and c) result graphs

**Creating a web-based educational resource (Task 5)** – Following the completion of all components of the OER (i.e. lab manuals, videos, and report preparing toolkit), a web-based multimedia e-book was created on Pressbooks. The book will be publicly available in Fall 2019. Gathering all developed OER material into a single location was another unconventional and effective way of making the course content even more connected with the students. Ten fundamental fluid mechanics lab experiment procedures with corresponding images, tutorial videos, and excel workbooks are included in e-book that is created on Pressbooks. Figure 3 shows the cover page and the Pressbooks interface of the e-book.



## 4.2 Implementation

**Implementing the educational platform (Task 6)** – The OER (educational videos, customized lab manuals, Excel toolkit) was uploaded to the Learning Management System (LMS) Blackboard, the online course management tool at UTA before the beginning of the fall 2018 semester. Students enrolled in the applied fluid mechanics laboratory course that semester were instructed to watch the educational video for each experiment before coming to the lab so that they could be acquainted with the equipment and the experiment procedure. The instructor (the PI) and his teaching assistant did not demonstrate lab procedures, as they would have in previous semesters (traditional lab teaching method) but helped students if they were needed help with any part of the experiments. Students also used the Excel toolkit to prepare their lab reports.

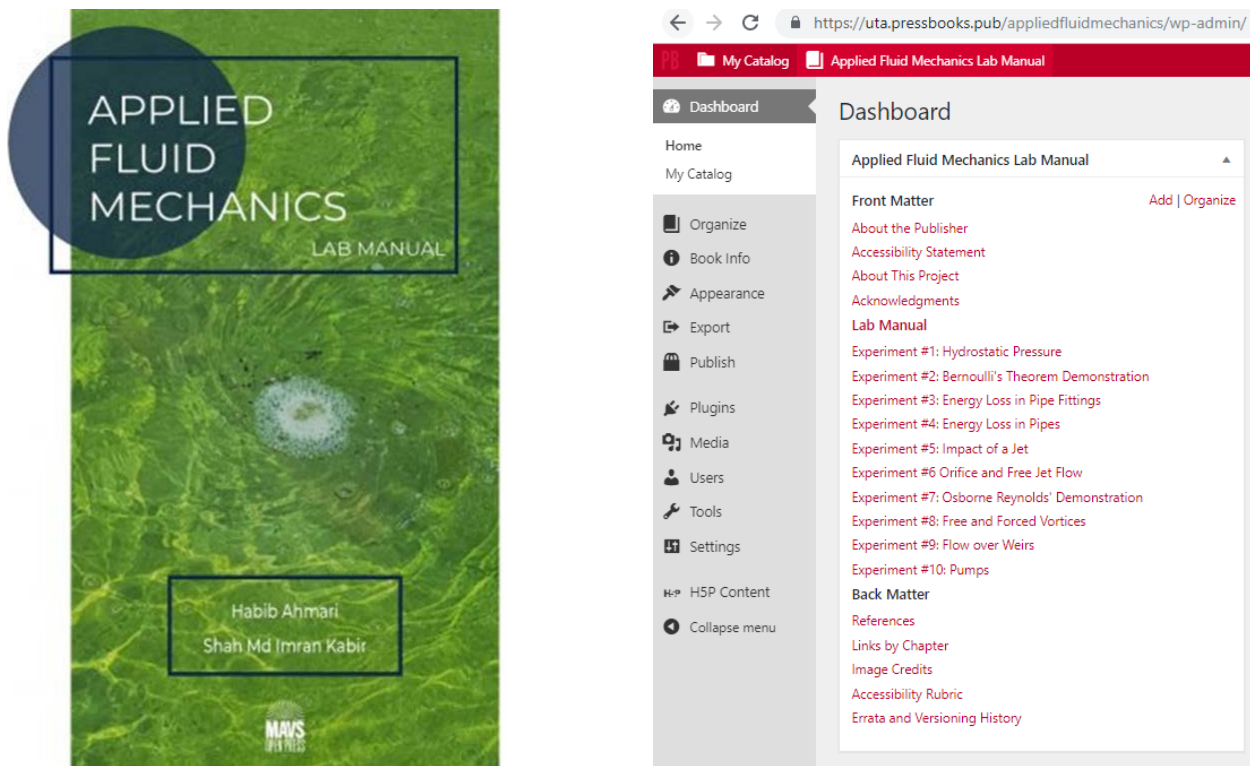


Figure 3: Cover page of the e-book (left) and Pressbooks lab manual interface (right)

**Performing student surveys (Task 7)** – Survey forms were circulated to all students enrolled in the course at the end of 2018 spring (traditional lab teaching method) and fall (OER-based method) semesters. Survey data comprised of some control variables was collected for the purposes of comparison and performing statistical analysis. These control variables included the student's working status (not working, working part-time or fulltime); engineering background (no experience, field experience, consulting experience, research project involvement); and time spent studying for the applied fluid mechanics lab course (hours per week). The students' performance was assessed based on lab their reports submitted for each laboratory experiment, quizzes, and the final exam.



### 4.3 Dissemination

**Preparing the final report and results dissemination (Task 8)** – The developed OER material in this project is publicly available to widely share the course material developed through this project with students and educators at other universities.

This report summarizes student surveys, synthesizes survey data, and presents the impact of utilizing OER on students' performance. Statistical analyses have been performed and presented to compare the results of the OER-based and the traditional lecture-based teaching applied fluid mechanics lab. The report also discusses the challenges and accomplishments that the project team experienced while creating and implementing the OER.

## 5. Analysis and Results

The effects of utilizing the OER on student performance and the cost of education were assessed based on the surveys conducted in spring 2018 (traditional method) and fall 2018 (OER method) and the students' grades for both semesters.

### 5.1 Students Performance Analysis

The grading structure for the applied fluid mechanics lab course is presented in Table 1. The lab report preparation and submission comprised 70%, and quizzes and the final exam were equal to 30% of the overall grade (each 15%). The lab reports, quizzes, and the final exam for two consecutive semesters, taught by the same instructor but with two different teaching methods, were graded using the grading scheme (Table 1). A summary of the results is shown in Table 2 and plotted in Figure 4.

*Table 1 Grading scheme of Applied Fluid Mechanics laboratory course*

<b>Categories</b>	<b>Percent of Overall Grade</b>
Lab Reports	70%
Quizzes	15%
Final Exam	15%

*Table 2: Summary of students' grades in spring 2018 (traditional method) and fall 2018 (OER method)*

	<b>Traditional Method</b>		<b>OER Method</b>	
	<b>Average</b>	<b>Standard Deviation</b>	<b>Average</b>	<b>Standard Deviation</b>
<b>Lab Reports</b>	89	6.7	93	8.3
<b>Quizzes</b>	72	12.8	64	11.8
<b>Final Exam</b>	66	15.6	72	11.6
<b>Overall</b>	83	6.8	85	7.5

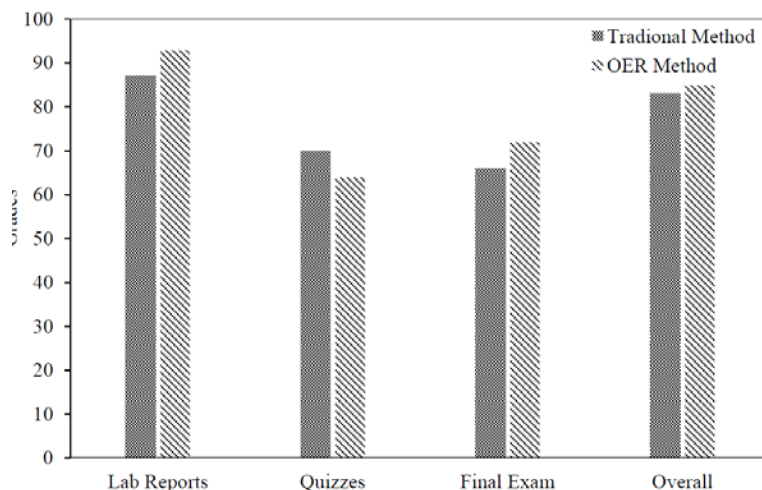


Figure 4: Comparison of students' grades in 2018 spring (Traditional method) and fall (OER method)

Table 2 and Figure 4 show that in the OER-based semester, students' average grades for lab reports, the final exam, and the overall grade were improved, whereas their grades for quizzes declined. The increase in the lab report grades could be attributed to the students having a better understanding of the experiments due to the educational videos and the Excel toolkits that helped them prepare their reports in a timelier manner. The higher standard deviation for lab report grades in the OER method indicates higher variability in the students' performance. It could have been caused by a few students not watching the videos before coming to the lab and/or not preparing their reports by fully utilizing the Excel toolkits.

The final exam was primarily based on conceptual questions. The improvement in the final exam grades could be due to the OER that helped students with their overall knowledge about the content of the course material. The quiz questions, on the other hand, were designed with data analysis that required some computations related to the experiments. Apparently, students who used the Excel toolkit to perform data analysis for their report were less proficient in mathematical calculations, which affected their performance in quizzes.

The grade distribution also signifies that the implementation of the OER method played an important role in students' performance in this course. Figure 5 compares the grade distribution of lab reports, quizzes, the final exam, and the overall grade. The percentage of students who obtained grade *A* in their lab reports increased significantly, from 59% in the traditional-based semester to 84% in the OER-based semester (Figure 5a). The percentage of students who earned grade *B* decreased from 29% to 8%. The students' overall grades were 47% *A* and 42% *B* in the OER-based semester, whereas in the traditional-based semester, 12% earned an *A* and 61% earned a *B* (Figure 5d). The grade distributions for the quizzes and final exam did not show significant variability between these two semesters (Figures 5b and 5c).

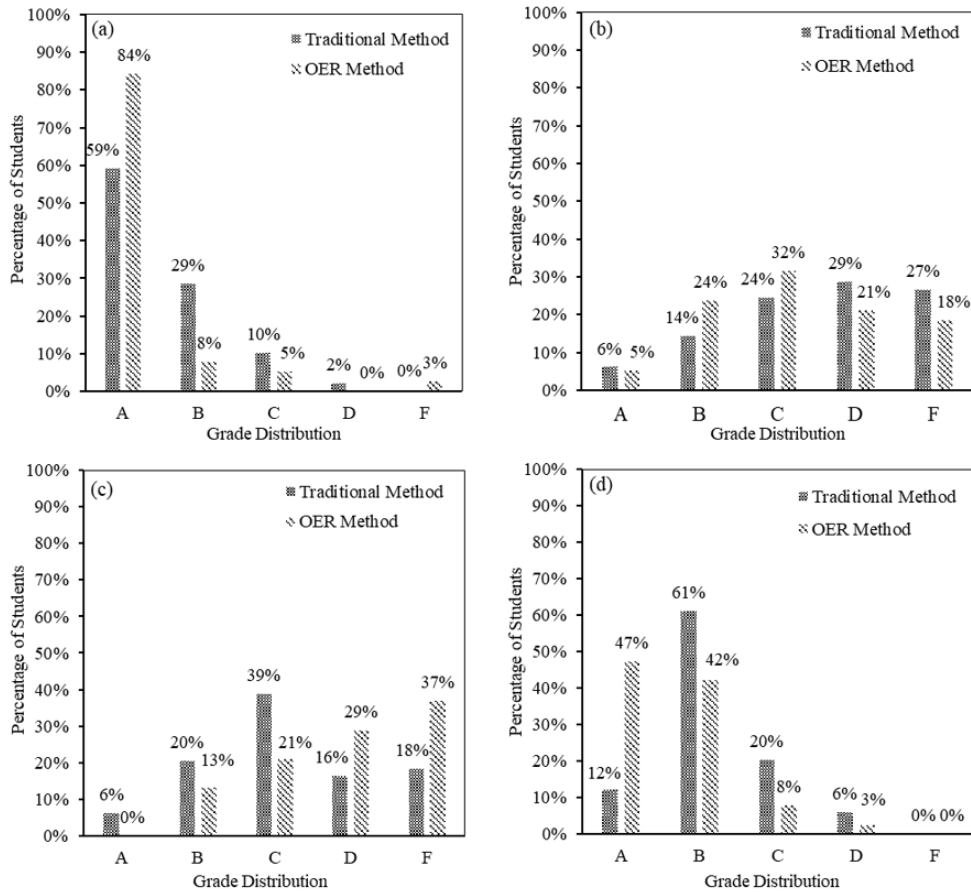


Figure 5: Grade distribution for (a) Lab reports, (b) Quizzes, (c) Final exam, and (d) Overall grades

## 5.2 Cost of Education Analysis

In addition to the benefit of having access to no-cost course material, time saving is very crucial for UTA's CE students since most of them work to pay their tuition and/or support their families. In the surveys performed at the end of the spring and fall 2018 semesters, students were asked about the number of hours they spent on preparing each lab report and their working status (not working, working part-time or fulltime). According to the survey data, an average of 65% of the students were working either full time or part time (Figure 6).

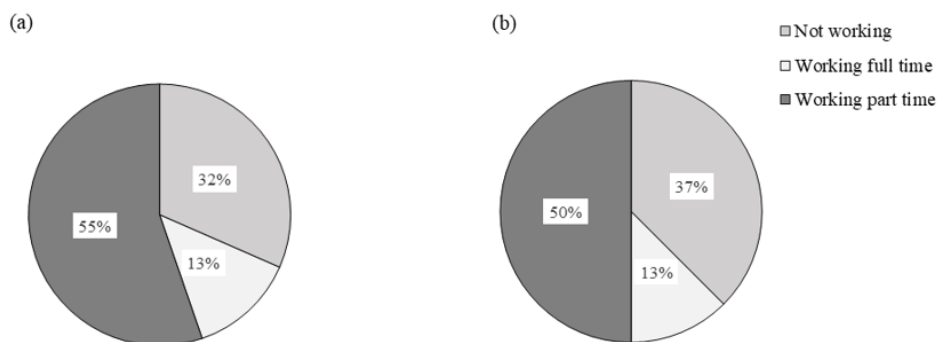


Figure 6: Students working status for (a) Traditional method and (b) OER method

On average, students spent 8.2 hours per week in preparing a lab report during the traditional-based semester. This value decreased to 4.8 hours in the OER-based semester (Figure 7). The standard deviation of the average amount of time spent while utilizing the OER methods also indicates less variability than that of the traditional method. Utilizing the OER saved students an average of 3.2 hours per report. If the student earned \$15 per hour, that would be an additional \$480 in earnings per semester ( $3.2 \text{ hr} \times \$15 \text{ per hr} \times 10 \text{ reports}$ ). A total of 100 students take this course at UTA annually. Considering that 65% of them are working, utilizing OER would allow the students to earn an additional \$31,200 per year ( $\$480 \text{ additional earning per semester per student} \times 100 \text{ students} \times 65\% \text{ working fulltime or part time}$ ).

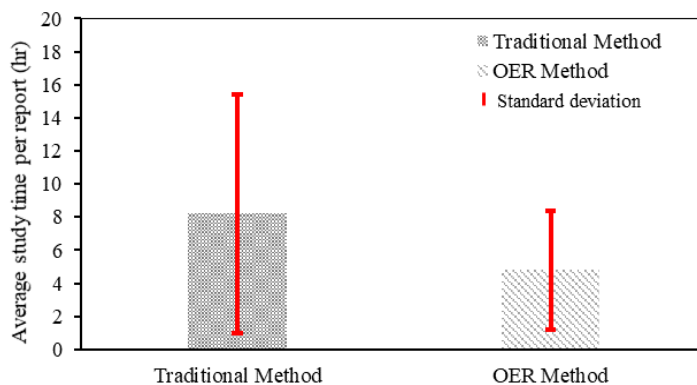


Figure 7: Average time spent by students to prepare one lab report

### 5.3 Qualitative Assessment to Evaluate Student Attitudes Toward OER

The results from the Course Evaluation Surveys conducted by the UTA shows that students who used the OER material enjoyed the course more than students in the traditional format lab. Following is sample students' responses to the following survey question.

*"Which attributes of the lab activities and/or the lab instructor helped you learn the material? (When the lab is next taught, what should be done in the same way?"*

- Having videos up at all times and having the GTA.
- The lecture on the labs and the videos provided, before we do them, helps to grasp a quick understanding before we do them.
- The lab reports.
- I liked the format of this course. The introduction to the course, then labs, then quiz is very organized. Also, the additional excel tables and videos really help as subsidized information to help in understanding.
- Firstly, watching the videos before coming to every lab is a great help and way to pre-learn. So, thank you for the lab experiment. Also, the exam after every 3 labs is also a good method to check student's ability
- The material was easily accessible and had many ways of viewing how to complete an experiment.

## 6. Challenges of OER Implementation

**Students' adoption to OER** – When a new system is launched, users will often resist change and show unwillingness to adopt a new system. One of the challenges that we initially faced was to make students watch videos before attending the lab. The instructor and the teaching assistant encouraged students about using free OER material, and they regularly monitored students' adaptation to this new system.

**Limitation of the OER Material** – The OER material (videos, lab manuals, and workbooks) are developed for the equipment at UTA Fluid Mechanics Laboratory. Even though this type of equipment is widely used by many universities in the U.S. and around the world, the OER materials may not be directly used for equipment developed by other manufacturers.

For sake of consistency in lab report preparation, some features of the Excel workbooks are locked. Consequently, students cannot make changes to the workbooks, if they decided to collect lab data by following different procedures than instructed in the lab manuals.

Students performance analysis showed that providing the Excel workbooks resulted in lower grades in their quizzes. Students who used the workbooks to perform data analysis for their report were less proficient in mathematical calculations, which affected their performance in quizzes.

**Shortness of the Educational Videos** – A short educational video of 4-6-minute length was prepared for each experiment for demonstration the experimental procedure. The videos were kept short to keep students engaged. However, it was found that this short content was inadequate for clearly demonstrating a few of the experiments.

**Limited Resources** – Developing educational material that targets a large audience requires resources. The quality of the work could have been much better if more resources, especially financially, was provided by the UTA Library or other offices. The PI was lucky that could hire students for this project who already had training and expertise in developing educational videos and workbooks

## 7. Dissemination of OER Implementation Benefits

**Conference Paper Publication** – The results from this research project was presented at the American Society of Engineering Education (ASEE) conference. The paper titled “Incorporating an Open Educational Resource into the Applied Fluid Mechanics Laboratory Course to Enhance Civil Engineering Education” was presented at 12<sup>th</sup> March 2019, at the University of Texas at Tyler.

**Involvement of Students and Educators around the World** – Educational video prepared for each of the experiments enables students and educators to understand the experimental procedure. To date, more than 21,000 viewers have watched the OER videos, and there are more than 100 subscribers following the PI YouTube Channel (Figure 1). The project team has been contacted by many individuals from the U.S. and overseas universities requesting access to the OER material.

The OER material has been viewed by many users since it was published on Pressbooks in 2018. A total of 3,779 pageviews was recorded in the past 11 months of which 2,227 pageviews reported during the period of January-June 2019.

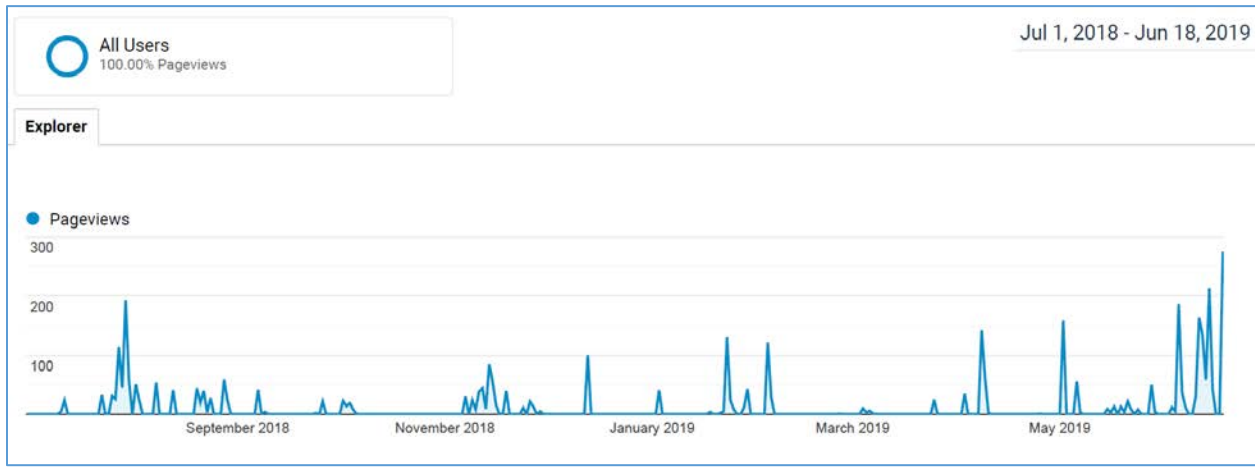


Figure 8: Number of pageviews of the OER published on Pressbooks since July 2019

## 8. Sponsor Support

**Monthly Reports** – One of the commitments to the project sponsor was to submit a monthly project progress report. Ms. Reed’s continuous feedback on monthly reports and monitoring during this time accelerated the team effort to finish this project on time.

**Development of Survey** - Ms. Reed provided the template survey used for data collection which helped to project team for conducting the survey in a consistent manner. Students were asked to participate in the survey at the end of the semester by their course instructor.

**Training Workshops** – The training workshops on OER and Pressbooks hold by the UTA Library greatly help the PI and his graduate students in developing the OER and publishing it on Pressbooks.

## 9. Recommendations and Future Work

**Future development of OER material** – The successful application of OER in applied fluid mechanics lab course depends on the feedback from the UTA students who will take the course in or from other universities’ students or educators. The team will be updating the OER material to improve the quality of the OER.

**Recommendations for the project sponsor** – The sponsor has a vital role in helping the project team by solving issues regularly. The project sponsor should also provide training to the project team about the technical aspects of the Pressbooks, especially with the engineering texts. It is also recommended to increase the project funding for the development of OER course materials.

## 10. Conclusion

An OER was developed and implemented at the UTA to transform the traditional teaching applied fluid mechanics lab. The OER provides students with a set of complete and open-access course materials that includes customized lab manuals, educational videos, and a lab report preparation toolkit, negating the need for dedicated textbooks and other resource materials. Student performance during two consecutive semesters was compared. In the first semester, the course was taught using the traditional method; in the second semester, students utilized the OER. Students acquired higher grades in the second semester, and their lab reports and final exam evaluations reflected a better understanding of real-world applications of fluid mechanics concepts and principles. In addition, utilizing the OER greatly reduced the amount of time required for students to successfully complete their course, allowing the 65% of our students who work to earn additional income that could help them overcome their financial barriers to education and to support their families. The qualitative assessment, obtained from the UTA Course Evaluation Surveys, showed that teaching with OER was well received by most students. The instructional resources developed through this study is shared with other educators, through an e-book created on Pressbook. Implementation of this open-access educational resources significantly contributes to the academic engagement and success of civil engineering students and is well aligned with the ever-increasing awareness of the transformative power of open education.

## Acknowledgement

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