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# IMPACT OF OPEN EDUCATIONAL RESOURCE ON IMPROVING LEARNING PERFORMANCE OF STUDENTS

**Dr. Atefe Makhmalbaf, The University of Texas at Arlington**

Dr. Atefe Makhmalbaf is an assistant professor at the UTA School of Architecture. She worked for Pacific Northwest National Laboratory (PNNL) as a research engineer and joined UTA after receiving a Ph.D. from Georgia Institute of Technology in Building Science. Dr. Makhmalbaf leads a Building Performance Analytics group at UTA. She develops decision support systems to enhance sustainable built environment. Since joining UTA, she has developed and taught several undergraduate and graduate courses in the area of building science, including energy modeling and sustainability assessment. Dr. Makhmalbaf's research activities have been published and recognized nationally and internationally. Her research activities have resulted in about 40 technical reports and prestigious journal and conference papers. Dr. Makhmalbaf is highly interested in Architecture pedagogy and experiments with innovative teaching pedagogies.

# IMPACT OF OPEN EDUCATIONAL RESOURCE ON IMPROVING LEARNING PERFORMANCE OF STUDENTS


## ABSTRACT

Development and adoption of open educational resources (OERs) have grown in recent years. Yet, we lack research on the performance of students in courses using OER and more specifically in architecture and engineering education. The objective of this research is to assess the impact of an OER platform for teaching building information modeling (BIM) course, taught to architecture, engineering and construction (AEC) students at the University of Texas at Arlington. This study examined the performance of AEC students in a BIM course before and after adopting the OER platform developed and also a combined OER and flipped classroom strategy. Hypothesis tests were performed to compare the averages of students' project and overall grades in three semesters that the BIM course was offered without the OER, with the OER, and with combined OER with flipped classroom. Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA) tests, which use linear regression were utilized to assess the potential main and interaction effects of the OER and control variables (i.e., GPA, major, employment status, family background, field experience, effort level, and past BIM experience) on the students' overall or project grades. Results show the averages of project and overall grades were improved in both semesters that the OER platform was provided and students performed even better when OER was used to enable flipped classroom strategy. The results of t-tests indicate that these improvements in the average project and overall grades have been statistically significant. The results of ANOVA and ANCOVA tests show that the OER platform was a significant factor in improving average overall and project grades even after considering the effects of the control variables (i.e., GPA, major, family background, field experience, effort level, and past BIM experience). It is expected that OER is effective in helping students to learn building information modeling more effectively.



**KEYWORDS:** Open Educational Resource; Innovative Teaching, Flipped Classroom, Building Information Modeling (BIM); Architecture, Engineering, and Construction Pedagogy; Quantitative Methods


## INTRODUCTION

The Internet has enabled access to open information resources since early 1990's. Online learning mediums such as e-books, podcasts, streamed videos, and virtual participatory environments such as social networking, wikis, and alternate reality worlds have grown significantly. Some instructors share their course materials and teaching ideas broadly, which expands learning and education equity. Online content such as open educational resources (OERs) have been developed to support higher education students. Open educational resources are teaching, learning, and research materials, commonly in the digital medium and public domain; an open educational resource may be released under an open license [1]. In other words, an OER allows others to access, use, adapt and redistribute the materials at no cost. An OER may include complete courses, individual course units or modules, textbooks, lesson plans, syllabi, lectures, assignments, game-based learning programs, quizzes, podcasts videos, audios, interactive simulations, and interactive multimedia) with various formats (e.g., text, video, animation, and hybrid media) [2]. In 2020, millions of people started working from home and students attended schools remotely due to the COVID-19 pandemic. As a result, internet usage, online content and the need to have even more open access resources increased dramatically.

Literature indicates students have expressed a positive attitude and perception towards open education resources [3] – [6]. For instance, Huntsman [7] showed that students reacted favorably towards replacing a conventional professional communication textbook with an open-access one, which demonstrated the promise of open access books. There are several guidelines, checklists, and rubrics to develop high quality open educational resources (e.g. [2], [8], and [9]); some of the criteria for successfully developing OERs are: (a) Quality peer review: reputation of authors and institution; (b) appropriateness of content: content is accurate and fully cited, learning level and source learning objectives are explicit; (c) technical issues and production quality: high readability of content; clear and understandable information; easy-to-navigate interface; (d) accessibility: availability of resources in various formats; adaptability and modularity; (e) interactivity: active learning; class participation; formative and summative evaluation of learning; (f) supplementary resources: links to other types and formats of open educational resources relevant to the subject; and (g) licensing to reuse, modify, and share.

However, despite widespread enthusiasm, there is little research on the performance of students, especially architecture and engineering students, in courses offered with open educational resources. Some studies indicate the positive perception and impact of using OERs in engineering and technical schools [10] – [12]. [10] includes a survey from engineering instructors , faculty, and students about their perceptions and requirements related to OERs. Most respondents indicated the cost reduction as the main benefit in addition to facilitating with inclusion of more practice problems, having access to interactive lessons, searchable content, and up-to-date materials [10]. Respondents' concerns were mostly related to the quality; yet they mentioned material selection is the instructor's responsibility. Students ability to access internet, their inability to assess sources, and lack of control over content were among other concerns mentioned [10]. Nipa [11] evaluated the impact of web-based OER materials and found engineering students and those with student loans had a more positive perception about OER and all students enrolled in the course chosen performed better based on their assignments, tests and projects compared to those who used traditional textbook. Zhao [12] shared results of a college-wide OER development and adoption across 26 of 28 academic departments and 116 courses and reported that retention rates increased and withdrawal rates reduced significantly in courses that used OER compared to non-OER courses.

Hence, the objective of this research is to better understand the impact of OERs on architecture, engineering, and construction students by developing and adopting an open educational resource (i.e., an open web-based multimedia platform) for teaching an architecture, engineering, and construction course and assessing the effects of the open educational resource on improving the performance of students enrolled. The building information modeling (BIM) course, jointly taught at the School of Architecture and Department of Civil Engineering at the University of Texas at Arlington was selected for this purpose. The objective of this course, which is a lab-based hands on modeling course is to enable students to understand fundamental concepts of BIM and be able to apply those concepts in practice by gaining building information modeling knowledge and skills. This course that is offered to architecture, engineering, and construction students enables the comparison of students' performances in the course. This study aimed to comparatively examine the performance of architecture, engineering, and construction students in BIM courses before and after adopting the OER in two different formats. Once OER was solely used as a resource and then it was adopted to enable flipped classroom. Flipped classroom is basically an innovative teaching strategy that works with moving the delivery of material (i.e., instructions) outside of formal class time and using formal class time for students to work on collaborative and interactive activities relevant to that material [13].

Theoretical and practical courses such as BIM are essential components of architecture and engineering curriculums. These courses are designed to consolidate the fundamental understanding of a subject (e.g., building information modeling) and give students the opportunity to gain practical and hands-on experience for design communication by creating an information model of the building. This course was taught for six consecutive semesters prior to the OER deployment, and course requirements, major topics to teach, and students' needs and expectations were well understood. Available course materials such as textbooks used prior to OER development were primarily narratives and challenging for students to visualize the procedures and follow the modeling instructions. The demonstrations across several courses taught by different instructors were not standardized although the same topics were included in each instructor's syllabai. Furthermore, the level of information given to students was not consistent through the semester, from one section to another or even within one section. The deficiency of coherent material for software courses pushed students towards accessing resources that often lack quality and consistency. Although free resources (e.g., YouTube videos) are increasingly available, they are unstructured, inadequate, unreliable, and confusing.

This paper examines the development of an OER for the BIM course offered to architecture, engineering, and construction students. Students pursuing a degree in an AEC-related field should gain knowledge and skills about BIM and its tools. However, BIM is an emerging topic and not part of many curriculums, but more and more programs are offering it across the globe. Valuable materials are limited while seizing opportunities promised by BIM depends on the proper preparation of students. At the University of Texas at Arlington, BIM is taught at the School of Architecture and the Department of Civil Engineering every semester by several different instructors. Yet, there is no open-source material available for this course. The open educational resource was designed to fill this gap.

## METHODOLOGY

To develop the OER platform, customized instructions were prepared for each building information modeling exercise within each chapter of the book. The web-based book has about 230 pages and includes 16 chapters as shown in Figure 2. Each chapter covers a specific topic and relevant exercises. Step-by-step instructions for each toolkit and modeling strategy were thoroughly explained for each exercise. These exercises cover various topics, including but not limited to the introduction to software interfaces and workflows, and modeling of walls, roofs, floors, ceilings, stairs, ramps, railings, structural systems, and mechanical, electrical, and plumbing systems. It also include exercises on adding materials, details and annotations, and preparing visualizations, renderings, and drawing sets. These are the standard topics that are covered in a fundamental building information modeling course offered to students with zero to minimum prior knowledge or modeling skills. The instructor did not customize the material to solely meet the needs of this research or her class, but standardized topics and materials were carefully selected so the OER can be adopted and used broadly by any instructor teaching the same course across the globe. Furthermore, this effort was part of a funded project and the university library searched through all available databased to assure there is no other multimedia platform for BIM. The

University of Texas at Arlington Building Information Modeling course was selected as a testbed for this project.

Figure 1 presents an overview of the methodology.

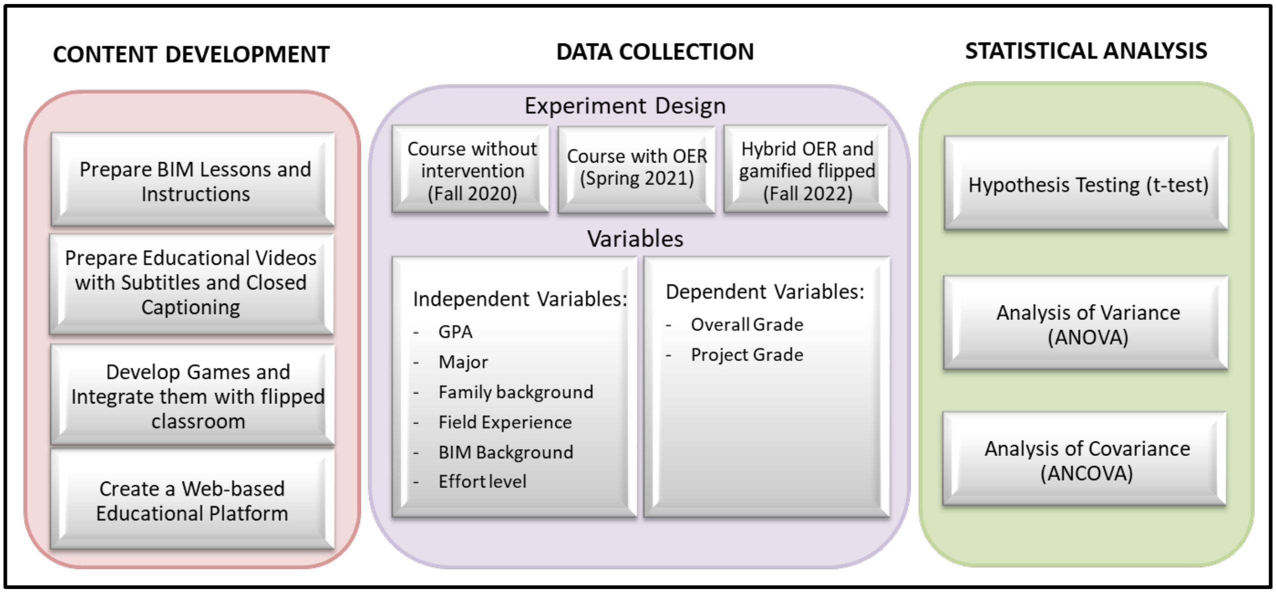


**Figure 1**: Overview of research methodology

In the OER developed, a short but detailed and high-quality video was recorded for each topic. After book chapters and videos had been prepared and developed, an educational platform was designed and created in close collaboration with the Office of Information Technology (OIT) and Libraries at the University of Texas at Arlington.

| | |
|---|---|
| Chapter 1: Revit Interface | Chapter 9: Materials, Visualization and Rendering |
| Chapter 2: Walls, Curtain Walls, Windows and Doors | Chapter 10: Details and Annotations |
| Chapter 3: Floors, Roofs and Ceilings | Chapter 11: Workflow \| Worksharing |
| Chapter 4: Stairs, Railings and Ramps | Chapter 12: Schedules and Project Phasing |
| Chapter 5: Adding - Modifying Families | Chapter 13: Drawing Sets and Construction Documents |
| Chapter 6: Massing - Conceptual Mass | Chapter 14: Site Modeling |
| Chapter 7: Model In-Place | Chapter 15: MEP - Fire Protection and Fabrication Parts |
| Chapter 8: Schematic Design and Room & Color Fill Plans | Chapter 16: Structural Systems |

**Figure 2**: List of Chapters included in the OER platform.

## Classes and Data Collection

Data were collected from BIM students in Fall 2020, Spring 2021, and Fall 2022. Data were collected from 68 students in Fall 2020, 29 in Spring 2021, and 37 in Fall 2022 who voluntarily agreed to participate in this study. The first course was taught without any intervention using traditional lecture-based classroom, where building information modeling instructions were given during the class/lab period. This was during the pandemic and the course was primarily offered online. A textbook was listed in the syllabus but because of the modeling nature of the course and the students' preference for visualization, students rarely used the book. Although classes were recorded, the videos were not easy to watch again because the instructor stops and waits for the students to finish tasks during the class. Videos from LinkedIn Learning were also listed for students to watch as additional learning material, however students found them to be overwhelming and they were not aligned with the textbook available although they both covered the same topics.The second course was also taught online , but then OER was offered as a resource. Instructions were still given in class but students could use the OER platform as a resource if they needed to. The third course was taught in-person using a combination of OER and flipped classroom. Students were supposed to watch lectures before coming to class and class time was used for class activities, quizzes, and problem solving through Q&A.

These courses were taught by the same instructor, the author of this article. Although this performance assessment study was done by the same instructor who conducted this research, the OER developed has been adopted by other instructors teaching the same course and students performance data will collected. Institutional Review Board (IRB) approval was attained before collecting data. In addition to the overall grades, the term project grades were also collected. To handle bias in grading, all assignments, exam, and project were graded by the instructor, the teaching assistant and a member of center of learning at the university. Overall and term project grades were used as the dependent variables, representing the students' performance (Table 1).

**Table 1.** Information about the dependent variables

| Dependent Variables | | |
|---|---|---|
| **Variable** | **Value** | **Type** |
| Overall Grade | 0-100 | Continuous |
| Project Grade | 0-100 | Continuous |

In addition to the dependent variables, six control variables were selected based on the relevant literature [14] – [17] and used to assure apple-to-apple comparisons of student performances in two semesters. These variables need to be controlled in investigating whether the open education resource helped improve AEC students' perforamances. Table 2 includes the values that these variables can have. A students survey was designed to collect results of these control variables.

**Table 2.** Information about the control variables collected through a survey designed in QuestionPro.

| Control Variables | | |
|---|---|---|
| **Variable** | **Values** | **Type** |
| GPA | 0-4 | Continuous |
| Major | Architecture<br>Construction Management<br>Civil Engineering | Categorical |
| Employment Status | Full-time<br>Part-time<br>Unemployed | Categorical |
| Family Background | Having a family background in AEC industry<br>Not having a family background in AEC industry | Categorical |

| | | |
|---|---|---|
| Field Experience | Having field experience<br>Not having field experience | Categorical |
| Effort Level | No hours<br>1-5 hours<br>5-10 hours<br>10-15 hours<br>15-20 hours<br>More than 20 hours | Categorical |
| Past BIM Experience | Having BIM experience<br>Not having BIM experience | Categorical |

**Statistical Analyses**

Hypothesis tests were performed to compare the averages of students' project and overall grades in two consecutive semesters that BIM course was offered with and without the open educational resource. More specifically, t-tests were used to compare the means of students' project and overall grades because the number of students in Spring 2021 and Fall 2022 were smaller than 50 students. The assumption here was that the mean of one group was greater than the other rather than being unequal and so one-sided t-test was used [18]. The null hypothesis of this test is that there are no statistically significant differences between the averages of students' project and overall grades.

Although the hypothesis tests can assess whether the overall and project grades have been improved in two consecutive semesters, they do not rule out the potential impacts of other variables on the observed improvements. In other words, the t-tests do not assess the potential significant main effects of the control variables (i.e., GPA, major, employment status, family background, field experience, effort level, and past BIM experience) or significant interactions between the open educational resource and control variables. Therefore, two-way Analysis of Variance (ANOVA) tests [19] were used to evaluate these effects between the open educational resource and the categorical control variables on improving students' performances to avoid misleading conclusions. More specifically, two-way ANOVAs were used to determine the effect of two independent variables (i.e., the open educational resource and a categorical control variable) on a continuous dependent variable (i.e., the students' overall grade or project grade). The ANOVA was repeated twelve times to cover two dependent variables and all six control variables once at a time.

Similarly, Analysis of Covariance (ANCOVA) tests [19] were used to evaluate these effects between the open educational resource and the continuous control variable (i.e., GPA) on improving students' performances. If the results of ANOVA tests show a statistically significant effect between the open educational resource and a categorical control variable, blocking was used to isolate the effect of the open educational resoruce from that of the categorical control variable. Through blocking, the samples were partitioned based on the categorical control variable with a significant effect, and t-tests were used to re-examine the effect of the open educational resource in each partitioned group.

## RESULTS

Sixty eight students participated in the study in Fall 2020 when the open educational resource was not provided. Twenty nine students participated in the study in Spring 2021 when they had access to the open educational resource and 37 in Fall 2022 when a combined OER with flipped classroom was adopted. Students participated voluntarily in this study. Table 3 shows that the averages of project and overall grades were improved in the semester that the open educational resource was provided. The results of t-tests show that these improvements in the average project and overall grades have been statistically significant because the p-values of the t-tests are both less than the significance level of hypothesis tests (i.e., 0.05); therefore, the null hypotheses of no differences between the average of grades can be statistically rejected for both tests. These statistically significant improvements show that the higher grades in Spring 2021 and Fall 2022 were not random. The average project grade improvement has been more than the average overall grade improvement. The larger difference in the average project grade improvement could be related to the availability of open educational resources that are highly valuable for completing projects.

**Table 3.** T-test results for the project and overall grades

| | **Project Grade** | **Overall Grade** |
|---|---|---|
| Strategy 1. Without Intervention | 79.6 | 90.0 |
| Strategy 2. With OER | 83.9 | 92.4 |
| Strategy 3. Flipped OER | 92.7 | 92.7 |
| Difference between 1 and 2 | 4.3 | 2.4 |
| p-value 1 and 2 (one-tailed) | **0.032** | **0.028** |
| Difference between 1 and 3 | 13.1 | 2.7 |
| p-value 1 and 3(one-tailed) | **0.00** | **0.05** |

Note: level of significance ($\alpha$) = 0.05; OER = Open Education Resources

The t-test results show that the average grades of students who had access to the open educational resource were higher than those of students who did not. However, the potential impact of control variables should be investigated to evaluate whether the improvements in the overall and project grades were primarily due to the availability of the open educational resource. Two-way ANOVA tests were used to assess the main and interaction effects of the availability of the open educational resource and each categorical control variable, presented in Table 2. The ANOVAs help determine whether the availability of the open educational resource is the primary reason behind the improvements. Table 4 shows the p-values of two-way ANOVAs conducted for the overall grade and a combination of the availability of the open education resource and each categorical control variable. The bold p-values in the table highlight the statistically significant effects or interactions (p-values associated with interactions are less than the level of significance). The results show that none of the main effects of the categorical control variables were statically significant, while the availability of the open educational resource was significant in all tests. Therefore, the availability of the open educational resource was a significant factor in improving average overall grades even after considering the effects of categorical control variables. In addition, there is only one significant interaction effect between the availability of the open educational resource and the students' majors. Blocking was performed to isolate the effect of the open educational resource from students' majors.

**Table 4.** Two-way ANOVA results for overall grades

| Control variable | Source | P-values |
|---|---|---|
| Major | Major | 0.313 |
| | OER Availability | **0.011** |
| | Interaction | **0.010** |
| Family Background | Family Background | 0.912 |
| | OER Availability | **0.015** |
| | Interaction | 0.703 |
| Field Experience | Field Experience | 0.056 |
| | OER Availability | **0.012** |
| | Interaction | 0.100 |
| BIM Background | BIM Background | 0.801 |
| | OER Availability | **0.015** |
| | Interaction | 0.214 |
| Employment Status | Employment Status | 0.189 |
| | OER Availability | **0.014** |
| | Interaction | 0.416 |
| Effort Level | Effort Level | 0.962 |
| | OER Availability | **0.016** |
| | Interaction | 0.336 |

Note: level of significance ($\alpha$) = 0.05

Table 5 shows the p-values of two-way ANOVAs conducted for the project grades and a combination of the open education resource and each categorical control variable. The bold p-values in the table highlight the statistically significant effects or interactions (p-values associated with interactions are less than the level of significance). The results show that there is no significant interaction effect between the availability of the OER and any categorical control variable on improving students' performances. The results show one statistically significant main effect related to students' majors. Blocking was performed to isolate the effect of the open educational resource from students' majors.

**Table 5.** Two-way ANOVA results for project grades

| Control variable | Source | P-values |
|---|---|---|
| Major | Major | **0.008** |
| | OER Availability | **0.029** |
| | Interaction | 0.490 |
| Family Background | Family Background | 0.536 |
| | OER Availability | **0.037** |
| | Interaction | 0.612 |
| Field Experience | Field Experience | 0151 |
| | OER Availability | **0.035** |
| | Interaction | 0.664 |
| BIM Background | BIM Background | 0.762 |
| | OER Availability | **0.038** |
| | Interaction | 0.858 |
| Employment Status | Employment Status | 0.092 |
| | OER Availability | **0.035** |
| | Interaction | 0.881 |
| Effort Level | Effort Level | 0.669 |
| | OER Availability | **0.039** |
| | Interaction | 0.581 |

Note: level of significance ($\alpha$) = 0.05

ANCOVA was used to examine the main and interaction effects of the open educational resource and the continuous control variable (i.e., GPA). The ANCOVAs help determine whether the availability of the open educational resource is the primary reason behind the improvements. Table 6 shows the p-values of two-way ANCOVAs conducted for the overall grade, project grade, and a combination of the availability of the open education resource and GPA. The bold p-values in the table highlight the statistically significant effects or interactions (p-values associated with interactions are less than the level of significance). The results show that the main effects of GPA were not statically significant, while the effects of the open educational resource were significant in all tests. Therefore, the availability of the open educational resource was a significant factor in improving average overall and project grades even after considering the effects of GPA. In addition, there is only one significant interaction effect between the availability of the open educational resource and GPA on improving the overall grades.

**Table 6.** ANCOVA results for the project and overall grades

| Source | Project Grade | Overall Grade |
|---|---|---|
| GPA | 0.122 | 0.711 |
| OER Availability | **0.047** | **0.014** |
| Interaction | 0.086 | **0.039** |

Note: level of significance ($\alpha$) = 0.05

In order to fully eliminate the impact of students' majors on the result of this study, blocking was performed to isolate the effect of the availability of the open educational resource; the student samples were divided into three groups based on major (construction, architecture, and engineering). The t-tests were performed on each block. Table 7 and 8 show the results of t-tests to investigate the isolated effect of availability of the OER and flipped OER on improving the overall and project grades of architecture, construction, and engineering students. The statistically significant p-values (less than 0.05, rejecting the null hypothesis of no significance) are highlighted in bold. Table 6 shows that the availability of the open educational resource is associated with statistically significant improvements in the overall grades of students who majored in architecture and civil engineering. However, there is not enough evidence to assess the impact of the availability of the open educational resource on the overall grades of construction students (associated p-value is greater than 0.05). Also, there is not enough evidence to evaluate the impact of the availability of the open educational resource on the project grades of architecture, civil, and construction students. This lack of evidence is due to the low number of observations in each block making the comparisons; For example, only seven construction students enrolled in the course in Spring 2021 when the open educational resource was available. These results lead to the recommendation that in the future, more data from each of these partitioned groups be collected to analyze the impacts of the availability of the open educational resource in each group.

**Table 7.** T-test results for assessing the isolated effect of the OER in improving the overall and project grades of architecture, engineering, and construction students

| | Architecture | Civil | Construction |
|---|---|---|---|
| No. observations in course with OER | 9 | 13 | 7 |
| No. observations in course without OER | 18 | 16 | 34 |
| Mean overall grade in course with OER | 95.6 | 93.3 | 86.8 |
| Mean overall grade in course without | 90.4 | 89.6 | 90 |
| Overall grade mean difference | 5.2 | 3.7 | -3.2 |
| p-value (for overall grade) | **0.029** | **0.047** | 0.052 |
| Mean project grade in course with OER | 87.0 | 85.5 | 77.0 |
| Mean project grade in course without | 83.9 | 78.9 | 77.6 |
| Project grade mean difference | 3.1 | 6.6 | -0.6 |
| p-value (for project grade) | 0.472 | 0.052 | 0.836 |

Note: level of significance ($\alpha$) = 0.05; OER = open educational resource

**Table 8.** T-test results for assessing the isolated effect of the flipped OER classroom in improving the overall and project grades of architecture and civil engineering students

| | **Civil** | **Architecture** |
|---|---|---|
| Mean overall grade in Flipped OER course | 91.7 | 92.2 |
| Mean overall grade in course with no intervention | 89.9 | 83.9 |
| Overall grade mean difference | 1.8 | 8.3 |
| p-value (for overall grade) | 0.131 | 0.370 |
| Mean project grade in Flipped OER course | 91.3 | 94.1 |
| Mean project grade in course with no intervention | 78.0 | 90.4 |
| Project grade mean difference | 13.3 | 3.7 |
| p-value (for project grade) | **0.000** | **0.001** |

Note: level of significance ($\alpha$) = 0.1

## DISCUSSION AND CONCLUSIONS

The average overall and project grades of students were improved by offering the open educational resource and combining that with flipped classroom. These improvements were statistically significant. The results of ANOVA and ANCOVA tests show that the open educational resource was a significant factor in improving average overall and project grades even after considering the effects of the control variables (i.e., GPA, major, employment status, family background, field experience, effort level, and past BIM experience). Building information modeling course is a software class so being able to watch the instructional videos again and again was beneficial and students found that very helpful. Students also commented on having both text and visualization since some students prefer to take notes over text. The book was visited more than 4500 times in 2022. Although flipped classroom was successful in terms of students' grades, the instructor realized students did not spend as much time watching the videos and their level of knowledge varied, which is a known drawback of flipped classroom. Hence, a combination of flipped and traditional classroom where instructions are given in class was found to be most effective in terms of learning details and ensuring what information is delivered to all students consistently. More data collection is recommended to statistically analyze the impacts of the open educational resource on improving students' performances in each major (i.e., architecture, engineering, and construction). Nevertheless, it is expected that the adoption of the open education resource platform to have a significant impact on the academic success of students learning BIM.

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