Redesigning Course Improvement Plan; A Case Study Based-on Learning Outcomes in Engineering Education

Article history
Received
20 December 2023
Received in revised form
11 April 2024
Accepted
28 April 2024
Published online
30 June 2024

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Abstract
Accreditation of engineering programs requires continuous improvement, and a course improvement plan helps accomplish this aim. Student-centered course design components for a particular course in the architectural engineering program is developed at Missouri University of Science and Technology. Method definition is developed and learning objectives, instruction types, and assessment tools are concluded with learning outcomes. Created course improvement plan meets the accreditation requirements partially. Learning outcomes are studied by the help of Bloom's Taxonomy. Instruction types include traditional lecture learning environment and problem-based learning environment. Content priorities are also help to conclude targeted learning outcomes. Success of proposed curriculum development is measured by survey and the results are used to create course blueprint and assessment matrix. The curriculum for the mentioned course in the case study results in transitioning from the existing learning environment to the desired learning environment which can be used as a sample for similar courses.

Keywords: Bloom's taxonomy, learning outcome, assessment tool, instruction type, course design.

Introduction

Curriculum needs to be improved for the program targeted to get accreditation. Due to the fact that, continuous improvement of engineering education is the primary target of accreditation process, what is known with cognitive science would be helpful to this process (Williamson, 2007). ABET (accreditation board for engineering and technology) in the United States provide competence banks to clarify the process to whom apply for accreditation (Earnest, 2005; Passow, 2007; Walther, 2007; Choudaha, 2008). Due to theoretical background and need for clarification of problem-based learning (PBL) in Architectural Engineering major, PBL was formalized at Missouri University of Science and Technology for building components design education. The proposed educational model includes a definition of the learning environment, formulation of PBL, appropriate building technologies, and a design guide. Boundary conditions with building structural systems in learning environment is specified inside the proposed educational model and discussed in a separate paper. Implementing existing curriculum development methods and educational theories will continuously improve engineering education. Based on the hypothesis, this paper aims to redesign a course improvement plan, provide application methodology, and present a taxonomy of educational objectives of a particular course in architectural engineering. The research question is herein; how a course improvement plan be designed? Moreover, as a result, how the success of this improvement plan shall be measured? A course improvement plan must follow the interaction between learning objectives, instruction, and assessment. The desired improvements on a course curriculum comprise well-regulated classroom activities, education theories, adding diverse teaching methods and better tracking results of teaching activities.

Diverse courses are taught in architectural engineering programs and "architectural materials and methods of building construction" course is one of these courses. Mentioned course is accepted as the case study in this paper. The objective of the case study is to support program accreditation with broader educational goal and increase the retention of knowledge for students in particular.

Active learning methodologies such as; PBL and hands-on learning are targeted to include into this course curriculum. Education of framing and panelized building systems is a component of the architectural engineering program. Early studies of this ongoing research based-on design definitions of framing and

Scaled model assembly of building technologies with teamwork

(a) cold-formed steel framing system	(b) timber framing system	(c) mix design as precast R.C. system and timber framing system	d) mix design as precast R.C system and cold-formed steel framing system

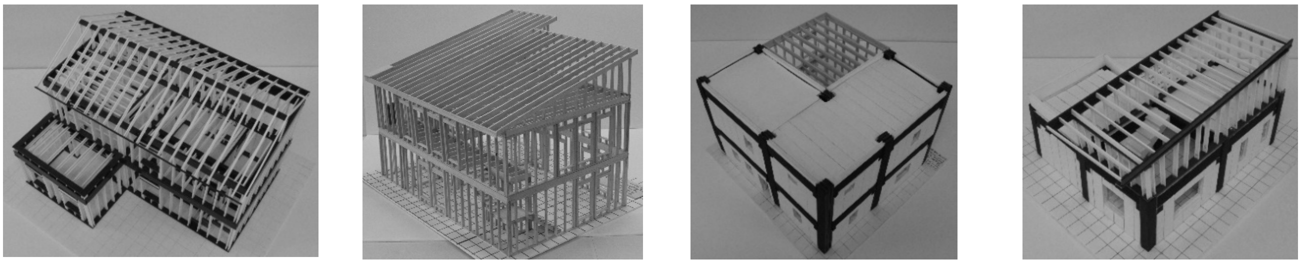

Figure 1. Visual samples for the results of learning event as PBL

panelized building systems are improved and formalized as an educational methodology. This approach can be used on multiple building technologies and particularly stick-built and panelized building systems are the application field of this educational model. Cold-formed steel framing, timber framing, reinforced concrete (R.C.) prefabricated system, autoclaved aerated concrete (AAC) panel system and structural insulated panel (SIP) system are the building technologies investigated inside this course. Visual samples for this learning event are depicted in Figure 1. Visuals are the results of scaled model assembly of building technologies with teamwork in PBL.

The paper is theoretically divided into two sections; first, tools to create a course improvement plan are defined, then curriculum improvement based on this method definition for the case study is introduced. A literature review that include: a methodology for a course improvement plan; a taxonomy of educational objectives; a case study on an existing course, and; a discussion based on research findings are the scope of this study. Targeted audiences are instructors who desire improvement on his/her course curriculum to provide a more effective learning environment in engineering education.

Literature Review and Method Definition

Architectural education is based on getting theoretical and applied information. Hence, experiential learning theory was mostly applied to architecture design courses (Avci and Beyhan, 2022). Architectural design studios are real environment to run inside blended learning pedagogic model (Bregger, 2017). Problem or project based learning (PBL) method has been widely adopted in engineering education as well because of its effectiveness on development of students' professional knowledge. But, PBL implementation has some challenges and little addressed in the current researches. Moreover, less attention has been paid on how these challenges in implementation are related to the diverse PBL practices (Chen, et al., 2020). In most cases, limited implementation of PBL is seen due to the program curriculum offered by educational institutions. PBL frequently adopted inside the existing traditional curricula (Mann, et al., 2020). Intended learning outcomes (ILOs) are created and clearly formulated in the curriculum as PBL competences. In reality, few engineering institutions succeed to adopt PBL method in their curricula at such a level, but there are efforts by several institutions through that direction (Miklos and Kolmos, 2022). In engineering education, implementing active learning methods is becoming popular as a new method of learning process and it is accepted as a prerequisite to get ready to their professional life when they graduate (Sukacke, et al., 2022).

The challenge herein is; how course design components mentioned in Figure 2 will be integrated into the case study. Learning outcomes, instruction types and assessment methods shall be re-evaluated according to the context of the case study. When the literature review is performed, method definition is mostly introduced generic samples. Instead of generic samples, figures and tables are reproduced according to the case study. Due to the fact that, literature review focus on creation of a method definition for the case study in this section. Figure 2 is also accepted as backbone of course improvement plan for the case study. The methodology of instructional design stages is suggested as analysis, design, development, implementation and evaluation (ADDIE) in another study (Sukacke, et al., 2022).

In order to partially meet the program accreditation, a course curriculum is intended to be improved. A course improvement plan can be designed by defining the taxonomy of learning objectives, learning outcomes, instruction types, content priorities and assessment tools. The improvement plan needs a careful analyze of course curriculum and an improvement methodology and measurement of success on applied educational model. Efforts required in three sections to succeed intended learning outcomes are depicted in Figure 3(b) (Felder, 2003). A template to document course design and to create a taxonomy of educational objectives is selected as

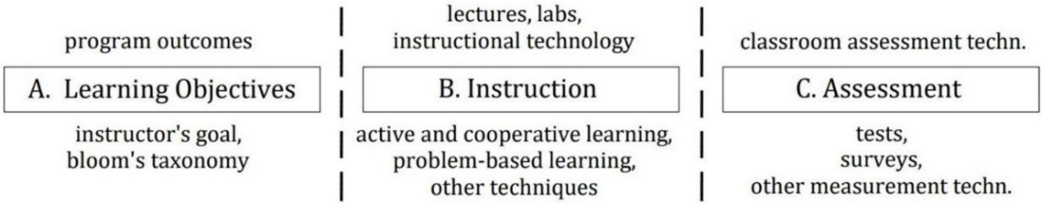

Figure 2. Student-centered course design components; learning objectives, instruction, and assessment (Felder, 2003)

course blueprint (Felder, 2016). Learning objectives with higher and lower cognitive domains are defined by using necessary action verbs in Bloom's Taxonomy. Producing a course assessment matrix presenting outcome-related learning objectives is also beneficial during course curriculum design.

Learning Objectives

As a result of a learning activity, knowledge and the ability of learners can be specified by defining learning outcomes. The learners' actions which is specified shall be observable and measurable. Clear expectations must be stated by learning outcomes used at course level (Figure 3(a)) (Osters & Tiu, n.d.). Knowledge, skills, or attitudes are introduced in outcomes. When planning a course, it is also recommended to take into consideration adjoining a couple of critical targets such as; communication skills including oral and written, interpersonal skills including teamwork, problem-solving skills in a variety of contexts, critical thinking skills in a variety of contexts, information competency skills: the ability to access information in various formats.

A taxonomy, specifically the preferred terms, can aid researchers search the literature by linking and suggesting related terms and proposing a hierarchical structure that helps in navigation (Finelli, 2015). The taxonomy of educational objectives is a scheme for classifying educational goals, objectives, and, most recently, standards. (Felder, 2016; Krathwohl, 2002). Bloom's Taxonomy, SOLO (the structure of observed learning outcomes) Taxonomy, EER (the engineering education research) Taxonomy, and Fink's Taxonomy were developed to be used in tertiary education. Bloom's taxonomy has been widely accepted for engineering education with a universal agreement that engineering graduates should be competent at analysis, synthesis, and evaluation (Bloom, 1956; Braband, 2009; Williamson, 2007). Bloom developed the taxonomy (hierarchy) of cognitive learning skills, allowing educators to systematically evaluate students' learning (Barrett, 2009; Schultz, 2005). Bloom's taxonomy was revised due to need in the course of the time (Anderson, 2001). Sample of wording is as following; define, explain, solve, analyze, criticize, design, etc. (Osters & Tiu, n.d.; Tulane University, n.d.). Figure 3(a) shows the action verbs (partially) in revised bloom's taxonomy based-on Anderson (2001) explanation. Improving the faculty's teaching ability is possible by using active learning methodology and a learning taxonomy can be developed to meet this target. Providing continuous improvement based on the accreditation process and establishing a standard terminology – a taxonomy of terms – aids in navigating diverse teaching methods and measuring learning outcomes in engineering education is the primary motivation for this research.

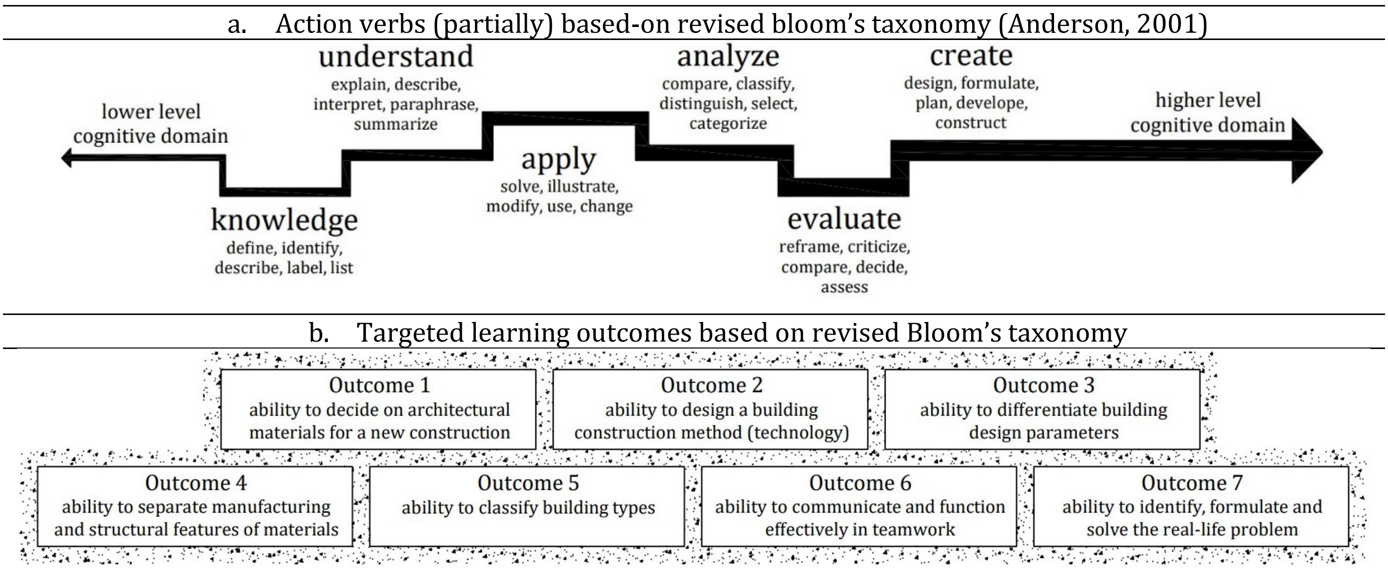

Figure 3. (a) Action verbs (partially) based-on revised bloom's taxonomy (Anderson, 2001), (b) Targeted learning outcomes based on revised Bloom's taxonomy

Based-on the course content and instruction types of case study, seven outcomes are decided and included in the method definition as a sample. Targeted learning outcomes of the “architectural materials and methods of building construction” course based on revised Bloom’s Taxonomy are depicted in Figure 3(b).

Instruction Types

The curriculum, the teaching methods, and the instructional tools shall be studied in depth to integrate technology into the tertiary education. David Kolb had introduced experiential learning which is the most widespread teaching theory (Ghaziani, 2013). Kolb’s learning cycle includes quadrants showing a set of activities and assist the instructor. Teaching in each quadrant promotes retention, encourages recognition of applications, and serves the diversity of students’ learning styles (Williamson, 2007). Kolb developed a system of selecting classroom activities based on his research related to adult learning (ASCE, 2004; Kolb, 1984; Williamson, 2007). Furthermore, students use different ways to get information and active learning is one of them. Active learning and PBL methods are mostly interchangeable. However, using any of them in engineering education is highly promoted due to the need for highly competent graduates with problem-solving skills in the workforce.

Graduates of architectural engineering programs are expected to ensure competence in technical and managerial levels, effective communication, continuous professional progress, ability in teamwork and responsible professional behavior (ASCE, 2004; Earnest, 2005). The hands-on learning experience with teamwork is also highly promoted to meet program objectives. The educational model for this course does not meet a program's whole objective but contributes to meeting some of the objectives. Delivery of course material as a teaching method can be organized in different ways, and it is named “instruction” herein. These instructions include traditional classroom lectures, online lectures, and lab activities. On the other hand, active, cooperative, or PBL can be included in any part of these instructions. The effectiveness of these instructions is different from each other; basically, longer retention of knowledge is desired by using diverse teaching methods.

Design parameters, manufacturing features, and building types are influential factors in understanding the design and building process. These are the primary course content for the “architectural materials and methods of building construction” course. Course content is split into five fundamental sub-title, some of which need enduring understanding. Wiggins (2005) presented that how content priorities shall be linked to the student learning outcomes. During the curriculum design of the course, content priorities shaped the necessary teaching methods based on the level of understanding. Figure 4 depicts the course's targeted level of understanding and content priorities based-on Wiggins (2005) explanation.

Contents of architectural materials and methods of building construction are defined as having content priority and need enduring understanding. Also, the first two items in learning outcomes require a higher cognitive domain. Consequently, the action verbs “decide” and “design” is selected for these learning outcomes. In order to achieve these learning objectives, a learning event is defined as PBL in a term project.

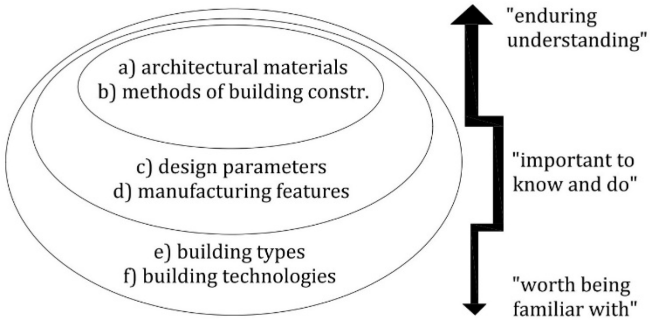

Figure 4. Clarifying content priorities for “architectural materials and methods of building construction” course

Assessment Methods

Assessment efforts are categorized as direct and indirect measures in order to collect evidence of student learning. These methods provide adequate feedback to the program to identify strengths and weaknesses (Maki, 2004). The two most used research instruments in quantitative research studies include questionnaires (surveys) and tests (Bachman, 2009). Students’ performance cannot be measured by only focusing on grades. But, if grading is linked with rubrics, it is a much better tool to identify the strengths and weaknesses of student performance. Two methods of assessment can be categorized as direct method with standardized exams and indirect method with survey (Osters & Tiu, n.d.). Learning activity has been measured in two methodologies, as depicted in Table 1. The first is a direct method based on a grading system using a rubric and peer assessment. The second is used indirectly to measure the effectiveness of learning activity through pre-post surveys.

Direct measurements of student learning and relation of these data with program outcomes are focused during accreditation process. (Williamson, 2007). Direct assessment methods include paper-based exams, multiple-choice tests, essays, assignments, and homework as course-embedded assessment, portfolio evaluation (presentation), and class projects (term project) as shown in Table 2. Indirect measurements of student learning, such as surveys, provide reliable feedback and can be used long-term to monitor the effectiveness of the teaching method. As an indirect assessment method, the survey is intended to monitor the performance of PBL tools and other course materials. Success of the learning environment is also measured by student surveys. Pre and post surveys can be included for term-based performance measurement.

Table 1. Direct and indirect assessment methods

	direct	indirect
method	**rubric**: instructor assessm.; peer assessm.	**survey**: pre-survey; post-survey
source	instructor & student	student
record	on-grade system	off-grade system
tools	percentage	percentage
period	term based	term based
graphic	table & quadrant	table & quadrant

The usage of the quadrant in Kolb's learning cycle (ASCE, 2004; Kolb, 1984) and Webb's depth of knowledge (DOK) (Hess, 2006; Hess, 2013; Webb's Depth of Knowledge Guide, 2009; Webb, 1997) is inspired to create a course-based assessment quadrant as an indirect method of the assessment tool. Cerovsek and others (2010) also suggest a quadrant to measure the performance of design competencies in the AEC domain.

Table 2. Assessment tools as direct method

Assessment Type		Frequen. (number per term)	Formative or Summative	How quickly students receive feedback from this assessment
Exams (paper based)	Short answer	3	summative	a week later
Quizzes (online)	Multiple choice	5	summative	instant
Essay	Short essay	1	formative	a week later
Lab Projects	Lab assign.	3	formative	a week later
	Lab activity	2	formative	a week later
Term Project	Present.	1	summative	a week later
	Hands-on activity	1	summative	a week later

Curriculum Improvement Plan for an Architectural Engineering Course

Curriculum improvement for an architectural engineering course needs a specific methodology which is defined in method definition by the help of literature review. But it is not only a review but to create a variation of existing methodology through architectural engineering education. Student-centered course design components in Figure 2 is the primary method to be used to redesign course improvement plan in this study. Learning objectives and instructions are redesigned and reproduced as course blueprint. Course assessment matrix links the course outcome with the program outcome. On the other hand, effectiveness of learning activity is also measured to verify the necessity of constant development effort on engineering education. Instruction types are not discussed in depth in this study due to the fact that being a separate topic out of the scope of this paper. This paper is particularly focus on redesigning course curriculum based on the learning outcomes and assessment of learning activity. To accomplish this task, course blueprint and assessment matrix are produced for the case study.

Course Blueprint and Assessment Matrix

The course blueprint includes mapping the course goals with the objectives, learning events, and assessment tools. This approach is used herein to classify learning events by dividing the course into modules as Module 1; preparatory blocks, and Module 2; PBL block. Learning objectives and course goals are prepared as per revised Bloom's Taxonomy. Student-centered course design components are derived from Figure 2 which are referring the outcome 1 to 5. Student learning objectives reflect the course content. Learning event is related with instruction types. Assessment tool is tied with rubric. Moreover, the course blueprint reflects the direct assessment method for this case study. In summary, the course blueprint, including partial course goals, learning objectives, learning events, and assessment tools for the

Table 3. Partial course blueprint; items (a and b) are derived from Figure 4

Course Goals	Student Learning Objective	Learning Event				Assesm. Tool		
		Lecture	Demonstration	PBL	Hands-on/PBL	Exam (short answ.)	Quiz	Team project
a) Students will decide architectural materials for a new construction	Compare different finishing materials	X	X			X	X	
	Examine thermal & fire related properties	X	X	X		X	X	X
	Use different types of windows, doors, roof & stair	X		X		X	X	X
b) Students will design a building construction method (technology)	Plan a light framing system	X	X		X	X	X	X
	Plan a prefabricated building system	X	X		X	X	X	X
	Plan a conventional building system	X				X	X	

"architectural materials and methods of building construction" course, is depicted in Table 3. Course description is mentioned in the course syllabus as the origin and the properties of architectural materials, methods of building construction and installation principles.

In order to track program outcomes a course assessment matrix was constructed for the course in case study. Outcome-related learning objectives are depicted in this matrix and the entries 1, 2, 3 are inserted to indicate the targeted level of outcome as slightly, moderately, or substantively. Based on the methodology mentioned herein, the course assessment matrix for the "architectural materials and methods of building construction" course is generated and depicted in Table 4. Targeted learning outcomes are linked to the Figure 3b.

Table 4. Course assessment matrix for "architectural materials and methods of building construction"

Outcome-related learning objectives	Outcome*						
	1	2	3	4	5	6	7
Compare different finishing materials	2						
Examine thermal & fire related properties	2					1	1
Use differ. types of wind., doors, roof & stair	2					1	1
Plan a light framing system		3				3	3
Plan a prefabricated building system		3				3	3
Plan a conventional building system		1					
Discuss structural parameters			3			2	2
Distinguish exterior wall systems			2			2	2
Describe soils & foundation systems			2				
Experiment concrete material				2		1	1
Use brick material				3		3	3
Discover steel & wood materials				2		2	2
Compare resident., commer. & public build.					2	1	1
Discuss low-rise, mid-rise, high-rise buildings					2	1	1
Examine fire-related construction types					1		

* objective address outcome
1= slightly, 2=moderately, 3=substantively

Effectiveness of learning activities

The course curriculum has been divided into modules based on content and type of learning environment. The survey is split into four modules: course content, traditional learning environment, hands-on learning environment, and measurement. The research was run for three years, and surveys regularly provided necessary feedback. The survey is performed two times per semester as pre and post-survey. Students rated the significance of each item using a scale of 1 through 10 (with 1 meaning unimportant and 10 meaning very important). The average rate of the significance of each question is depicted in Table 5 in which pre and post surveys' results belong to third year of the research. Averages of pre and post-survey results are used to create Table 5. To measure the performance of the learning activity, an assessment method using quadrant is generated to provide valid and reliable data, strengthening the findings of PBL activity in architectural engineering. This quadrant consists of modules along with course material. Generated quadrant including results of three successive years presented in Figure 5. Four modules including course content, traditional lecture learning environment, hands-on learning environment and measurement methods are illustrated along with a scale of 1 through 10 in a chart. The scaling is derived from the survey results indexed in Table 5. This radar chart monitors the strengths and weaknesses of learning environments and course materials to enable the instructor to make necessary revisions. Results of three successive years are reflected in Figure 6, which focuses on traditional and hands-on learning environments.

Providing design flexibility resulted in considerable improvement in PBL activity per the radar chart. Efforts to improve the educational model during the time resulted in positive as depicted in the radar chart. Enrolled students are mostly sophomore level due to being an introductory course. Some intern experiences are mainly observed among students. Moreover, many students have 1-2 years of work experience. There is a regular increment in the time in Figure 6 due to improvement efforts of the applied educational model. Cargo container design and main PBL activity are impacted positively due to providing design flexibility at building type and technology. There is a minor declination in item C3 in the year 2 result because of having hardship with model making material of aluminum foil during assembly of the cold-formed steel framing system. This caused a negative thought about the activity, which can be read similarly in item C4's design guide. Hence, material features are directly proportional to the desired learning environment's satisfaction. Despite having difficulty working with multiple building technologies in a PBL environment, the overall study still got a remarkable value, with 7,4 out of 10 in year 2. However, after taking necessary actions on the PBL environment in the following year (year 3), the effectiveness result reached 8.40 in year 3 in item C3. The design guide results are directly proportional to the results of the PBL activity. Considerable improvement in cargo container design in item C2 is also read in the table. On the other hand, masonry wall mock-up activity has the first rank in the table each year, resulting in up to 8.96. 2^{nd} is teamwork in C5, 3^{rd} is site visit in B5 and 4^{th} is PBL activity. Lecture notes in item B2 also received a significant rise up to 8.31. Students in item C5 always welcome teamwork. When we compare the average rates of items B and C, item C (8.33 out of 10) as a hands-on learning environment has higher rates than item B (7.56 out of 10) as a traditional learning environment.

Table 5. Average significance rate of each question belongs to year three

Module		Measured Course Material	Average Rate (Pre-survey)	Average Rate (Post-survey)	Module		Measured Course Material	Average Rate (Pre-survey)	Average Rate (Post-survey)
Module A (average rate; 8.01 out of 10) Course Content	A.1	Architectural materials	8.36	8.00	Module C (average rate; 8.33 out of 10) Hands-on Learning Environment	C.1	Brick wall mock-up	9.00	8.92
	A.2	Methods of building construction	8.31	8.32		C.2	Cargo container design	7.83	7.43
	A.3	Building types	8.33	8.14		C.3	Scaled model of term project	8.53	8.27
	A.4	Design parameters	7.92	7.70		C.4	Design guide/hand outs	8.03	7.91
	A.5	Manufacturing features	7.43	7.57		C.5	Teamwork	8.47	8.86
Module B (average rate; 7.86 out of 10) Traditional Learning Environment	B.1	Lecture	7.61	7.61	Module D (average rate; 7.63 out of 10) Measurement	D.1	Paper based exam	7.42	7.40
	B.2	Reading (lecture notes)	8.39	8.22		D.2	Quiz	7.00	5.94
	B.3	Documentary movie	7.49	6.81		D.3	Lab assignment	7.97	7.91
	B.4	Material test	8.03	7.54		D.4	Rubric for cargo container	8.29	7.80
	B.5	Visit of construction site	8.56	8.30		D.5	Rubric for term project	8.20	8.40

Pre-survey results (white) / Post-survey results (grey)

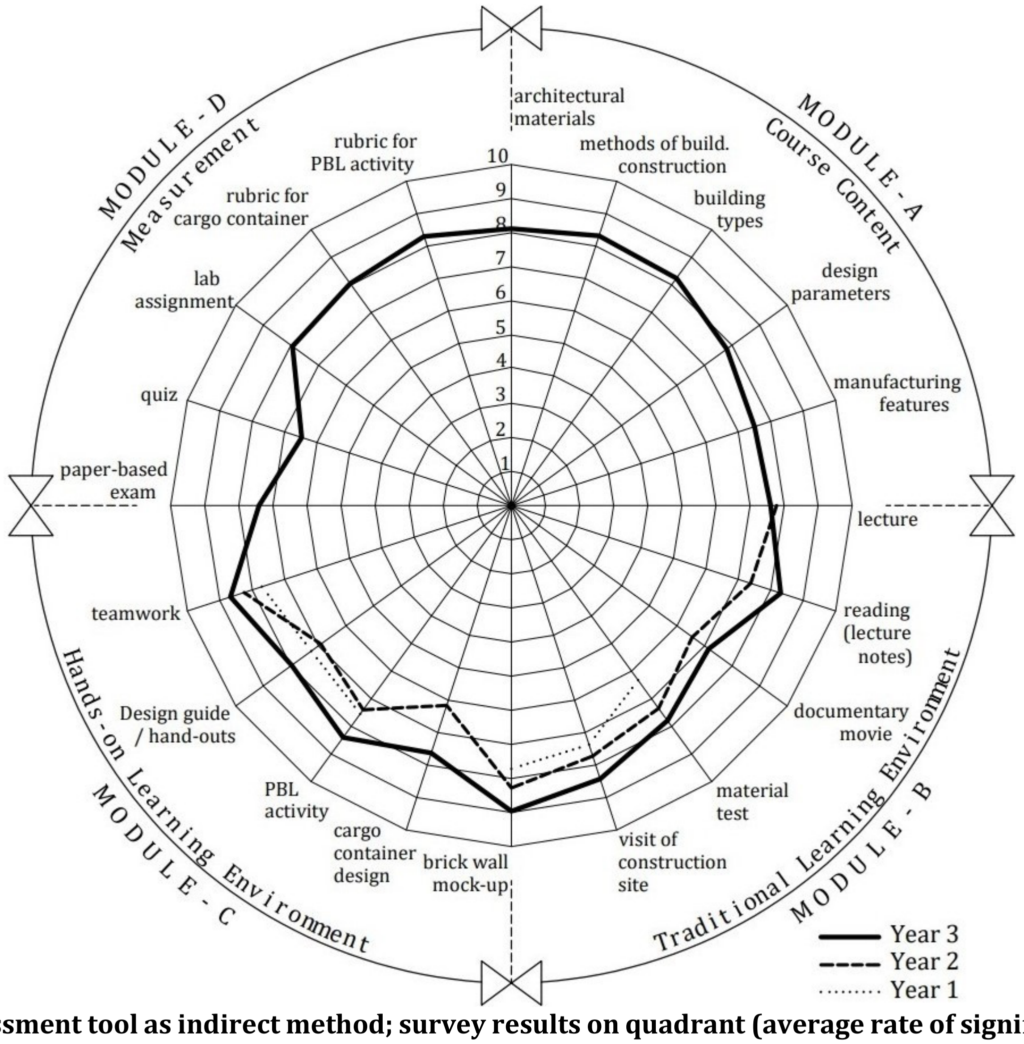

Figure 5. Assessment tool as indirect method; survey results on quadrant (average rate of significance of each question on radar chart)

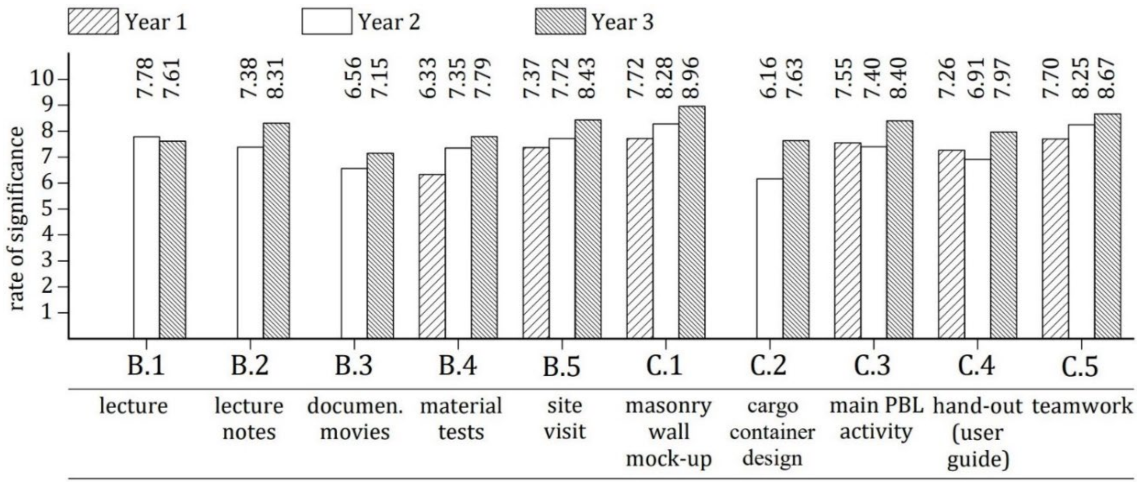

Figure 6. Average rate of significance of each question depicts the results of survey

Besides the traditional lecture learning environment, PBL is an alternative to support teaching fundamentals of architectural materials and methods of building construction. The hands-on learning experience is crucial for students to improve their design skills, resulting in longer retention of desired knowledge. Based on the survey results, the PBL activity demonstrated, on average, a 12% improved retention of materials compared to the traditional lecture settings. Therefore, combining the educational methods, the traditional lecture learning environment, and PBL is recommended based on the survey results and overall student performance. Giving students basic knowledge on the subject enables them to proceed with their studies more consciously in a PBL environment.

Conclusion

Continued improvement of architectural engineering education, which is a necessity of program accreditation, is provided partially by applying advanced curriculum development methods and educational theories on a particular course. In addition, the taxonomy of learning objectives assures the overall goal of improving student performance and expectations. This paper shows how an existing learning environment can be altered by using a well-conceived goal connected with a series of objectives and assessments tailored to the course being examined. The task is accomplished by applying clearly defined application methodology which includes student-centered course design components; learning objectives, instruction types and assessment tools. These components are transferred inside the course blueprint and course assessment matrix in order to illustrate graphically as the course improvement plan. Course learning outcomes meet partially program outcomes which is one of the main target of this study. Success of learning environment is measured by surveys each year and helps to create constant improvement on course curriculum. Survey results show that positive impact of active learning over the traditional lecture learning environment. Based on the survey results, the PBL activity demonstrated, on average, a 12% improved retention of materials compared to the traditional lecture settings. Further development of this method is being shared and implemented in other courses in the architectural engineering program based on these findings. The curriculum for the mentioned course in the case study results from a transition effort from the existing learning environment to desired learning environment. Classification of learning outcomes and implementing diverse teaching and assessment methods resulted in such a definition of the course improvement plan. Method definition in this paper is recommended to educators looking to implement similar changes in their courses.

Discussion on the study is mostly on its link with program accreditation and measurable benefits. It is thought that case study partially meets program accreditation. But this can be measured or a comparative analysis can be performed which provides a deeper analysis as a further study. Moreover, a more critical examination of any limitations of the study and the potential scalability of the course improvement plan would be beneficial. Beside these topics which have directly related with this paper, there are other ways we can look at the study from different perspectives. Having these experience on a particular course in architectural engineering brings further questions in detail as diverse point of view, such as;

- How does rethinking organizational culture with teamwork at active learning conclude in similar courses in architectural engineering education?
- What are the benchmarks between homework and real-life problems in active learning by using educational technologies?
- How open-ended / out-of-the-box study can be performed effectively by students in engineering education?
- How architectural engineering graduates can better meet the expectations of the building industry using PBL?

These research questions may help better understand the benchmarks of active learning with different aspects of architectural engineering education. On the other hand, performing the proposed course improvement plan in other related courses may provide a comparative analysis of applied educational theories. Discussion in this paper shows that further research can bring diverse aspects of active learning implementation to architectural engineering education.

Conflict of interest

The authors declare that they have no conflicts of interest.

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