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Problem-Based Learning with Framing Construction in Architectural Engineering

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Abstract

Problem-based learning (PBL) is an alternative to traditional lecture learning environment. In order to support teaching fundamentals of framing construction, PBL was used in a course in Missouri S&T. Hands-on learning experience for longer retention of desired knowledge was the main goal of this case study. Education of framing construction is a component of architectural engineering and variety materials are in use to assembly framing system in construction industry. Scaled model activity is targeted in PBL block and this activity directly dependent on material which is available, affordable and workable by the students. Balsa stick which has these properties is the choice reason of using timber framing system in PBL block. Due to the experiences in the world, it is recommended that using multiple educational models together as preparatory blocks including traditional lecture learning environment and PBL together. PBL block is supported by preparatory blocks such as construction site visits and mock-up assemblies. PBL activity narrowed through "the task project" on framing construction to be completed by the students in limited time. A survey was held in order to determine outcomes of the activities and PBL had positive impact on the traditional lecture learning environment in architectural engineering.

Keywords: Problem-based learning, framing construction, architectural engineering

Introduction

Traditional lecture learning environments have been criticized as being not suited to all students and not developing the prerequisites for professional expertise; the emphasis can be on giving information rather than learning (Dochy, 2005; Forsythe, 2010).

In practice, young professionals need the ability to analyze problems, to separate complex matters into sub-problems and to solve these problems without losing sight of the whole Picture (Grabe, 2010). Problem-based learning (PBL) helps to bridge the gap between academia and practice (Smith, 2005). PBL can be described as a learning environment where the problem drives the learning (Klegeris, 2011). PBL is an approach to professional education that stresses the use of real-life problems as a stimulus for learning (Smith, 2005). PBL is viewed as a model for classroom activity that shifts away from teacher-centered instruction and emphasizes student-centered projects (Url 1, 2014). This technique usually involves learning in small groups, which are supervised by tutors (Klegeris, 2011; Graaff, 2003). PBL asks for an active learning attitude and students are in a constructive investigation (Dochy, 2005; Yousuf, 2010).

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John Dewey, educational pragmatism, supported the *"learning by doing"* approach to education as far back as the early 1900's, which is the essential element of PBL (Url 1, 2014; Koschmann, 2014; Forrester, 2004). Formalized PBL began in the late 1960's at Faculty of Medicine McMaster University in Canada by Howard Barrows and rapidly flourished as an educational technique in the health sciences (Smith, 2005; Marcangelo, 2009). At first PBL was mostly applied in new schools in 1970's, starting fresh with the development of a completely new curriculum, like the University of Maastricht in the Netherlands, Newcastle University in Australia and the University of Aalborg in Demark. These were among the first medical schools to adopt PBL (Graaff, 2008; Banerjee, 1996). Also, PBL has been formally adopted by some architectural schools in the world. The architectural faculties at Newcastle in Australia and Delft in the Netherlands, as two examples, made the transition to a formalized PBL curriculum in the 1990's (Smith, 2005). Since then many different varieties of PBL have emerged and PBL is widely regarded as a successful and innovative method for engineering education (Dochy, 2005; Graaff, 2003; Srinivasan, 2007).

Possible PBL outcomes are; an intrinsic motivation to learn, effective problem-solving skills**,** self-directed, life-long learning skills, effective collaboration skills,improved understanding and retention of course content (Smith, 2005; Klegeris, 2011). It is a very common experience that students are more motivated and work much harder with the PBL model than with traditional teaching methods (Graaff, 2003). The instructor is the facilitator of the learning process; the instructor does not have the role of transmitter of knowledge. She/he stimulates the group discussions and monitors the social group processes. The problems are used as a tool to identify the required knowledge to eventually solve the problem (Dochy, 2005).

Another aspect to evaluate learning methods is learning pyramid. Also, engaging with "practice" or "problem" has significant importance in learning pyramid. Lecture has 5%, reading has 10%, audio-visual has 20%, demonstration has 30%, discussion group has 50%, practice by doing has 75%, teach others has 90% average retention rate in learning pyramid (Figure 1) (Url 2, 2014).

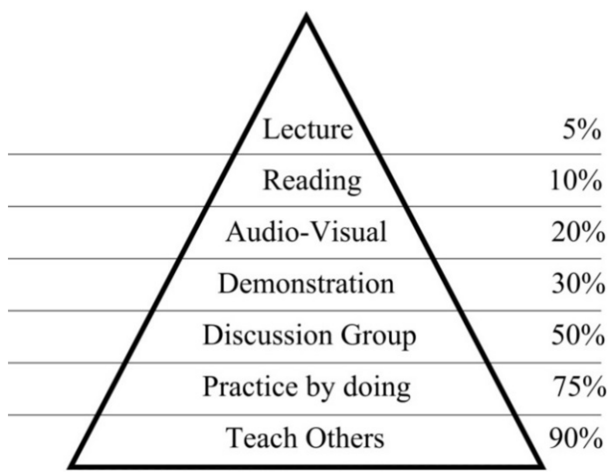


Figure 1: Learning Pyramid with Average Retention of the Educational Methods (Url 2, 2014)

Criticism leveled at US engineering schools include: they offer too few "practical" and "hands-on" courses in terms of freshman engineering design experiences (Sheppard, 1997). As a field, PBL is still in the developmental stage. For example, there is not sufficient research or empirical data to state that PBL is a proven alternative to other forms of instruction in engineering schools (Url 3, 2014). The aim of this article is to discuss how PBL can be used in architectural engineering education by course curriculum design and whether it has positive impact on traditional lecture learning environment or not. The scope is using this educational model over framing construction as a case study. Literature research, course curriculum design, presentation of case study and student evaluation are the methods used in this article.

1. PBL in Architectural Engineering

The Faculties of Architecture in Newcastle University (Australia) and Delft University (Netherland) were among the first to embrace this new PBL educational methodology. Both faculties started to develop their problem based curriculum after the example of medical school education (Banerjee, 1996).

PBL Curriculum in Newcastle University; Integrated PBL was introduced in 1984 in Faculty of Architecture Newcastle University in Australia. The integration of subjects in a PBL curriculum is by no means an easy task. In the beginning, there was no formal lecturing. Between 1984 and 1995, the concept was gradually modified and now various educational formats are applied. In some areas, there are lectures supporting the 'phase problems' and tutorials to build up a theoretical base and model testing sessions to exercise technical skills, etc (Banerjee, 1996).

PBL Curriculum in Delft University; By the end of the 1980's criticisms from outside the faculty of architecture at Delft University resulted in a proposal to develop a new curriculum. The PBL curriculum in Architecture was modelled in 1990 after the example of Maastricht, with thematic blocks, integration of theoretical knowledge and practice through cases discussion, supervised by a tutor. The implementation of the PBL curriculum in the faculty of Architecture in Delft University has to be characterized as a top down decision. As a consequence, the new PBL curriculum in Delft University faced some difficulties. Step by step elements of the PBL curriculum were altered or changed back into the old familiar format. A little more than fifteen years after the introduction of PBL, the last leftovers were removed (Graaff, 2008).

In both cases, full integration of the technical disciplines proved not to be completely successful. Students may lack the necessary minimum of prior knowledge to be able to formulate productive learning goals. As a consequence, the continuance and sequencing in the curriculum is broken. Based on these experiences, an alternative is suggested in which various educational formats are employed to support the problem-based learning process. Prior to introducing the "*PBL learning blocks*", a series of "*preparatory learning blocks*" are offered (Table 1). This allows the students to master some subjects in which their prior knowledge is below a minimum level. Preparatory blocks should provide students with knowledge they can apply in PBL blocks, and the PBL blocks should motivate students to explore further in-depth study(Banerjee, 1996).

Table 1: Phases of Proposed Learning Environment (Banerjee, 1996)

Phase 1	**Phase 2**
PreparatoryBlocks	PBL Block

It is essential that architectural engineering students develop both quantitative and qualitative understanding of engineering concepts and principles. Small-scale modeling provides students with opportunities to discover that learning structural engineering principles can be an enjoyable experience that leaves a stronger impression for longer retention (Url 3, 2014). Three fundamental types of project work can be distinguished in PBL (Figure 2): *the task project, the discipline project and the problem project* (Graaff, 2003). The task project is characterized by a very high degree of planning and the choices are made for students in advance. The problem project is a full scale project in which the course of action is not planned in detail by the instructor. In terms of analogy of a football game, this means that the students have the ball but lack the playing regulations and a marked playing field. The freedom on design or studied subject is increased and limitation on PBL is decreased through *problem project* (Graaff, 2003).

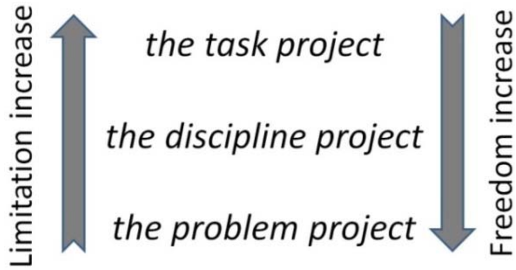


Figure 2: Types of Projects used in PBL Environment (Graaff, 2003)

2. Case Study with Framing Construction

Framing construction is highly demanded by construction industry and it is still widespread around the world. Particularly, basic knowledge of timber framing and cold formed steel framing system are needed by engineers and architects. Therefore, education of framing construction is a component of undergraduate architectural engineering program (Yildirim, 2014b).

Instead of using single learning method in framing construction education, using multiple methods including PBL is beneficial for the students in order to longer retention of desired knowledge. PBL with framing construction has been applied in a course of Missouri S&T Civil, Architectural and Environmental Engineering Department in spring 2014 semester. The course name is "ArchE 2103 – Architectural Materials and Methods of Building Construction" and it is an introductory undergraduate course. The course description can be summarized as a study of the origin and properties of construction materials, methods of building construction and installation. A variety topic are covered in the course syllabus such as; material properties of wood, concrete and steel, construction methods of masonry structures, prefabricated reinforced concrete systems, wood light frame construction, structural steel and cold-formed steel framing system etc. The course has lecture and lab sections and also, lab section is divided in three parts as material test activity, mock up assembly activity and scaled model study. PBL was in use in lab section and hands–on learning is experienced by the students in order to achieve better understanding and longer retention of the fundamentals of framing construction. Both traditional lectures and construction site visit activities were included in the preparatory block prior to the PBL activity (Table 2). Traditional way of lectures has been used as class-based instead of using alternative on-line lectures.

Table 2. Scope of PBL Activity in Missouri S&T ArchE 2103 Course (Yildirim, 2014a)

Phase 1. Preperatory Blocks	**Phase 2. PBL Block**
a) traditional lectures (lec.)	scaled model study (lab.)
b) construction site visit (lec.)	
c) material test activity(lab.)	
d) mock-up activity (lab.)	

Scaled model of framing construction is strictly dependent on material which is available, affordable and workable by the students. Cold-formed steel framing system, timber framing system and prefabricated reinforced concrete (r.c.) stick system were previously studied as scaled models. Results of 1/20 scale model of prefabricated r.c. system produced from foam board was not satisfactory and a 3D printer result was costly for the students. On the other hand, it was difficult to find small members symbolizing galvanized C and U cold-formed steel profiles and it was not easy to work in 1/20 or 1/10 scale by the students.

Since, scaled models of cold formed and r.c. system were seems like experimental efforts which had difficulty to repeat each year. Whereas, balsa sticks are widely available and workable while considering a scaled model study. That is why the framing construction in ArchE 2103 course was selected as timber framing system (Yildirim, 2012a; 2012b).

2.1 Preparatory Blocks

After being introduced the basic knowledge on framing construction in the lectures, material tests have been performed to show material properties. Construction site visit and mock–up assembly activities were also performed as preparatory blocks prior to PBL block.

• Construction Site Visit

Basic principles of timber framing were introduced in the lectures as prerequisite for construction site visits. They observed and obtained knowledge from the instructor and builder regarding the fundamentals of framing construction during their site visit (Figure 3). This provided a good learning environment with actual materials and construction before starting their scaled model study. The framing construction in Figure 3 is a sample of floor joists, load bearing and non-load bearing walls with timber, and in Figure 4 is sample for non-load bearing walls with galvanized steel profiles.

Figure 3: Visiting of Timber Frame Construction site in Rolla, Missouri by ArchE 2103 Students in Spring 2014 term (Yildirim, 2014a)

Figure 4: Visiting of Missouri S&T Biochemical Building (Bertelsmeyer Hall) construction site in Rolla, Missouri by ArchE 2103 students in spring 2014 term

• Mock-up Assembly Activity

The mock-up assembly was a preparatory exercise for the students before starting their timber frame scaled model study. Each framing construction has some specific installation principles. The students had been introduced to the basic principles of timber framing construction such as; in-line framing, on-center stud location, principles of platform framing, building envelope, etc. The sizes of the mock-up were scaled for the students in order to better handle and enable them to complete in fixed lab time. As illustrated by Figure 5, the study was not a full building study but it was a partial mock-up of the corner of a two-story house. The roles of instructor were; monitoring the student's performance on the learning activity and helping in critical details to a better understanding of the framing.

Figure 5: Mock-up Assembly of Timber Framing (Yildirim, 2014a)

Beside partial mock-up assembly of timber frame housing in ArchE 2103 course, an expert demonstrate a partial brick veneer over timber framing wall to show relations between materials in actual sizes (Figure 6).

Figure 6: Mock-up Demo of Brick Veneer Over Timber Framing Wall in ArchE 2103 Course

2.2 PBL Block

The enrollment of ArchE 2103 course was 52 students at spring 2014 semester. 13 teams with 4 team members were formed by the students for PBL block. The duration of the PBL activity was 5 weeks at the end of the term. Therefore the scope of the study is selected as "task project" in terms of PBL activity, since this scope brings more limitations that means to complete "the task project" in limited time by the students as per explained in section 1, Figure 2. The PBL activity was introduced to the students at lab section by providing information as shown in Table 3. It is important that the students totally understand "the task project", possible outcomes, scope and methodology in order to complete the scaled models on time and successfully. Hence, before starting the scaled model study, students must have basic knowledge of framing construction and all related data of "the task project". Required information was provided to the students by using hand-outs (design guide).

Table 3: Introduction of PBL Activity to the Students (Yildirim, 2014a)

1. Introduction of the problem	2. Duration of the study	3. Used material
4. Learning method and outcomes	5. Selection of team members	6. Lab safety rules
7. Distribution of building types	8. Hand-outs (design guide)	

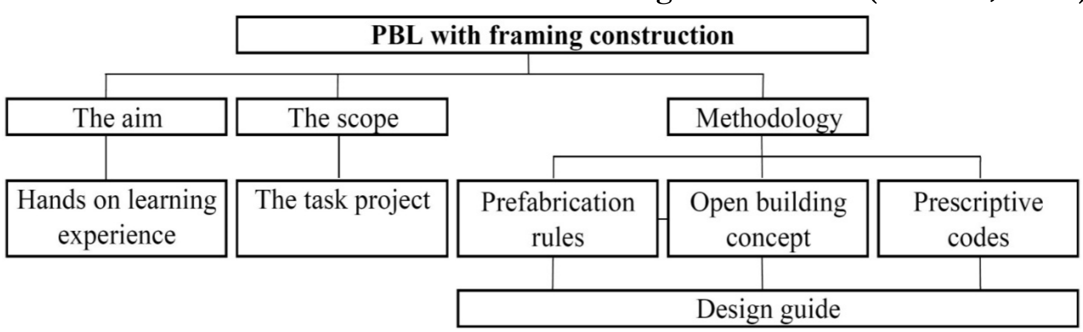
Also the main goal of the activity was that be exposed to team-based learning by working together in teams. Buildings consist of a variety of subsystems and require different kind of expertise during design and construction phases. Since, team work between the variety architectural and engineering disciplines is an essential part of a success building construction. On the other hand, supervising 13 projects in teamwork is more applicable in lab schedule for both the instructor and the students. Therefore, team work as a learning activity was selected in the PBL block instead of individual effort of the students. The task for the students was completion of a 1/20 scale timber framing system in a teamwork effort. The role of instructor was to monitor the process of the study and supervise the students regarding how they use the provided documents. The hand-outs are also accepted as design guide. Design guide included written and visual documents (Table 4).

Table 4: Types of Hand-Outs (Design Guide) (Yildirim, 2014a)

written documents	visual documents	
* design limitations * lab safety rules * definition of used materials * evaluation method (rubric)	* building types & used modules * header (lintel) types and details * images of previous studies	* building floor layout * a set of project sample * perspectives showing steps of learning activity

Provided hand-outs (design guide) were produced by the help of prefabrication rules, open building concept and prescriptive codes. These three notions are creating the used methodology in PBL with framing construction. The formulation of PBL with framing construction is shown in Table 5. The notions used in Table 5 are out of scope of this article and can be discussed separately in another article. Moreover, written and visual documents can be also discussed separately as well.

Table 5: Formulation of PBL with Framing Construction (Yildirim, 2014a)



Students may perform their ability and knowledge which they received during preparatory blocks on PBL block by hands-on experience. The scope of "the task project" was completion of a 1/20 scaled model of a two-story house. The students were informed that there are two methods to install a framing construction, i.e. stick-built system and panelized system (Figure 7). Both methods were allowed to use and the decision was belong to teams. One team worked with one method and students were promoted to observe other groups for details and methods of assembly. Observing both methods by the students during the assembly of 1/20 scale model, was a good experience for the students to learn pros and cons of working with both methods. The panelized system was much more preferred by the students and resulted in good communication between team members and distribution of responsibility between team members was well determined.

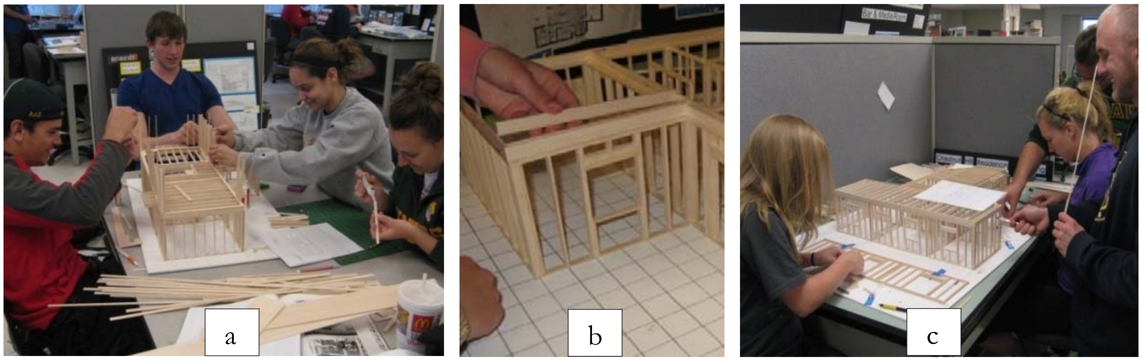


Figure 7: Scaled Model Assembly as Stick System (a and b) and Panelized System (c) (Yildirim, 2014a)

Foam board was used as base board for the scaled model and 24 inch grid was accepted as spacing between studs and floor joists. Building types with one and two story options helped the students to understand the variety of wall and floor combinations. Roof slope was applied as 4/12 in all building types. Hip roof style was applied to experience basic roofing knowledge as installation principles. A typical staircase compatible with all building types was preferred in order to maintain standardization. The typical balcony dimension was applied in all building types as 24 inch cantilever. The results of 1/20 scale timber framing system are shown in Figure 8 and Figure 9. A peer assessment by the students with having 20% rate and a rubric by instructor with having 80% rate was also performed for PBL activity at the end of the semester.

Figure 8: Results of PBL Activity in ArchE 2103 Course

Figure 9: Results of PBL Activity in ArchE 2103 Course

3. Evaluation of Learning Environment

In order to assess the results of PBL activity in ArchE 2103 course, a survey was completed by the students two times per term as before and after. An initial survey was performed before the PBL activity and the second survey was performed after completion of the scaled models. The survey questions shown in Table 6 focused on the educational value of the variety blocks of the course (Cowan, 2008).

Table 6: Survey Questions (Yildirim, 2014a)

1	Please indicate your academic level. a. Freshmen b. Sophomore c. Junior d. Senior
2	Pleasei ndicate your level of construction experience? a. None b. Some, intern etc. c. 1 – 2 years' work experience d. 3 – 5 years' work experience
3	Rate the importance of performance testing of constructional materials in the lab for this course
4	Rate the significance of visiting a building construction site for this course
5	Rate the educational value of having lab exercises on partial construction methods (like mock-ups)
6	Rate the educational value of the scaled model study on wood framing systems
7	Rate the educational value of the building types used in scaled model study
8	Rate the teamwork effectiveness for the scaled model study
9	Rate the educational value for building a scaled model out of cold formed steel framing
For questions 3 through 9 please rate the statement using a scale of 1 through 10 (with 1 meaning unimportant…….and 10 meaning very important)	

There were 42 participants in the first survey and 49 participants in the second survey. The major academic standing of the students was sophomore with 55% and 67.34% of the students had no construction experience (Table 7). The students rated the statements for questions 3 through 9 in the survey using a scale of 1 through 10 (with 1 meaning unimportant and 10 meaning very important) andaverage rate of significance of each questionis shown in Table 8.

Table 7: Percentage of Academic Standing (a) and Construction Experience (b) (Yildirim, 2014a)

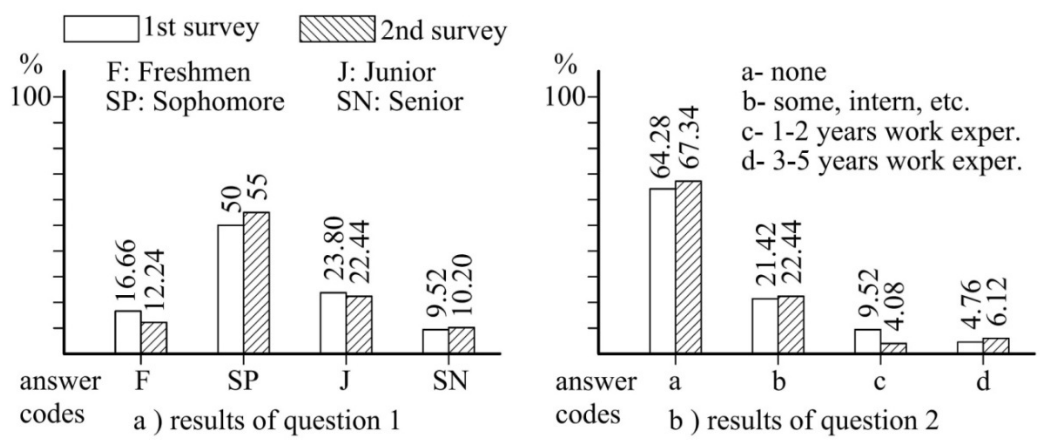
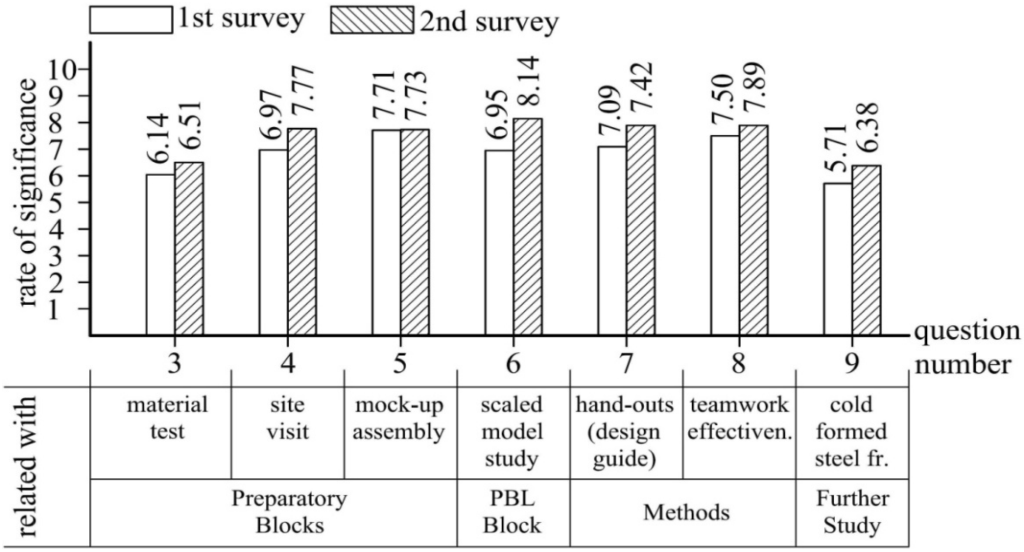


Table 8: Average Rate of Significance of Each Question (Yildirim, 2014a)



Question 3, 4 and 5 are related with preparatory blocks and question 6 is related with PBL block. Remaining questions are for used method and further study. The PBL activity affected the outcome of the traditional learning environment positively as shown in Table 8.

Question 3 with 6.02% difference and question 4 with 11.47% difference shows the improvement on learning environment. There is not a remarkable change in the result of question 5 as a result of the PBL exercise. The highest improvement was observed in main PBL activity in question 6 by the difference of two survey 17.12%. The results of the question 7 and 8 are almost same with the difference of 4.65% and 5.2%. The survey results showed that there was positive impact on educational value of the hand-outs. Considering the survey results in terms of educational value; question 6 as PBL block had the highest value with 8.14 and question 8 as method of teamwork effectiveness was second rank with 7.89 as illustrated by Table 8. Material test activity in question 3, had the lowest value with 6.51 (Yildirim, 2014a).

4. Conclusion

Besides the traditional lecture learning environment, PBL as hands-on learning experience is an alternative to support teaching fundamentals of framing construction in architectural engineering. Particularly hands-on learning experience is highly desired in architectural engineering programs. This article shows the research results as to prove whether or not PBL is a proven alternative to other forms of instruction in architectural engineering education. On the other hand, because of not being completely successful of full integration of technical disciplines and lack of necessary minimum of prior knowledge to be formulated in PBL environment, the application of PBL as a stand alone curriculum caused difficulties in some universities in the world. Hence, it is recommended to use a combination of the educational methods, preparatory blocks including the traditional lecture learning environment and PBL together. So, the recommended education model is split up as a preparatory blocks supplemented with a PBL block. The effectiveness of a PBL activity was monitored by a survey in this case study. The survey results showed that the PBL activity had positive impact over the traditional lecture learning environment and students overall performance increased when compared to the traditional classroom setting. PBL activity with framing construction narrowed through "the task project" in order to provide better course management in limited time. Usage of panelized system for framing construction is recommended during scaled model assembly since having better teamwork effectiveness. Site visit and mock-up assembly activities were also beneficial for the students to observe actual size of materials and details prior to PBL block.

The challenge, some programs are slow to fully integrate this methodology due to lack of knowledge in developing a PBL learning environment.

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