Applicability of Multiple Building Technologies in Building Components' Design Education

Semih G. Yildirim[1], Stuart W. Baur[2]
[1] Visiting Scholar, [2]Assoc. Prof.

Abstract

Problem-based learning (PBL) as a part of course curriculum in architectural engineering education has already been formalized through longer retention of desired knowledge. The components of educational model are defined as learning environment, formulation of PBL, applicable building technologies and design guide. This paper aims to present applicability of multiple building technologies in building components' design education. Design guide is the backbone of this educational model and needs improvement in order to be used for the education of multiple building technology. Scaled model materials are evaluated due to their features and these features directly affect the students' performance in teamwork. Quantitative feedback are received from students by survey. Model materials and the effects over PBL environment are evaluated. Teamwork creates an effective working environment for the students to accomplish the task on time. Improvements are required for peer assessment and rubric and flexibility on building types is discussed.

Keywords; Problem-based learning, architectural engineering, building technology, hands-on learning

Introduction

Hands-on learning experience is highly desired in architectural engineering curriculum to maintain longer retention of desired knowledge. To create an active learning environment is targeted and an educational model is developed for this purpose[1]. Building components' design is the main application field of this model, since competency on this subject is necessary for architectural engineering students which is based on architectural materials and methods of building construction. The educational model has been already formalized[2] and improved[3] in Missouri S&T Architectural Engineering Program. The components of the educational model can be summarized in; definition of learning environment, formulation of problem-based learning (PBL), definition of applicable building technologies and creation of a design guide (Table 1). In fact, such an educational model requires this much component in order to create well-defined of the goal, scope and methodology for desired learning environment. The notion of PBL is covering hands-on learning experience and this was the reason to be selected as definition of learning environment. It is possible to use PBL in a wide range of higher education, such as; medical and computer science. That is why a formulation is required to be used particularly in architectural engineering program. The scope is also narrowed through some particular building technologies and a design guide is created which serves to the students as part of “the task project”.

Table 1. Components of proposed educational model

Educational Model			
1. Learning Environment	**2. Formulation of PBL**	**3. Applicable Building Technologies**	**4. Design Guide**
problem-based learning	prefabrication rules, open building concept and prescriptive codes	Five building systems	Hand-outs for the "task project"

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[4]. Three fundamental types of project work can be distinguished in PBL; *the task project, the discipline project and the problem project* [5]. Limitation increases through the task project and the freedom increases through the problem project. PBL is part of lab activities in ArchE2103 course and called as “term project”. Teamwork was essential to fulfill the term project successfully. Duration of the study is main determinative for the scope of the PBL module in the course. Students’ motivation is dependent on the degree of participation, in other words; increasing of freedom may result in positive feedback from the students. Due to having limited time in a semester, it is necessary to put boundary on the term project. The boundary or the limitation is also called as “design requirements” in design guide. Consequently, time and the freedom are indirectly proportional with the limitation on the term project (Figure 1). For instance; students were responsible for accomplishment of only scaled model as term project in 5 weeks in spring 2014 semester, whereas 7 weeks study was covering cad drawings in spring 2015 semester which needs to be considered structural framing/penal design because of not handing-out necessary framing/panel drawings to the students.

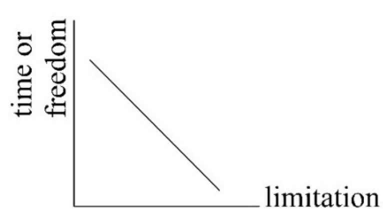


Figure 1. Relation between design limitation (requirements) and time or freedom

The applicable building technologies in proposed educational model are selected as timber framing system, cold formed steel (CFS) framing system, reinforced concrete (RC) prefabricated system, autoclaved aerated concrete (AAC) panel system and structural insulated panel (SIP) system. The common ground of all these systems are being either stick-built or panelized building systems beside being industrialized building systems which are the main choice reason of these particular building technologies. A design guide can serve the students to better understanding of these system in PBL environment. The task for the students in teamwork is accomplishment of a scaled model of selected building technology as a term project. Timber framing system had been solely selected in spring 2014 semester due to material features of balsa stick as being available, affordable and workable. A survey had been held based on assessment of educational value of course activities in spring 2014 semester (Yildirim, Baur, LaBoube, 2014). The purpose of one question was evaluation of applicability of multiple building technologies and the question was; "rate the educational value for building a scaled model out of cold formed steel framing". The average significance of this question was 6.38 out of 10 and let us to consider multiple building technologies in spring 2015 semester. On the other hand, giving option to the teams may result in increase of student participation in PBL activity was the other reason. Due to the fact that, three building technologies among five were selected in spring 2015 semester;

a) Timber framing system,
b) Cold formed steel (CFS) framing system and
c) Reinforced concrete (RC) prefabricated system.

This paper aims to evaluate the applicability of multiple building technologies in building components design education and present latest improvements on proposed educational model.

1. Preparatory blocks prior PBL activity

A few architectural faculties has applied full integration of PBL in their curriculum as a top down decision in 1990's. Due to their experiences, 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 was broken. Based on these experiences, an alternative was suggested in which various educational formats were employed to support the problem-based learning process. Prior to introducing the "*PBL learning blocks*", a series of "*preparatory learning blocks*" were offered. 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[6]. This approach had been accepted in ArchE2103 course in Missouri S&T in spring 2014 and 2015 semesters. Beside the traditional lecture learning environment, hands-on learning experience is aimed in lab activities. Prior PBL activity, preparatory blocks have been performed such as;

a) Brick veneer wall mock-up assembly (Figure 2)
b) Visiting of construction site (Figure 3)
c) Cargo container design in 1/50 scale model (Figure 4)

It is important to note the course title is "architectural materials and methods of building construction" and these activities helps the students to better understanding of the course content. Each team completed a partial brick veneer wall mock-up (1' x 2') in the lab. On the other hand, after having had introductory knowledge in the lectures, the students had a site visit of a construction with CFS framing system. Moreover, modular construction unit design is implemented based on cargo container design features. A team based discussion group was aimed to stimulate doing exercise on a real life problem at their major. A poster presentation and a 1/50 scale model has been submitted by teams at the end of the activity.

Figure 2. Brick veneer mock-up assembly over timber framing dry wall

Figure 3. Visiting of Missouri S&T Phi Kappa Theta Fraternity House construction site in Rolla, Missouri in spring 2015 semester

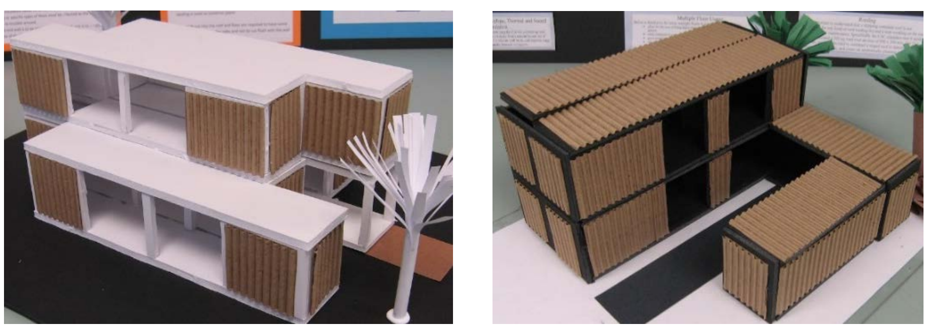


Figure 4. Sample models of cargo container buildings in 1/50 scale

2. Multiple building technologies in PBL activity

Multiple building technologies have been applied in ArchE2103 course during spring 2015 semester which was different than last year. Survey results in spring 2014 were effective for this decision as previously mentioned. Design guide needed some improvements due to be responsive to all applicable building technologies during PBL activity. Particularly, material type, methods of construction, dimensions of building components shall be included inside the design guide as data. Same building types were used as last year but the teams had option to select the building technology after introducing the PBL activity. While starting to PBL activity, the students were informed about the pros and cons of working on each building technologies. Balsa material for timber framing system, aluminum foil for CFS framing system, balsa and foam board for RC prefabricated system have been used during assembly of scaled models (Figure 5, 6, 7).

Figure 5. Assembly of timber framing model in 1/20 scale

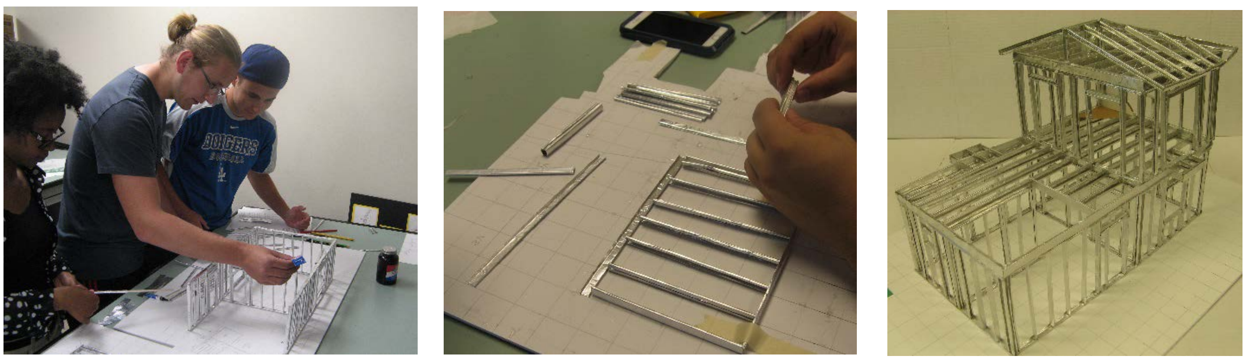


Figure 6. Assembly of partial CFS framing model in 1/20 scale

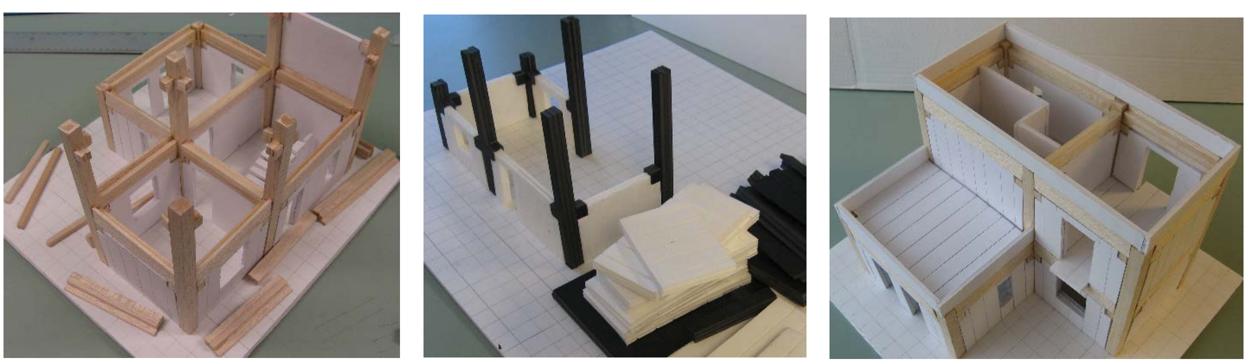


Figure 7. Assembly of RC prefabricated model in 1/32 scale

Due to workability of model materials, scope of the PBL activity varies for each building technology. Maintaining fairness between teams was aimed by doing so. A partial model in 1/20 scale was expected from CFS framing teams, since having difficulty and taking considerable amount of time of scaled C and U profile production. On the other hand, a smaller scale was accepted as 1/32 for RC prefabricated system due to available foam board thickness.

3. Survey

A survey was held two times per term as before and after, in order to assess the results of educational methods in ArchE2103. An initial survey was performed before the PBL activity and the second survey was performed after the completion of the scaled models. The survey questions shown in Table 2 focused on the educational value of the variety blocks of the course[1, 3]. Questions are grouped in Table 3 and the number of questions is increased to 15 in spring 2015 semester. The students rated the statements in the survey – between question 3 and question 13 - using a scale of 1 through 10 (with 1 meaning unimportant and 10 meaning very important) and average rate of significance of each question is shown in this section. Learning environment has been classified according to learning pyramid and so, question 3 to question 9 are grouped under preparatory block and question 10 and 11 belong to PBL activity. The classification gives ease of assessment and opportunity to do necessary improvements due to survey results. On the other hand, question 12 and 13 focused on the methodology and question 14 and 15 deal with the flexibility on PBL environment. 39 students enrolled to the class in spring 2015 semester. There were 36 participants in the first survey and 25 participants in the second survey. The major academic standing of the students was sophomore with 72% and 56% of the students had no construction experience (Table 4).

Table 2. Survey questions

1	Please indicate your academic level.
	a. Freshmen b. Sophomore c. Junior d. Senior
2	Please indicate 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 educational value of the lectures for this course
4	Rate the educational value of the lecture notes on blackboard for this course
5	Rate the educational value of the "Documentary Movies" related with technical content
6	Rate the importance of performance testing of the construction materials in the lab for this course
7	Rate the significance of visiting a building construction site for this course.
8	Rate the educational value of having lab exercises (e.g. brick masonry mock-up)
9	Rate the significance of discussion group like the "Cargo Container Design Features"
10	Rate the educational value of the scaled model activity with building technologies
11	Rate the educational value of the building types used in scaled model study
12	Rate the educational value of the "design guide / hand-outs" used in scaled model study
13	Rate the team work effectiveness for the scaled model study
14	I prefer to select another building type instead of what was from the hand-outs
	a) strongly disagree b) disagree c) average/neutral d) agree e) strongly agree
15	Which building technology do you most like to work with during the scaled model activity?
	a) Precast RC b) timber frame c) CFS frame

The PBL activity affected the outcome of the traditional learning environment positively as per in Table 5 question 3 to 7. Particularly, teamwork effectiveness increased considerably as 9% after the PBL activity and had the highest value with 8.60 out of 10. Masonry wall mock-up assembly had the second rank in the table with 8.39 out of 10. Cargo container design activity has the lowest value among others and the reasons and development proposals are discussed separately. Being outside the box and not being a “task project” like in PBL activity can be named as basic reasons.

It is important to note there is considerable amount of declining in the educational value of PBL activity as per in Table 5 question 10 and 11 conversely previous year. 7% in question 10 and 10 % in question 11 are noted. This result shows that it is worth to examine the applicability of multiple building technologies in building components design education. On the other hand, Table 6 shows important data related with this decline in PBL activity. 40% of the students are okay with existing building types but, other 40% of the students look for more flexibility on building type in Table 6a. Another remarkable results are shown in Table 6b concerning with building technologies. In first survey, only 5.55% of the students interested in RC prefabricated system, but after the PBL activity this value increased up to 16%. 10% decline of the timber framing at second survey shifted to RC prefabricated favor. The most astonishing result from the survey results is; nobody wants to study scaled model of CFS framing system either before or after the PBL activity according to Table 6b.

Table 3. Classification of questions according to learning environment

Learning pyramid		Learning environment	Question no.	
1	Lecture	Traditional lectures	3	**Preparatory block**
2	Reading	Lecture notes on blackboard	4	
3	Audio Visual	Documentary movies	5	
4	Demonstration	Material Test	6	
		Visiting of construction site	7	
		Brick masonry mock-up	8	
5	Discussion Group	Cargo container design	9	
6	Practice by doing	Scaled model study with necessary cad drawings	10, 11	**PBL**
Methodology		Design guide / hand-outs	12	
		Teamwork	13	
Flexibility on PBL Environment		Building type	14	
		Building technology	15	

Table 4. Percentage of academic standing (a) and construction experience (b)

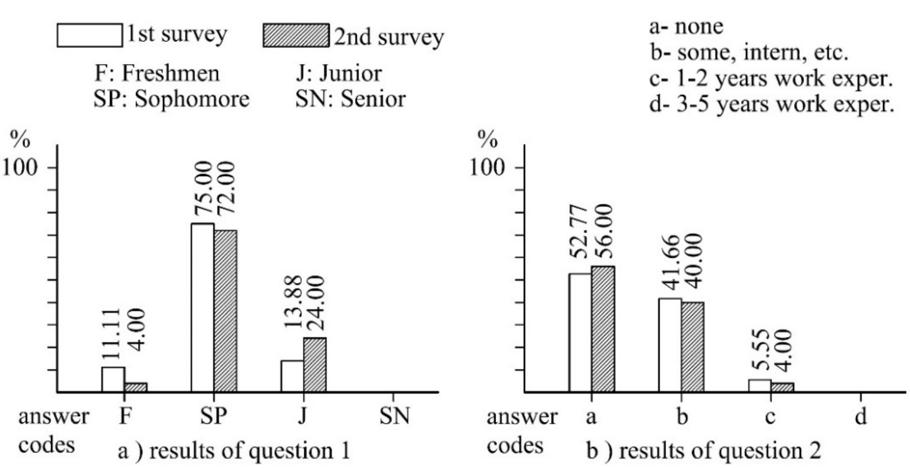


Table 5. Average rate of significance of each question

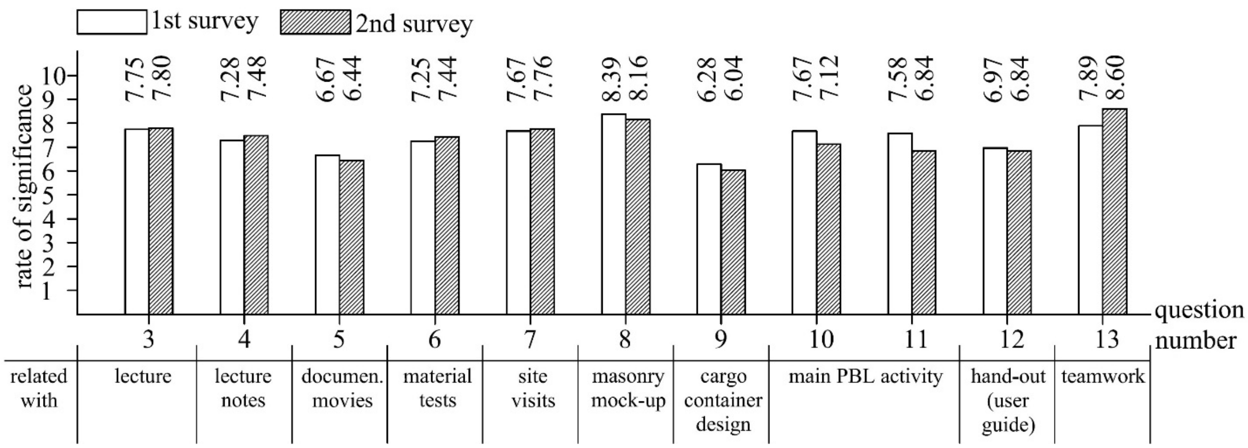
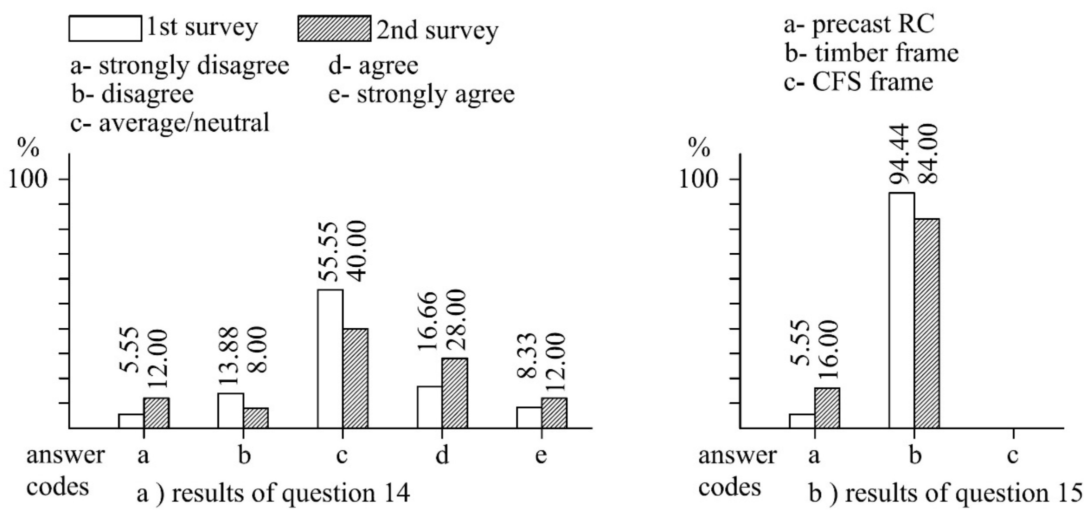


Table 6. Percentage of flexibility on building types (a) and building technologies (b)



4. Assessment of PBL activity

Material features are directly proportional with the satisfaction of desired learning environment. Table 7 shows some particular features of model materials which shows consistency with the survey results. Sample timber framing scaled models in the lab belong to previous year give comprehensive idea to the students that what they will install. R.C. prefabricated teams convinced after assembling of scaled model that the scaled model assembly is not as much as they afraid at the beginning. On the other hand, having hardship with the production of scaled C and U profiles resulted in dissatisfaction of the students who study with CFS framing system. Mentioned reason directly affected the survey results as well. There were 11 teams consisting of 3 or 4 students in PBL activity. 4 teams with 14 students (35,89% of all) studied with timber framing system, 4 teams with 15 students (38,46% of all) studied with CFS framing system and 3 teams with 10 students (25,64% of all) studied with RC prefabricated system. Having hardship while working with heavy duty aluminum foil causes negative thoughts on 38,46% of all students and resulted in the survey as declining educational value of PBL environment.

Table 7. Used materials for model production and their features

Materials	Applicable building technology	Notes			
		Available	Affordable	Workable	Results
Balsa wood	Timber framing and RC prefabricated	**X**	**X**	**X**	**V**
Foam board	RC prefabricated	**X**	**X**	**X**	**S**
Heavy duty aluminum foil	CFS framing system	**X**	**X**		**F**
P = Poor, F = Fair, S = Satisfactory, V = Very Good, E = Excellent					

Despite of having some difficulty working with multiple building technologies in PBL environment, the overall study still got a remarkable value with 7,12 out of 10 in second survey in Table 5 question 10. The results of the activity are being presented in Figure 8.

A peer assessment has been done by the students to assess the participation of team members after the PBL activity. Furthermore, it is observed that a peer assessment on other building technologies may help them to increase their knowledge on different building technologies. By doing so, they will be aware of the details of other teams' studies. Due to application of different building technologies, the rubric shall serve all three building technologies while grading the results of the activity. Pre-designed building types were proposed to the teams at the beginning of the PBL activity and were handed-out by the instructor. On the other hand, the students were informed that if they desire, they can use another building type which they can design or find an existing design somewhere else in order to have design flexibility on building types. But they preferred handed-out building types at the beginning of PBL activity. Whereas, In Table 6a, considerable amount of the students look forward to have design flexibility on building types. The reason for this could be; consideration of activity time, dissatisfaction of CFS teams or hesitation on thinking outside the box. But, anyhow, it is necessary to develop a methodology to give them design flexibility over building types.

Figure 8. General overview of timber and CFS framing models in 1/20 scale and RC prefabricated model in 1/32 scale

Conclusion

Due to survey results belong to spring 2014 semester, flexibility was requested on building technology by students and applicability of multiple building technologies have been evaluated in this paper. Design guide needs some improvements to be responsive to each building technology. PBL has positive impact over traditional environment due to survey results presented herein. Also, preparatory blocks are necessary for a successful PBL environment. Teamwork was greatly welcomed by the students since getting highest rate in the survey. Workability of model material is critical during scaled model assembly, since it is observed a negative thought on CFS framing system after PBL activity. In order to maintain fairness between teams, the scope of the activity can be changed such as in scale and/or in the size of the model. CFS framing models were installed partially in 1/20 scale and RC prefabricated models were installed fully in 1/32 scale. 38.46% of all students were working with CFS framing system and they did not satisfy with their activity due to hardship of model material production. Despite this dissatisfaction, the overall PBL activity still got a remarkable value with 7.12 out of 10 in the survey. RC prefabricated teams had hesitation on studying with this building technology at the beginning, but they satisfied once they assembled the model. The paper shows that multiple building technologies are applicable in building components design education by taking into account the model material features.

References

1 Yildirim, S. G., Baur, S. W., LaBoube, R. A. 2014a. Fundamentals of framing construction in architectural engineering; a hands-on learning experience. 2014 Midwest Section Conference of the American Society for Engineering Education, Sept. 24-26, 2014, University of Arkansas, Fort Smith, AR, USA. [Online] Available: http://www.uafs.edu/sites/default/files/users/yildirim.pdf

2 Yildirim, S. G., Baur, S. W., LaBoube, R. A. 2014b. Formulation of problem-based learning in “building components design” education. Journal of Engineering and Architecture, Vol. 2, No. 2, Dec., 2014, pp. 13-26. Published by American Research Institute for Policy Development, NY. [Online] Available: http://dx.doi.org/10.15640/jea.v2n2a2

3 Yildirim, S. G., Baur, S. W., LaBoube, R. A. 2014c. Problem-based learning with framing construction in architectural engineering. Journal of Engineering and Architecture, Vol. 2, No. 2, Dec., 2014, pp.63-73. Published by American Research Institute for Policy Development, NY. [Online] Available: http://dx.doi.org/10.15640/jea.v2n2a6

4 Url 3.Introduction to project based learning. [Online] Available: http://bie.org/images/uploads/general/20fa7d42c216e2ec171a212e97fd4a9e.pdf (June 10, 2014)

5 Graaff, E. D., Anette Kolmos, 2003. Characteristics of problem-based learning. Int. J. Engng Ed. Vol. 19, No. 5, pp. 657-662, printed in Great Britain, Tempus publications. [Online] Available http://www.ijee.ie /articles/ Vol19-5 /IJEE1450.pdf.

6 Banerjee, H. K., Graaff, E. D., 1996. Problem-based Learning in Architecture: Problems of Integration of Technical Disciplines,European Journal of Engineering Education, Volume 21, Issue 2, (pp. 185-195), 1996.

Biographical information

Semih G. Yildirim, Ph.D., (Corresponding Author), Visiting Scholar, Department of Civil, Architectural and Environmental Engineering, Missouri University of Science and Technology, email: yildirims@mst.edu
Stuart W. Baur, Ph.D., Associate Professor, Department of Civil, Architectural and Environmental Engineering, Missouri University of Science and Technology, email: baur@mst.edu