Laboratory-Based Learning to Study the Pullout Test of an Anchor in Concrete

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ABSTRACT

This paper presents the evaluation of laboratory-based learning in civil engineering study on the topic of a single pullout test of an anchll-outr embedded into concrete according to ASTM E488/488M standard. In this study, the authors developed the laboratory handout and designed a series of learning approaches for the students to make them to understand the consequences. A total of 55 students, currently studying at King Mongkut's University of Technology Thonburi, in Civil Technology Education program, was joined in this study. Evaluation tool used in this research was descriptive questions to evaluate the competency in this topic in three different stages, before learning (pre-test), after giving a full lecture in the classroom (post-test 1), and after giving a full lecture and laboratory-based learning (post-test 2). All the questions were proved by index of item objective congruence (IOC) from the three experts in this field of study. To discuss and compare the results, all the queries were analysed as follows: the average ($\bar{x}$), standard deviation (SD), and t-test value. The results showed that students' learning achievement increased scores for the pre-test (29.25%), post-test 1 (60.10%), and post-test 2 (88.30%). The results indicated that students' knowledge was significantly improved after laboratory-based learning. Their knowledge and skill were developed, including theory and practice through this learning method, so that it should be proposed for teaching and learning in civil engineering.

Keywords: Laboratory-Based Learning, Pullout Test of Anchor, Engineering Education

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Introduction

At present, science, engineering and technology play very important roles to develop the country so that education in those fields developed fast. In general, theory is used for detailing of a supposition of ideas intended to explain phenomena or something, and using practical laboratory to study and analyze those problems. In technology education, laboratory learning is highly necessary for teaching technical students because they can extremely understand between the results of a theory and practical work. Because of its essentials, there are many laboratories established to teach civil engineering students, i.e. concrete structure, soil mechanics, and other laboratories. For an example, testing concrete is used to study of its compressive strength, tensile strength, workability, and durability. Normally, laboratory learning has prepared to deal with practical work after they have learned the content theory in the classroom(Lyle and Albert, 2005). In engineering education, laboratory learning has been commonly used for teaching approach whenever today and tomorrow. (Grayson, 1993) Moreover, teaching engineering without laboratory assessment of an experimental work, it cannot compare the results between the theory and practice. (Stephan, 2002) The previous researchers proposed that teaching students of concrete compressive tests in large group could help them enhance self-learning, but (Dieog, Manuel and Miguel, 2016; Abdulwahed, and Nagy, 2009) presented in a large group of students can disturb teaching and students' learning. According to their present in, in this study students were divided into six small groups with three learning stations in order to ease the experts teaching and students learning in Laboratory-based learning section. Generally, they have used laboratory exploration to predict the results of testing, reporting, and understand the nature of those problems. Furthermore, laboratory work was used to demonstrate the problem, including data collection, report the results, and others. Due to explained that concrete laboratory was used to collect the data, to analyze, and to report the results. For an example,

teaching structural analysis through design, building, and testing of wooden truss in the classroom and giving the assignments to them to build the beams and concretes (cylinder) to tests, and reporting the results presented in. (Solis, Tomero and Galvin, 2012)

Regarding the previous researchers' works showed that they have taught students with an easy or normal of laboratories learning in concrete technology or concrete structure, i.e. concrete compressive strength tests, flexural testing of concrete beams or others, but some difficult experimental works they have not yet propose for teaching students in their laboratory coursework. For their teaching approaches of the previous works, they were easily used to train students to understand because they were not complicated to study. Otherwise, pullout test is intricate to investigate in the experimental procedure and learning assessment with a long progress through a specimen preparation to finish the test, and it has not explored or performed by the previous researchers in their laboratories teaching and learning. Moreover, teaching of pullout test has not yet established and it will play an important key for the present and the future learning, so that a single pullout test according to ASTM standard: E488/488M is proposed for teaching students in this research. Furthermore, in this study students learning achievement will be discussed between self-learning (SL) and classroom learning (CL), and classroom learning and laboratory-based learning (LBL) in the same content theory, including both basic concept and practical work with the real project of an anchor inserted into concrete as shown in Figure 1. In addition, the three exams of content theory will be conducted on the same queries and exam times, and students learning styles are separated into three phases, including, SL, CL, and LBL.

For SL section, the authors informed students about the pre-test exam and guide them some important websites to teach the pullout test of anchors inserted into the concrete. After finishing the pre - test exam, the authors and the experts gave the full lecture of content theory about pullout test of anchors

inserted into concrete in the CL and completed (post-test 1) in the morning section. After that, the experts gave full training on the real practice work of pullout test of anchors inserted into concrete to the students in LBL section and completed (post-test 2) in the afternoon section, the CL and LBL were completed for a whole day. All tests processes were studied of students' learning achievement.

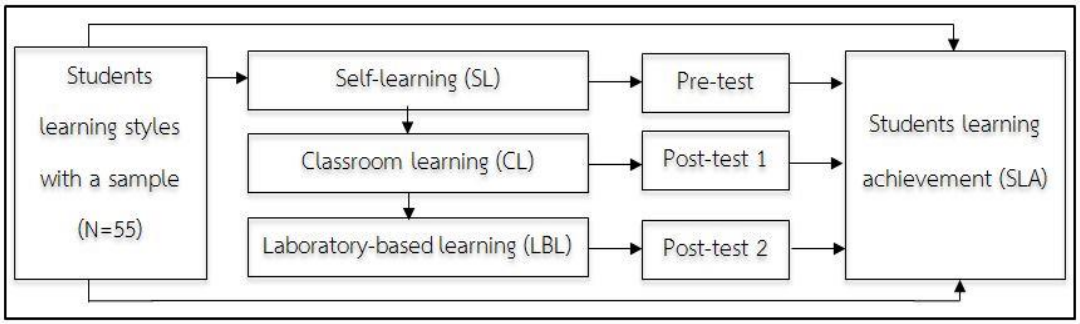

Figure 1 The instrument of students' learning styles

Research Objective and Significance of the Research

The objective of this research is to develop laboratory-based learning in civil engineering in the topic of a single pullout test of an anchor embedded into concrete according to ASTM E488/488M standard, and evaluating students' knowledge development before and after the learning progresses, i.e. pre-test (before having the lecture), post-test 1 (after full lecture in classroom completed), and post-test 2 (after full lecture in classroom and laboratory section finished).

The findings of this study will help to increase the benefit of students learning styles that LBL plays an important role in engineering education at the present and the future. Regarding the results of the three tests, LBL showed that students learning achievement were positively developed, so the researchers found LBL gave more effective on teaching approaches. Thus, laboratory sections that apply these teaching and learning approaches from this study will be able to train students better for their learning and future careers. The teaching and learning

approaches in this study can use for developing school curriculum to improve students' performance in laboratory learning, and the study will help to develop the educational advancement that many researchers were not able to explore, so that this teaching and learning styles is presented as a new teaching and learning methodology.

Research Methodology

1. Population and Samples

The population and samples were received from undergraduate students in civil technology education program at the Department of Civil Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi. They were studying in the third year, semester one, and authors selected students, currently learning in the coursework of concrete and construction materials (concrete technology laboratory section) to join in this study.

2. Research Tools

The data were collected throughout the answers of the descriptive questions. The descriptive questions had 20 queries which were divided into four main sections, namely, general information of anchors, the characteristics of the adhesive anchor, the characteristics of the expansive anchor, and the behaviors of pullout test and one section was sub-divided into five queries as shown in Table 1. For a query gave one score, and the total score was 20 marks. The three exams, namely, (1) pre-test, (2) post-test 1, and (3) post-test 2, were used to evaluate students learning achievement. A questionnaire was prepared by the authors and the queries were proved by the index of item objective congruence (IOC) from the three experts in the field of this study before giving to the students.

3. Analytical Tools

The data collected was analyzed three times to find out the average ($\bar{x}$) and standard deviation (SD) of each test. Moreover, these data were analyzed by using t-test value to compare according to distinguishing between SL and CL, and CL and LBL. Before getting the data collection to analyze in this study, students were invited to have three

exams assessments, and they answered with the 20 queries with a query given a score (one mark).

The measurement of this study progressed through two weeks and divided into three parts, i.e. SL, CL , and LBL. Therefore, the authors informed students about the exam of pullout test of an anchor embedded into concrete and they introduced some websites that taught the content. The first week of the evaluation, they gave the pre-test exam to the students that they have been confirmed. After they completed the pre-test exam, the authors informed students to prepare themselves and come to the classroom to join the special training course provided by the experts from Hilti (Thailand) Co., Ltd , and the authors, on next week through the CL (morning section) and LBL (afternoon section).

Table 1 The detail of descriptive questions

Part	Details of question
I. General information on anchors	1) What is an anchor? 2) What is the application of an anchor in construction? 3) What is the design standard for anchor based on the concrete capacity design method? 4) How to install a deformed bar into harden concrete? 5) What is the meaning of selection of concrete according to the design standard?
II. The characteristics of adhesive anchor	6) How to install an adhesive anchor? 7) What are the precautions during adhesive anchor installation to prevent load under achievement? 8) What are the advantages and disadvantages of using adhesive anchor without cleaning up the hole prior to the installation? 9) What are the safety issues used when installation of adhesive anchor? 10) Explain on the definition of curing time of adhesive anchor installation?
III. The characteristics of expansive	11) What is the mechanism of an expansive anchor in transferring load?

anchor	12) What is the most important step to the installation of the expansive anchor so that they work effectively under tension? 13) What are the diameter and the depth of the hole to be drilled for installing expansive anchors having a diameter of 12 mm and a length of 70 mm? 14) What are the advantages and disadvantages of using an expansive anchor? 15) What are the consequences of installation expansive anchors with too close spacing in terms of load carrying capacity and failure mode?
IV: The behaviors of pullout test	16) How to investigate if anchors are ready for load transferring after installation under tension? 17) What are the failure modes of post-installed anchors under tension? 18) How to design anchors to prevent them from the concrete breakout failure mode? 19) Under concrete breakout failure mode, what is the distance from an anchor center to the edge of the projected area? 20) How to design anchors to achieve steel failure mode?

4. Classroom Learning

The second week of the evaluation in the morning section, the experts from Hilti (Thailand) Co., Ltd had a special training course on anchors types, adhesive products, and their specifications to the students, including, to introduce the anchors and its applications in construction industry, to explain the anchor types and their behaviors (two types of anchors, namely adhesive anchor and expansive anchor were used in this study), to guide how to use anchors and their products to follow the technical standard and product instructions (setting time, temperature sensitive, hole depth and its dimensions, drill a hole and insert an anchor into concrete, and cleanness of the hole), and teach how to use adhesive product with safety. After that, the authors taught the mechanism of pullout test of anchors and its behaviors to the students, i.e. to teach the mechanical

properties of anchors and general behaviors of pullout test, to explain the operation of pullout test set up, and test schemes (from start to finish), to provide examples how to plot the graph of pullout load-slip relationship to find out the pullout load and displacement at the maximum load, to introduce the equations (calculation notes) in ACI 318 in appendix D (anchoring to concrete) to predict load, to give examples of how to measure the failure mode, and determine the angle of the concrete pullout. After finishing full lecture in the classroom, students invited to take the (post-test 1). Before students were leaving the classroom of the morning section, the authors and the experts suggested them, coming to the LBL section in the afternoon.

5. Laboratory-Based Learning

After finishing the morning section, students came to the LBL section in the concrete technology laboratory, and the experts prepared for teaching materials to teach them. In this study, teaching materials of pullout test of an anchor inserted into concrete, i.e. anchor types (adhesive and expansive anchors), concrete specimens, adhesive products, bolts and nuts, dispensers, blow-out pump, torque bars, safety glasses, dial gauge, loading ring, loading shoe, pressure gauge, hydraulic jack, and crip, were carried to the laboratory for teaching students. Before starting in this section, students were separated into six small groups (the experts were easily teaching and students were easily learning) with three learning stations (station 1 taught about all the adhesive anchor learning processes, station 2, about all the expansive anchor learning progresses, and station 3, about pullout test set up, and testing).

5.1 Station 1: Adhesive anchor learning processes

Before starting the real practice work with the pullout test of an anchor embedded into concrete, students were suggested to take gloves and safety glasses before starting the project. For each learning station of adhesive anchor, the experts taught them about how to drill a hole (having 14 mm of a hole diameter, a hole diameter should be larger than the size of adhesive anchor diameter 2 mm, within the specific of a

hole depth designed, with a longer depth about 10-20 mm), how to clean the hole (the dust inside the hole must be cleaned out before installing an anchor), how to use the adhesive product with the right way and safety by following the product instructions (they must check the expiration date of adhesive product before using it), how to install the anchor (adhesive anchor, they must install in the straight position). After filling the adhesive product of Hilti HIT-HY 110 inside the hole with an adhesive anchor, they should wait at least 1 hour in order to freeze the adhesive before having the test.

5.2 Station 2: Expansive anchor learning progresses

Before starting the real practice work with the pullout test of an anchor embedded into concrete, students were suggested to use gloves and safety glasses before starting the project. For each learning station of expansive anchor, the experts taught them about how to drill a hole (having 12 mm of hole diameter, a hole diameter must be the same size of expansive anchor diameter, within a specific embedded length designed, with a longer depth about 10-20 mm), how to clean the hole (the dust inside the hole must be cleaned out before installing an anchor), how to install the expansive anchor by applying a torque bar on the anchor screw facing with the corresponding loads to follow the technical standard recommended by manufacturer (they must install in the straight position). After expansive anchor finishing installed, it can test immediately.

5.3 Station 3: Pullout test set up and testing

Accordingly, the specimens preparation finished, the students were given an opportunity to learn details of pullout test setup and testing for each group learning stations. In this section, the experts and the authors supervised them to make the test setup of pullout test with teaching materials (see in teaching materials and learning of test procedure). For testing section, two students invited to practice with the tools. A student used a hydraulic jack to apply loads (using his/her hand), one student read the dial gauge (displacement values), and other

students written all loads and displacements that were given by the readers. This testing progress was applied to all groups learning stations. After all testing finished, each group learning stations had 1 hour and half to calculate all results and discussions of pullout behaviors, i.e. pullout loads, pullout load-displacement relationships, failure modes, using equations in ACI 318 in appendix D (anchoring to concrete) to predict loads, to compare the effect of using anchor types, the effect of the embedded lengths installed for each test, and finally they suggested to submit all test results to the authors. Before finishing the evaluation in this study, all of the students were requested to come to the classroom, and then they completed the post-test 2 (after having the full lecture in the CL and LBL section).

Results

From table 2, the research found that the (post-test 2) of the students' scores (=17.66, SD=1.92), were statistically significant difference, higher than the (post-test 1) of the students' scores ($\bar{x}$=12.02, SD=2.75). Moreover, the (post-test 1) of the students' scores were developed higher than the pre-test of the students' scores ($\bar{x}$=5.85, SD=1.96), and the (post-test 2) of the students' scores were statistically significant difference, prominently higher than the pre-test of the students' scores. According to these results, they showed that students learning achievement before they learned of content theory in SL were slowly upgraded, but they were mainly developed after finishing the full lecture in CL, and they were mostly improved through a training course of LBL on the real practice work, respectively. Regarding the p-values (p=.00*), were smaller scale than the alpha of .05 (p<.05) so it meant that this research work was significantly difference at level 0.5 (p<.05).

Table 2 Students learning achievement test of 55 samples

Learning Achievement		Mean	Std. Deviation	t-test	Sig.
CL and SL	Post-test 1	12.02	2.75	15.81	.00*
	Pre-test	5.85	1.96		
LBL and SL	Post-test 2	17.66	1.92	31.59	.00*
	Pre-test	5.85	1.96		
LBL and CL	Post-test 2	17.66	1.92	18.20	.00*
	Post-test 1	12.02	2.75		

*p<.05

Conclusions and Discussions

This paper presented the results of using LBL to teach students at King Mongkut's University of Technology Thonburi. The teaching method was designed to encourage and motivate students to learn about content theory and practice the real work of pullout test of an anchor embedded into concrete. Based on the results of the three exams, it found that students learning achievement were positively improved through a pre-test, post-test 1, and post-test 2, respectively. Regarding these results, LBL will help to expand the comfort of students learning styles and it can set an important key success in engineering education at the present and in the future. Having on the results summarized, LBL showed that students learning achievement were better developed if it was compared to SL and CL. The researchers found LBL was more effective on teaching approaches, and they could apply these teaching and learning approaches from this research to gain a better students' learning performance. LBL used in this study can apply for future teaching and learning styles and it can also use for developing school curriculum of civil engineering major. Furthermore, LBL had helped the students' knowledge development and

technical knowledge improvement, including both basic concept and application of theory. In addition, this teaching path can enhance students' abilities and knowledge advancement to find the better problem-solving, and it could help them by giving chances to comprehend how to deal with problems at the present and in the future in their prospective careers. Moreover, this teaching methodology is used to increase the quality of teaching and learning in civil engineering.

Generally, CL gave much of the theory and basic knowledge of calculations, but it has less effectiveness how to achieve by doing so that practical work can allow students to perceive the process of building and testing. For LBL students can study details of learning by constructing that they can learn about how to make the test set up and testing. Regarding the results of students learning achievement throughout the three exams, the researcher found and they can be calculated the percentages of students' SL scores (29.25%), were lower updated than the students' CL scores with a percentage (60.10%), and it was lowest developed than the percentage of students' LBL scores (88.30%), respectively. In this study, the researchers have applied the three styles of learning approaches in order to evaluate students' learning achievement by using three exams, namely, pre-test, post-test 1, and post-test 2. Each test showed the researchers , (delete comma) about the students' abilities and their knowledge development were significantly constant or increased. For this study, the researchers used a pre-test to measure the students' knowledge related to the content of pullout test assessment or it was usually called a control test before having the treatments or lecture (CL and LBL). According to a pre-test, the researchers can be analyzed and summarized the results of students' knowledge improvement through the post-test 1 and post-test 2. In the LBL section, students can learn both of theory and practice with the real project of pullout test, they tried to find out a solution to make the test set up quickly and reduce time to have testing. Moreover, they can

study of detailing of an experimental procedure of pullout test or other experimental laboratories, from a getting started to be successfully finished, and how to summarize the testing results (technical report). Fortunately, they can ask the experts directly or immediately when they have misunderstood on testing processes or how to achieve by doing with a real practice, and LBL can give them a lot of benefits of laboratory procedure both concept and practice. Due to the result of LBL students' score can be shown that using LBL has much better developed of students learning achievement.

The results of each test were used, to compare the three styles of learning progress by obtaining each test evaluation and determine the percentages of them. Having seen on the result of LBL (88.30%) using the three exams in this research was improved greater than (86.60%) of teaching second-year pharmacy students using active-learning laboratory activity, they evaluated students' knowledge by applying the two styles of learning approaches, including classroom learning and active-learning laboratory actively presented in. (Krista et al., 2015) Regarding the results of the three exams through a control exam and two treatment exams, the researchers found that LBL used for teaching students was successfully completed because students' capacities developments and their knowledge were significantly improved.

The first limitation in this study is used for teaching and learning of civil engineering students in the course of concrete and construction materials (concrete laboratory section) with a sample group study to evaluate on the students learning achievement. The second is focused on the test-re-test bias, which conducts the three exams. Therefore, students knew that they have three tests in different procedures of a week for each test and totally completed in two weeks with the same content and the same exam times.

For the future work, this teaching and learning style could apply for teaching undergraduate students for other subjects in civil engineering, i.e. soil mechanics, transportation and highway

engineering, and other laboratories. Before the pretest assessment, students should have the handout and read it in order to get some basic concepts and knowledge of content theory. Furthermore, in order to reduce the test-re-test problems of the same content measurement, the researchers would be able to give the content handout to the students before having an exam or any tests. For providing a content handout related to the test, it can help students to have some knowledge to take a future exam, and the researchers will not prepare more tests for them for collecting data and evaluate their knowledge. Moreover, the researchers should give them at least a week from the first exam to other exams in order to make sure that how many percentages the students can remember the content theory and practical work.

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