Embedded Knowledge and Skill of Engineering Students with Transitional Links among the Basic and Advanced Engineering Courses: Pre-investigated Case of Civil Engineering

Bhokha S[1], Sangtian N[1], Phannikul I[1], Leungvichchareon S.[2] and Subsomboon K.[2]
[1] Faculty of Engineering, Ubonratchathani University, Ubonratchathani, 34190, Thailand,
[2] Faculty of Engineering, Naresuan University, Phitsanulok, 65000, Thailand,
Tel. 081-924 0094, Facsimile: 045-353 333 Email: sdhabhon@ubu.ac.th

Abstract

This paper presents importance of the transitional links among the basic and advanced engineering courses in attempts to build and strengthen the embedded knowledge and skill of the engineering students. Freshman year students need motivation to drive their desire in engineering perspectives prior building knowledge and skill by means of formal lessons. Transitional links need verification of the embedded capability prior to continue strengthening with the advanced courses to ensure that they would be able to explore and apply the embedded knowledge and skill in professional practice, maintain the Life-Long-Learning. Context of the embedded knowledge and skill deals with the capability in problem recognition, applying proper approach and tool, conceptual and systematic thinking, reasoning, modeling or synthesizing, analyzing, computing, interpreting, generalizing, producing, reporting and communicating. Process of building and strengthening the knowledge and skill of the engineering students is presented with the illustrative basic and advanced civil engineering courses i.e. Engineering Drawing and Building Design. It is concluded that transitional links among the basic and advanced engineering courses in conjunction to the appropriate approach or technique support the learning process to build and strengthen the embedded knowledge and skill of the engineering students which help them to understand the engineering perspectives in order to be the qualified professional engineer.

Keywords: engineering education, embedded capability and skill, transitional links, building, strengthening

1. Overview

Engineering works need an "embedded capability" which means both the explicit and implicit knowledge and skill gathered from learning process and professional practice which can be recalled and applied i.e. the capability in problem recognition, reasoning, conceptual and systematic thinking, applying the approach or tool (e.g. using heuristics, rules of thumb, case-based and scientific process), generalizing (capability to resolve the unforeseen problem), modeling or synthesizing, analyzing or computing, interpreting, producing or reporting (sketching through detailed design and other means of results or output) and communication skill. The engineers should also responsible for saving (economical), safety, social, environment and sustainability.

ASCE [1] proposed "body of knowledge rubric" or the integrated outcome of the three main areas i.e. foundation, technical and professional which should fulfill five levels of achievement: 1) knowledge; 2) comprehension; 3) application; 4) analysis; and 5) synthesis and evaluation. Achievements could be accomplished by means of formal education (Bachelor's background) and pre-licensure experience (through the Master degree or equivalent credits of acceptable graduate level or upper level undergraduate courses in a related specialized technical or professional practice areas). The technical area consists of experiments, problem recognition and solving, design, sustainability, contemporary issues and historical perspective, project management, breath in civil engineering area and technical specialization [4], [5]. The future technical and professional breadth or practice education of the engineers would be supported on four foundational legs i.e. natural sciences, mathematics, social science and humanities.

In Thailand, the offered engineering programs and courses are prepared in accordance to the Engineer Act B.E. 2542, the Ministerial Rule B.E. 2550 [2], the Ministry of Education Announcement B.E. [3] and related announcements which have been launched by the Council of Engineering, Thailand (COE). They also aim to fulfill five to six domains of learning of Thai Qualification Framework (TQF), following the Education Act B.E. 2542 and amendment (2nd Education Code B.E. 2545) and Ministerial decrees (B.E. 2552 and B.E. 2553) which are: 1) ethical and moral development; 2) knowledge; 3) cognitive skill; 4) interpersonal skills and responsibility; 5) analytical and communication skills; and 6) psychomotor skill (when applicable). The ethical and moral development deals with ability to define or assign priority to the problems, understanding of the impacts from applying the engineering knowledge to the individual, organization, social or environment, understanding the historical and contemporary context of engineering profession [4], [5]. The knowledge concerns capability in basic Science, Engineering and Economics and the integration among those fields to solve the engineering problems towards the innovation, capability to use the computer and problem solving skill. The cognitive skill means systematic thinking, reasoning, capability in identifying and representing the problem, researching, analyzing, making conclusion, capability in imagine or create an idea, flexibility in applying the body of knowledge, self and Life-Long-Learning skill. The interpersonal skills and responsibility deal with capability in communication, team-working, leading, monitoring, decision making based on adequacy and reliable information or data and concerning the safety. The analytical and communication concerns capability in applying the mathematics or statistics as well as the computer as the problems tool, ability in using the media, technology or proper ways of communication (i.e. verbal, writing, sketching) and ability in computing or related engineering tool. In addition, the courses with laboratories or practice need to fulfill the psychomotor skill. The attempts to fulfill the domains of learning are represented in curriculum mapping. It is important that all the offered courses in each program of study should definitely fulfill the domains of learning with reasonably proportion thus, links among the courses are most necessary rather than the pre-requisition forms of studying plan.

2. Implementation and Problems

The programs of study or courses have to conform the concerned the TQF and requirements of the COE and emphasize the effective learning process and qualified graduates. Transitional links among the courses and integration of all related fields incorporation with the prerequisite and plan of study should corporate and support the mentioned objectives. However, implementing the learning process would have different problems according to the levels of student. The freshman year students would have little or no engineering knowledge and skill, the basic engineering courses in conjunction to the impressive motivation and teaching technique are necessary. On the other hand, learning process for the junior or senior students may need to recall the embedded capability prior to continue strengthening the knowledge or skill in preparation to be the professional engineers. Therefore, the common problems found in learning process of the freshman year and upper levels of student should be investigated and determined (Table 1) in order to support necessary plan or adjustment to the courses or programs of study.

Table 1 Common Problems or Incapability of the Students in Taking the Basic and Advanced Courses.

Categories	Causes and Problems
Desire, motivation and drive in engineering career	Freshman year students lack of experience to understand the engineering perspectives, need impressive introduction or lessons to start learning, to motivate and drive the desire to be a professional engineer.
Basic knowledge and skill	The students could not understand the context of the courses, lack of capability to recognize the problems, could not apply basic approaches for problem solving i.e. heuristics, rules of thumb, approximation, graphic and lack of qualified free-hand sketching to launch idea or concept.
Reasoning, analyzing or computing	The student lacks of conceptualized and systematic thinking so that they could not have capability to recognize or represent the problem, incapable to recall and apply the sound knowledge and skill to represent the problem domains, perform analyzing process or computing.
	The students could not perform represent the domains of problem i.e. apply the physical or mathematical models to analyze or compute the outputs or fail to interpret the results.

Table 1 Common Problems or Incapability of the Students in Taking the Basic and Advanced Courses (Continued).

Categories	Causes and Problems
Reasoning, analyzing or computing	The students misunderstand the design process or fail to perform the design because of lacking self practice or exercise.
	The students misunderstand or ignore the real practice i.e. regulations, standards or codes of practice as well as the "constructability" works.
	The students and fail to perform self-validation to eliminate the truncation errors in computing or calculating (which is considered minor errors) by various methods of (rough, random, backward calculation or apply alternative approach).
Recalling and apply the embedded knowledge and skill	The students could not perform conceptual and systematic thinking and they could not recall the embedded knowledge or skill to resolve the more complex problems (lack of capability in generalizing which use the learnt knowledge or skill to solve the unforeseen problems).
Self and Live-Long-Learning	The students could not understand the necessity to maintain self and Life-Long-Learning in relation to rapidly changes or progress in technology.
Design outputs	The student lacks of capability in conceptual and systematic thinking to understand or perform the inputs-process-outputs process of transferring the theoretical works to the real works). They could not adopt the case-based engineering to simplify the works or further reasonably adapt or modification.
	The students lack of generalization capability to recall the embedded knowledge and skill to the creation and productivity i.e. report, sketching or drawing, model or prototype and lack of communication skill for giving the explanation.

3. Methodology and Cases

This paper proposes the schematic process of building-strengthening the knowledge and skill of engineering students (Fig. 1), which consists of basic and advanced engineering course triangles with three layers each, placed in the opposite direction in the opposite direction. The upward triangle represents stages of motivating and learning through the built knowledge and skill of the students which would be accomplished by means of the basic courses e.g. engineering drawing, ethics, engineering mechanics and materials. The downward triangle represents the stages of recalling the embedded knowledge and skill in order to continue strengthening and exploring for applying in professional practice by means of the advanced courses.

In this paper, the basic course "Engineering Drawing" in conjunction with the advanced course "Building Design" are selected to illustrate the process of building and strengthening the embedded knowledge and skill for the civil engineering students. The former represents the basic engineering course deals with lettering, orthographic projection, orthographic drawing and pictorial drawings, dimensioning and tolerance, sections, auxiliary views and development, freehand sketches, detail and assembly drawings, basic computer - aided drawing. The latter represents the advanced engineering course deals with building regulations, architectural concept and design of building, form and structural systems, structural members, engineering systems in building, small to large scale building, high-rise building, Public building, Small to medium scale industrial factories, bridge structure, off shore and retaining structures.

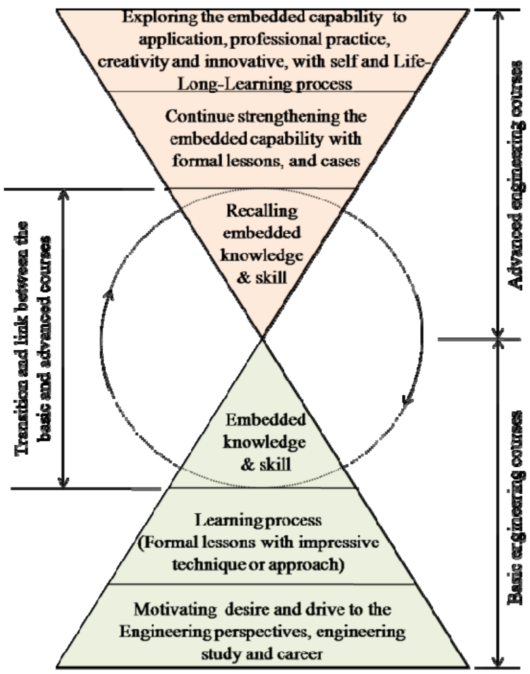


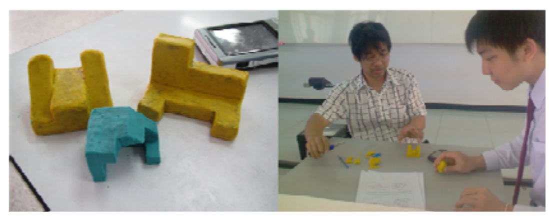
Fig. 1 Building-Strengthening the Knowledge and Skill Process for Engineering Students

The Engineering Drawing starts reviewing the history of engineering drawing i.e. timeline of ancient civilizations (Architect and structure), Egyptian first drawing instrument (Imhotep's instrument), famous icon language (Hieroglyphs), Roman technology (Arabic language and Roman numeral, architectures and structures), "Vitruvian man" (basic human dimension and distance zone) and hundred idealized designs by Leonardo da Vinci, golden ratio (Leonardo Fibonacci series), prototype of steam engine by Thomas Newcomen, Watt's engine, steam locomotive drawings by Robert Fulton, inventions of Thomas Edison, freehand sketch of Volkswagen by Ferdinand Porsche, drawings of the Wright brother airplanes. In addition, cases of classic drawings in Thailand are also included e.g. drawings of Khun Tan tunnel, Ananta samakhom throne hall, Sam Sen water supply plant, Don Muang airport. Following the motivation and drive, freehand sketch which is the simplest way to draft the imaginary idea is introduced, drawing instrument, lines, lettering, dimensioning and scaling are consecutively described and following with deliveries of the main contents. In addition, the stages of development and interrelation among the three approaches i.e. freehand sketching, manual drawing and computer-aid drawing are emphasized in order to realize that the students should have the sound basic knowledge and skill to perform the more complex tasks or assignments.

The students are required to create freehand sketch of idea and plan prior to exercise the detailed drawings which typically need the uses of proper instrument, standardized lines, format, scale and standardized lettering. Class attendance and interactive participation with lecturers are more important than the take-home assignments to ensure the achievement of communication skill. Common techniques of interactive teaching and validation are: dialoging, 3-D models with transparent glass or box (demonstration of parallel projection), computer simulation, quiz and post-test (Fig.2).

(a) Motivation and Drive

(b) Learning with Approaches and Technique



(c) Validation of Learning

Fig. 2 Illustrative Learning Process in the Basic Course

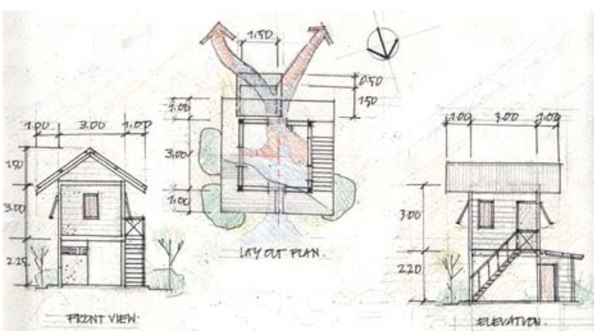
Even the teaching and learning process are slightly different from the past, the courses evaluations and feedbacks during semester 1/2009 through 1/2011 are satisfactory (Table 2). However, further observation, more significant quantitative measurements technique and correlation statistics between or among the basic and advanced courses would be the next phase of research.

Table 2 Selected Items of Course Statistics.

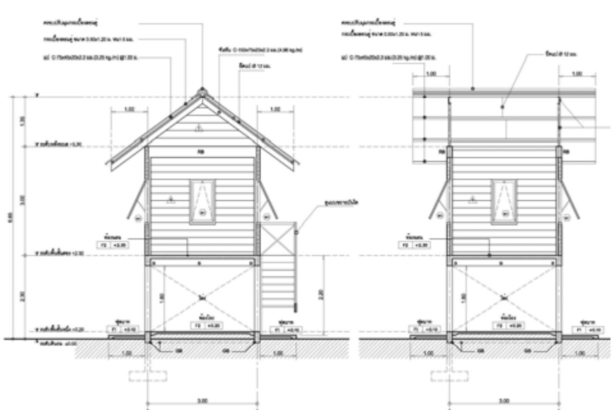
Item	Semester		
	1/2009	2/2009	1/2010
Enrolled student	327	307	288
Class average (GPA)	2.39	2.67	2.35
Class weighted scores : Motivation (10%) : Post-test (5%)	 4.25/10 2.25/5	 4.57/10 2.95/5	 6.17/10 3.95/5
Course evaluation	4.58	4.65	4.72

The illustrative advanced course starts with subjective pre-testing, the students are required to recall and integrate the embedded knowledge and skill they had learnt to recognize and represent the problems i.e. the problems start with needs of a structure (Space, form and function) and constraints (Land plot and budget), the architectural and engineering design must conform related building regulations, economics and green concept (Saving, safety, environment and sustainability) therefore field investigation would be necessary. Further, they are required to explore the conceptual and systematic thinking with the embedded knowledge and skill to find the optimum solution for the needs and constraints (Reasoning, rules of thumb, case-based, analytic) in forms of conceptual design sketch. Class activities and the outputs would be useful for the necessary adjustments of lessons and teaching plan. Problem based assignments, journal (Lecture notes), quiz, examination and post-test are used to monitor and validate the achievement of learning and the embedded capability. Following the completion of the course, the students should be able to prepare the completed detailed design and drawings of the constructability buildings (Fig.3).

(a) Need, Constraints and Field Investigation



(b) Sketch of Conceptual and Systematic Thinking



(c) Detailed Design and Drawings

Fig. 3 Illustrative Process in the Advanced Course

5. Conclusions and Recommendations

This paper presents the attempts in building and strengthening the embedded knowledge and skill of the engineering students to fulfill the requirements of both COE and TQF to achieve the qualified engineers for professional practice. The basic and advanced engineering courses form pre-requisite sequence of study plan and curriculum mapping need transitional links to ensure the achievement of all learning domains and the embedded capability. Various learning and teaching approaches and technique are needed depended on the context of the courses or the students.

It is recommended that transitional links and cross-validation among all the basic and advanced engineering courses should be planned in manner to help the more efficiently validation of the programs according to the TQF. More significant quantitative approach of evaluation the success of building and strengthening the embedded knowledge and skill of the engineering students should be determined and applied.

6. Acknowledgement

The authors would like to thanks to Dr. Jirapong Kasiwitamnuay, Department of Mechanical Engineering, Chulalongkorn University for kind permission of using the teaching materials in his Engineering Drawing Website (http://pioneer.netserv.chula.ac.th/%7Ekjirapon/index.html). Grateful thanks are due to Dr. Sumana siripattanakul, Dr. Thaveesak Vangpaisal and Miss Laong Palodom for valuable support and joining the authors to teach the course “Engineering Drawing”.

References

[1] American Society of Civil Engineers Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future, 2ndEds Committee on Academic Prerequisite for Professional Practice ASCE.

[2] Ministry of Education, Ministerial Rule B.E. 2550; Thai Qualification Framework

[3] The Ministry of Education Announcement B.E. 2553, Thai Qualification Framework – Engineering.

[4] BHOHHA S. History and Case-Based in Engineering Courses, 5th CEDT Proc. April 2007, pp 95-100.

[5] BHOKHA S. and SANGTIAN N. and PHANNIKUL A and SUBSOMBOON K, Value Added in Civil Engineering Design, 7th CEDT Proc. April 2009, pp 236-240.