Target Competency Indicators of Project Based Learning (PBL): Take Project Courses of Mechanical Engineering from Universities of Science and Technology in Taiwan as an Example

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Abstract

The study examines courses adopting a problem-based learning approach offered by departments of mechanical engineering in Taiwan's universities of science and technology, seeking to identify student learning outcomes and key competency indicators for courses of the type. Interviews and focus groups were administered to teachers of project courses. The results from the analytical hierarchy process showed 20 target competency indicators and four dimensions of learning outcomes specifically expertise, generic skills, teamwork skills, and attitude. The study found that expertise and attitude were more important than the other two dimensions, which was in line with the need of small and medium-sized machinery enterprises in Taiwan.

Keywords: Project-based learning (PBL), vocational education, technical education, mechanical engineering practice

Introduction

Education plays an extremely important role in developing knowledge, skills, and attitude that facilitate economic growth, and the goal of vocational education in general focuses on the development of employability skills. Creative thinking, innovation, communicating skills, teamwork skills, adaptability, and confidence are the fundamental qualities employers hope to find from their employees. Most of highly educated employees however lack such qualities. Indeed, global recessions have led to low employment and high unemployment since 2008. The Global Talent 2021 report by Oxford Economics predicted that by 2021, Taiwan would face serious shortages of senior managers and labor [1].

PBL is a systematic approach of teaching and learning, which prompts students to integrate and apply knowledge and skills to various learning activities through elaborately design tasks and complex but real problems [2]; it also offers more learning opportunities and facilitates more interaction [3]. A body of research on PBL [4] confirm its positive influence on learning outcomes. How to use this well-known teaching approach effectively under a real-world scenario, however, remains a challenge [5]. Competency indicators for courses in a PBL fashion must be discipline-specific and should be considered as references for course development, teaching evaluation, and learning strategies to enhance course effectiveness.

The current study seeks to establish competency indicators for courses with a PBL pedagogy in the field of mechanical engineering via examining project courses of departments of mechanical engineering in Taiwan's universities of science and technology. These indicators are expected to serve as references for project courses to improve teaching effectiveness and learning outcomes. Specifically, the study aims to explore the nature of PBL and to determine competency indicators and their weights in project courses taught in departments of mechanical engineering.

2. Literature review

2.1 Nature of Project Based Learning

PBL revolves around professional fields or issues in daily life, and it allows students to interact with their classmates and encourage them to employ scientific methods to solve problems together under the guidance of teachers. The philosophy of PBL can be interpreted in two ways as follows.

First, PBL is an instructional method. PBL can be used as a tool to encourage students to become independent learners [6]. It is a systematic teaching strategy that involves students in exploring complex but real problems and in learning activities promoting the integration of knowledge and skills. From the teacher's point of view, PBL entails plans, arrangements, and problem-solving in addition to performance, observation, and reporting of results [7]. Thus PBL shall follow a logical procedure to instruct student learning, including observing, comparing, deducing, case analyzing, and problem solving and it shall also involve various in-class and out-of-class teaching activities [8].

Second, PBL is a learning method. PBL is a student-oriented learning mode aiming at enhancing students' academic performances [9]. It requires learners to collect and analyze data in an interactive and cooperative way, and to develop the theme according to objectives. Students are supposed to solve problems they encounter during the course of product design, making, assembling, and testing, and their learning outcomes will be assessed [10]. Students in courses adopting a PBL approach are encouraged to work, discuss, and share views with their team members [11]. By doing this, learners become aware of various learning methods, strengthens the bonds, and recognize their own strengths and weaknesses. Also, PBL promote interaction and betters communicating skills [12].

In a word, PBL is of great value to both teachers and students. It a teaching pedagogy to teachers and a learning strategy to students. Through PBL, instructors may design their lessons plans according to the contents and characteristics of project courses, which helps students participate in activities. Their learning outcomes will be evaluated in terms of performance, project works, and reports. As for students, they are offered opportunities to develop a variety of skills in problem-solving, data collection, and data analysis, in addition to attitude.

2.2 Learning Outcome of PBL

The idea of PBL embraces the concept of "learning by doing" proposed by John Dewey. That is to say, students acquire knowledge and skills of different fields through different learning activities. The process also helps them establish self-confidence, and stimulates their motives [13]. Moreover, teachers employ PBL to customize and diversify learning so that learning is not confined to certain fields [14].

When PBL is used in engineering design courses, most students give positive feedbacks; thus, it helps to build confidence and to become be self-driven learners. Also, teachers' instruction and support during the process will further influence the outcome in a positive way [15]. Problem-solving and communicating skills can be strengthened through PBL if it is introduced into engineering courses [16]. PBL can equip students with abilities of critical thinking, creativity, collaboration, cross-cultural communication, computation, and career and learning self-reliance . It will also culture advanced thinking, innovative and critical thinking, cooperation, social networking, management skills, communicating skills, and problem-solving skills [17, 18].

3. Research Methodology

3.1 Research Design

This research was conducted in two stages. In the first stage, experts' opinions and suggestions about the set-up of competency indicators and the structure of professional competence were collected through interviews and focus group discussion. In the second stage, the Analytic Hierarchy Process (AHP) was employed to investigate and analyze experts' opinions about the weights and relative importance of the competency indicators.

3.2 Research Participants

The participants in the interview, focus discussion, and AHP were different individuals. Four experts accepted the interviews and they were from two different backgrounds. Three of them had experience teaching project courses in the field of engineering and the fourth participant was an expert from the industry of mechanic engineering.

Given colleges in Taiwan vary according to location and characteristics, and public schools are different from private ones, 10 college teachers from departments of mechanical engineering in public and private colleges from different parts of Taiwan were selected for the focus group discussion.

3.3 Research Tools

In the focus group, competency indicators for PBL and the structure of professional competence derived from the interviews and literature were discussed, reviewed, and modified.

AHP adopted a self-constructed structure of PBL competence after which was checked and confirmed by the focus group, a hierarchical poll with a focus on learning outcomes of PBL was developed for further examination and data analysis.

3.4 Data Analysis

The audio files from the interview were transcribed into texts and encoded to perform an encoding analysis. The contents included the four dimensions of PBL learning outcomes from the literature review. Choice Maker, an analysis software, was adopted to carry out the hierarchical analysis on the results of the hierarchical poll of PBL learning outcomes to obtain eigenvector and eigenvalue.

4.Results and Discussion

4.1 Result of analysis of interview data

On the basis of PBL's learning outcomes obtained from the previously stated methodology, the following were found: First, the dimension of communicating abilities extended to cover three factors of exchanging and coordinating, oral expressing and public speaking. Second, the dimension of executing abilities was widened to include six abilities of spotting and settling problems, gleaning, sorting and analyzing data, self-teaching, purchasing materials and tools, manufacturing and polishing, emulating (designing and crafting); third, to the dimension of team-working abilities, an indicator of learning mutual help was added. Last, the dimension of generic skills amplifies to contain four attitudes of being positive, proactive, positive thinking, and persistence.

4.2 Result Analysis of the Focus Group Discussion

After the focus group discussion and following an analysis of the categorization of abilities, the names, contents and the meaning of the dimensions, we modified the dimensions and increased the number of the competencies to twenty as follows:

Dimensions of expertise: meaning the expertise in mechanics necessary for completing tasks of project during the process of implementing practical projects. The abilities involved are mechanic designing, mechanic processing, mechatronic integration, information applying, purchasing of material and tools.

Dimension of generic skills: meaning widely required abilities regardless of the field during the process of implementing practical projects. The abilities involved are creative thinking, critical thinking, problem solving, knowledge integrating, public speaking and data collecting and analyzing.

Dimension of teamwork skills: meaning the teamwork abilities necessary for team members to collaborate during the process of implementing practical projects. The abilities involved are team-working, communicating and coordinating, mutual-help learning, and social networking.

Dimension of professional attitude: meaning the dedication necessary for team members to achieve targets of project tasks during the process of implementing practical projects. The competencies involved are being positive and proactive, self-teaching, persistence, confidence, and sense of accomplishment.

4.3 Result of analysis of hierarchical investigation

Fifteen copies of hierarchical polls were issued, and fourteen were retrieved, indicating a 93.33% retrieving rate. These were all responded completely, and found by consistency examination with C.R. values all under 0.1, meaning all the retrieved copies are valid, with validity rate at 100%.

The values of feature vectors were calculated to figure out relevant importance of the first level of dimensions in learning outcomes. The results, as shown in Table 1, indicate that professional attitude is the most important (with eigenvector at 0.3269), followed by expertise (with eigenvector at 0.3240).

Table 1 The learning outcome of the first level dimensions by AHP

Dimension	Eigenvector	Ranking
expertise	0.3240	2
generic skills	0.2357	3
teamwork skills	0.1134	4
professional attitude	0.3269	1

To know the relevant importance of the second dimension, and the relevance importance of all dimensions, apart from calculating its value of eigenvector, the results were further multiplied by the value of eigenvector of the dimensions of learning outcome to arrive at the value of weighted eigenvector. The results are shown in Table 2.

The weighted eigenvector of four dimensions of learning outcomes and twenty ability indexes were studied, combining with data analysis and comparing. It was discovered that being proactive was the most important factor while social networking ranked the lowest. The top ten vital factors of competencies were, in the order of importance: 1) Being proactive, 2) Mechanic designing, 3) Mechatronic technique, 4) Persistence, 5) Mechanic processing, 6) Problem solving, 7) Confidence, 8) Creative thinking, 9) Sense of accomplishment and 10) Self-teaching.

Indictor	Indicator Eigenvector	Hierarchy Eigenvector
mechanic designing	0.30	0.10
mechanic processing	0.22	0.07
mechatronic integrating	0.26	0.08
information applying	0.13	0.04
purchasing of material and tools	0.10	0.03
creative thinking	0.23	0.05
critical thinking	0.07	0.02
problem solving	0.30	0.07
knowledge integrating	0.16	0.04
public speaking	0.13	0.03
data collecting and analyzing.	0.12	0.03
team-working	0.26	0.03
communicating and coordinating	0.34	0.04
mutual- help learning	0.31	0.04
social networking	0.09	0.01
being positive and proactive	0.31	0.10
self-teaching	0.13	0.04
persistence	0.24	0.08
confidence	0.17	0.05
sense of accomplishment.	0.15	0.05

Table 2 The eigenvector and ranking generated of learning outcome dimensions by AHP

Therefore in this year, students need to take professional attitudes like being proactive, persistent and confident, and be equipped with expertise before launching their career and matching the talents needed by Taiwan mechanical industry which comprises mainly small- and medium firms. Although generic and teamwork skills can be acquired during practical projects, those competencies are not the goal of target design or the focus of teacher's concern. The results obtained from the AHP analysis in this study agrees with the opinions on the most important ability targets.

The researchers thus think that when teachers hope students will obtain expertise and professional attitude through the PBL, an approach widely adopted in the practical project courses, students will unite learning and doing, and complete their projects smoothly and punctually. Although other competencies like generic and teamwork skills are not emphasized for their value, students do acquire those competencies in the process of executing the projects.This study believes that universities of science and technology should optimize courses of practical projects and teaching as well as learning methods of PBL to help students integrate knowledge and skills they learn in the college, and equip them with vital competencies and employability through PBL's process, and meaningful practical projects that engage cooperation with the industry.

5. Conclusion and Suggestions

This study has great educational value and important implications in terms of PBL, an effective instruction and learning approach in its nature and contents. Teachers design appropriate lessons to guide students according to objectives of project courses. Learning outcomes are evaluated by students' performance, works, and reports. Project courses indeed offer students opportunities to develop problem-solving, data collection, data analysis skills as well as expertise and attitude.

The results obtained from the study can be used as references by teachers in planning, designing, teaching project courses as well as assessing the learning outcomes of their students. Also, the findings can help students develop their learning strategies such as course planning, technology study, and career development. However, since the field discussed in this study is mechanical engineering, the results may not be fully applicable to other disciplines and the relative importance of the dimensions and competency indicators may vary too. Thus it is suggested that further research should be conducted based on the current study to explore dimensions of learning outcomes and target competency indicators of each field. The results may provide crucial implications for pedagogy, course design, material development, and evaluation, facilitating the effectiveness of teaching and learning.

Given that project courses are considered as a manner to bridge the gap between practice and theory, students need to possess relevant knowledge and skills in the first place. The five target competency indicators of the expertise dimension listed in the study can help departments of mechanical engineering at universities of science and technology to refine their courses and contents so that students will acquire basic and important theoretical knowledge and core skills before moving on to project course. In this way, when students set their hands on the projects, they are prepared to acquire more extensive and complex expertise through real practice.

In a word, target competency indicators of PBL found in this study equal to certain core employability skills, suggesting project courses conducted in a PBL approach are of practical value, which helps students adapt to the real world and prepares them for future employment. For these reasons, it is suggested that PBL as a teaching and learning approach be introduced to and applied in not college higher education but also primary and middle education so that students can be cultured in a more realistic environment.

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