# AC 2010-424: A STUDY OF PROJECT-BASED STEM LEARNING IN TAIWAN

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# A Study of Project-Based STEM Learning for Senior High School Students in Taiwan


## Abstract

The purpose of the study was to investigate the effects of incorporating the Project-Based Learning (PBL) with STEM activity (Science, Technology, Engineering and Mathematics) for senior high school students. It attempted to explore the effects of the PBL on students' academic performance and performance of learning process.The project of "Cup Speaker" was designed for this study. There were 40 students from National Pingtung Girls Senior High School and 44 students from National Nei-Pu Agricultural-Industrial Senior Vocational High School in Taiwan. The competition of creativity design for the "Cup Speaker" was carried out for four weeks. The STEM activity was incorporated with PBL strategy and websites. In addition, the researcher played a role of tutor in this project to help solve students' problems. Content analysis was adopted to analyze students' projects and learning processes of STEM websites followed by questionnaire and interview to explore students' learning satisfaction. The major findings of the study were: 1. students from different educational systems demonstrate different characteristics of works; 2. DIY is the most critical design factor of STEM in PBL; 3. technology is discussed the most, whereas mathematics is discussed the least on the forum of the website; and 4. "teaching material design of STEM activity" is the most significant factor of students' learning satisfaction.


**Keywords**: STEM, Project-Based Learning (PBL),


## Research Background and Motives

In recent years, the U.S. has placed emphasis on the development of Science, Technology, Engineering and Mathematics (STEM), and such focus is related to the fundamental concept upon pragmatism education. Most Americans agree that educating students in the STEM education is very important to U.S. competitiveness and economic prosperity[1]. Marshall also mentioned that nations must transform STEM education and talent development to nurture a more blended generation of STEM talent, innovation and entrepreneurial leadership[2]. The goal of the U.S. is to be the leader of global technology. The K-12 Engineering Education Programs (KEEP) Seminar Series for high school juniors and seniors provide students with opportunities to observe research presentations by scientists and engineers in a wide array of specialties in order to understand how the STEM disciplines are integrated and to understand the possibilities for their future career paths[3]. In Taiwan, since the pressure

of high school and college entrance exams still exist, learning and instruction are still based on cognition. As to secondary education, with limited instructional hours, teachers can only briefly describe the teaching materials. Although the lecture-based instruction allows students to acquire knowledge, it cannot enhance their skills and abilities to apply the knowledge to problem-solving. There are few STEM programs in public K-12 schools even that teachers think STEM lessons are required and important[4].

Project-Based Learning (PBL) is a model that organizes learning with projects[5]. PBL is a systematic approach which allows students successfully to learn knowledge and skills from complicated issues and the planned tasks. Laffey defined that PBL places demands on learners and instructors that challenge the traditional practices and support structures of schools. Learning from doing complex, challenging, and authentic projects requires resourcefulness and planning, new forms of knowledge representation in school, expanded mechanisms for collaboration and communication, and support for reflection and authentic assessment[6]. PBL incorporates the content of different subjects[7, 8], and allows the students to pose the questions and investigate various issues in real situations. Since PBL involves the teaching materials of different subjects, students would be able to absorb knowledge completely. Also, the integration of different subjects in PBL meets the principle of integrated curriculum of STEM. Thus, PBL upon technology learning can be the best strategy to implement STEM curriculum. This study intends to develop STEM in PBL in order to investigate the effects of learning as well as learning satisfaction in Taiwan.

## Research Purposes

The research purposes are:

1. To develop the instructional activities and teaching materials of STEM in PBL.
2. To evaluate students' learning satisfaction of STEM in PBL.
3. To demonstrate the characteristics of the students' works in different educational systems.

## Activity Design and Implementation

### Activity Design of PBL

The "Cup Speaker" activity was based on STEM as the content and PBL was the instructional and learning approach. The activity emphasized on "learning by doing"

and demonstrated the scientific theories and knowledge learned in the past. It also enhanced the students' technology literacy. The activity design was based on the guidebook of Project-Based Learning (translated by International Education and Resource Network, 2007). In this research, five major planning processes of PBL were developed, including setting the goals first then planning, designing "guided questions", making evaluation plans, organizing the project, and process management.

The contents of the STEM project include:

- Name of the activity: Cup Speaker;
- Participants: Students of senior high schools and vocational schools;
- Length of Instruction: Four weeks;
- Web platform: STEM platform;
- Contents of STEM in the Cup Speaker activity (as shown in Table 1).

Table 1 Contents of STEM in the Cup Speaker Activity

| Science | Technology | Engineering | Mathematics |
|---|---|---|---|
| S1 Vocal phenomenon | T1 Selection of materials | E1 Problem-solving | M1 Exponent and logarithm |
| S2 Sound wave principle | T2 Use of tools | E2 Creative thinking | M2 Calculation of sound pressure(dB) |
| S3 Principle of electricity and magnetism | T3 Manufacturing | E3 Modeling design | |
| S4 Fleming's right-hand left-hand rules | T4 Development of speakers | E4 Structure design | |
| | T5 Structure and principle of speakers | E5 Graph reading and making | |
| | T6 Correct operation of the speakers | E6 Speaker engineering and life | |
| | T7 Test, adjustment and modification | | |

**Activity Process**

The learners' PBL learning process contains five stages, including preparation, implementation, presentation, evaluation, and modification and four-phased tasks on the website of STEM. Each task involved several cycles of the PBL process. The researchers managed the website of STEM, and assisted the students with the

accomplishment of cup speakers (as shown in Figure 1). In addition, students participated in groups for the PBL Cup Speaker activity with the same procedures, materials, rules, quality of performance, and evaluations.

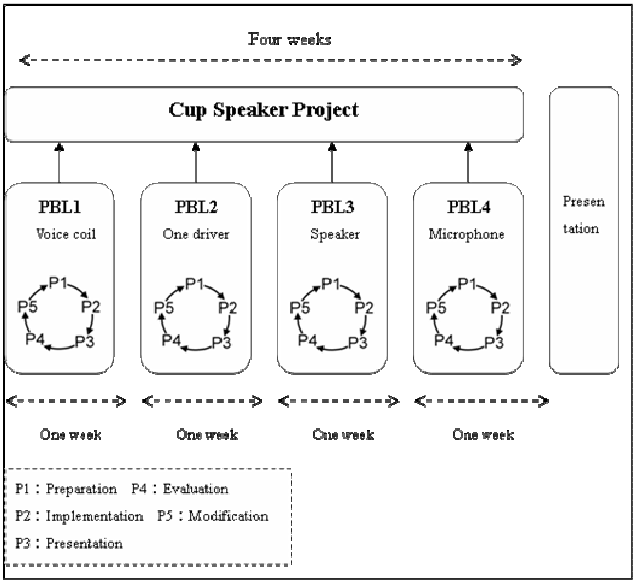


Figure 1 Implementation of the PBL Cup Speaker Activity

## Evaluation

The contents of evaluation on the activity include presentation of project report, test of efficacy of works, and on-line interaction (as shown in Table 2).

Table 2 Contents of Evaluation

| Content of evaluation | Criteria of evaluation | Approach of evaluation | Type of evaluation |
|---|---|---|---|
| Presentation of project report | Presentation of design of works<br>Oral report<br>Written report | Presentation of works<br>Performance of works<br>Evaluation on report | Summative evaluation |
| Test of efficacy of works | Test of the efficacy of the works | Evaluation on practice | Summative evaluation |
| On-line interaction | Files of learning process<br>Frequency of on-line interaction | Evaluation on files<br>Group observation | Formative evaluation |

## Subjects

The subjects were a total of 84 high school students, 40 students were from National Pingtung Girls Senior High School and 44 students were from National Nei-Pu Agricultural-Industrial Senior Vocational High School in 2008.

## Data Analysis and Discussions

### Evaluation of the Works

The featured works were selected from 21 works of two schools (as shown in Table 3). With regard to the features of the works, senior high school participants showed more creative and decorated, whereas the vocational school students were better at manufacturing skills.

Table 3 Featured works

| | | |
|---|---|---|
| National Pingtung Girls Senior High School | | |
| National Nei-Pu Agricultural-Industrial Senior Vocational High School | | |

### Analysis on the Factors of Students' Works

The creativity shown in the works of different groups was surprising. Some of the students' works could not be evaluated directly from the appearance and the researcher

recognized the students' contribution and originality in the internal design and descriptions of the works. The students were interviewed about their key factors of design. The following critical factors were found in the study:

- Unexpected findings from Do it yourself (DIY) process
- Disassembling experience
- Consulting the experts and masters
- Experiments
- Books and internet information
- Prior knowledge and ability
- Investigation of the products in the market

Most of interviewees indicated that DIY was the most critical design factor for STEM in PBL, the next important factors were books and internet information.

**Frequency Analysis of the Contents of STEM**:

The contents of forum on the website of STEM were analyzed as shown in Table 4. According to the data of the forum of STEM website, the most frequent discussed was Technology (T); next was Science (S); and Mathematics (M) was the least discussed by students. The students of the two schools obtained similar results.

Table 4 Stem content frequency analysis

| Schools | Science | Technology | Engineering | Mathematics | Total |
|---|---|---|---|---|---|
| National Pingtung Girls Senior High School | 268 times<br>26% | 550 times<br>53% | 170 times<br>17% | 42 times<br>4% | 1030 times<br>100% |
| National Nei-Pu Agricultural-Industrial Senior Vocational High School | 66 times<br>31% | 105 times<br>49% | 27 times<br>13% | 15 times<br>7% | 213 times<br>100% |

**Analysis of Learning Satisfaction of the STEM Activity**

At the end of the STEM activity, questionnaire survey was employed to investigate students' learning satisfaction of the activity. The contents include STEM learning

attitude, teaching material design of the STEM activity, PBL strategy and contents of STEM related concepts (as shown in Table 5). The mean scores of the four domains are around 4.0, indicating the students highly agree with the contents of domains on a 5-point scale. Especially, students are mostly satisfied with "teaching material design of STEM activity" and least satisfied with "Contents of STEM related concepts."

Table 5 Analysis of learning satisfaction

| Construct | Mean | SD | Items | Mean per Item | Rank |
|---|---|---|---|---|---|
| STEM Learning Attitude | 24.37 | 3.77 | 6 | 4.06 | 2 |
| Teaching Material Design of the STEM Activity | 41.58 | 5.89 | 10 | 4.16 | 1 |
| PBL Strategy | 32.37 | 4.76 | 8 | 4.05 | 3 |
| Contents of STEM Related Concepts | 75.58 | 11.45 | 19 | 3.98 | 4 |

**Conclusion**

According to the findings of the data analysis and discussions, the conclusion and suggestions are presented as follows:

1. Students from different educational systems have the difference of technology capacity and characteristics in works: In terms of the features of the works, senior high school students are more creative, whereas the vocational high school students are much good at manufacturing skills and sound effect. The accomplishment of both groups of students in two schools is significant, and the activity results in various originality and characteristics. Senior high school students are more creative in design, whereas students in vocational high school tend to be able to improve and reconstruct the prototype more.
2. DIY is the most critical design factor of STEM: The decision-making factors of the design include unexpected findings from the DIY process; disassembling experience; consulting the experts and masters; experiment, books and online information; prior knowledge and ability and investigation of the products in the market. DIY is the most significant one. Thus, it is important for teachers to provide students DIY activities.
3. With regard to the forum, technology is discussed the most; whereas mathematics is discussed the least due to the STEM activity is the DIY of technological product oriented. After repetitive experiments, the students tend to discuss the issues related to technology instead of mathematics because the students' prior

competence and mathematics is only applied in the test stage.

4. In terms of learning satisfaction, the "teaching material design of STEM activity" is the most significant among all the satisfaction factors. Regarding the satisfaction with the constructs of STEM, Technology is the most significant and Mathematics is the least significant.

## Suggestions

1. Improvement of the content distribution of in STEM activity: When designing the activity, it is suggested to properly distribute the contents of STEM in the learning process.
2. Provide DIY-oriented STEM activities: Students are mostly satisfied with the DIY activity. Learning by thinking can trigger the students' learning motives the most. Thus, teachers should provide student-centered DIY activities combining with their life experiences and social issues.
3. STEM activity can be implemented with PBL: Technology subject can be the best meet the PBL. In addition, STEM activity upon technology and DIY can complement PBL perfectly. Thus, PBL should be incorporated with STEM activities.

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