The Integration of Project-Based Teaching and Learning to Enhance Knowledge and Creative Thinking Skills for Students in Science-Based Technology Demonstration Classes, Thailand

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Abstract
The aims of this research were 1) The integration of project-based learning to enhance knowledge and creative thinking skills; 2) Comparative assessment of students' learning progress through the utilization of project-based learning; 3) Examination of the capacity for creative output via project-based endeavors; and 4) Student satisfaction regarding project-centered learning management. The study involves 14 students enrolled in Pre-Engineering curriculum. The instruments utilized in this study encompass the instructional activity arrangement plan, assessments measuring learning and creative output capabilities, and satisfaction surveys. Statistical employed comprise mean values, standard deviations, and independent paired t-tests.
The study results reveal that:
1. The project-based learning activities led to significant gains in knowledge, understanding, and learning skills. Students were able to apply their learning collaboratively and bridge existing knowledge with new insights. Additionally, they demonstrated the ability to develop their own projects, evaluate group outcomes, and take pride in their achievements. The overall average value for this aspect was 3.90.
2. The statistical analysis revealed a significant improvement in post-learning progress compared to pre-learning at a significance level of 0.01.
3. The ability to create innovative works through collaborative project-based learning across various activities showed an overall increase. This was assessed based on four aspects: Ability, Creative Ideation, Application of Ideas and Knowledge, and Appreciation. The overall average value for this aspect was 3.59.
4. Students expressed high satisfaction towards project-based learning, both in terms of learning activity organization and the educational benefits. The overall average value for this aspect was 4.26.

Keywords: Integrated Teaching and Learning, Creative Thinking Skills via Project-Based Approach, Science and Technology Classroom Demonstration

Introduction

The Technology Foundation Science Laboratory Classroom under the supervision of the University (TU) represents an extension of collaborative efforts from a pilot program in vocational technology education management at the technical college level (Collaborative Learning Program between Lanna Rajamangala University of Technology and San Kamphaeng Technical College). This initiative transpired between the academic years 2018-2020 in Diploma of Mechatronic and a collaborative educational prototype development project based on technology has been jointly undertaken by Lanna Rajamangala University of Technology Lanna and the Office of the National Science, Technology and Innovation Policy Commission, encompassing an educational framework for a 3-year vocational certificate and/or a 2-year advanced vocational certificate, followed by a 4-year bachelor's degree. The jointly organized educational programs adhere to the central vocational certificate curriculum set by the Office of Vocational Education Commission. The educational approach follows the format of a continuous education system, encompassing the foundation vocational certificate level, higher vocational certificate level, and subsequently the bachelor's degree level. This framework is modeled after the Advanced Technology Preparatory School, Technical College, and Institute of Technology of Lanna Rajamangala University of Technology. This university-affiliated institution serves as a regular school and designates master's degree students as mentor teachers, who are responsible for student well-being, learning support, and project advising for vocational certificate students. Moreover, university and college faculty participate in teaching and knowledge dissemination in collaboration with industry professionals. This program also focuses on imparting fundamental practical skills to meet industrial standards. The curriculum is emphasis on integrating academic and practical knowledge which derived from industrial context that aims to cultivate student attributes congruent with pursuing further studies in advanced vocational technology education. From the reason above, graduates can pursue two educational aspects: 1) The productivity students are able to study in advanced vocational certificate program. 2) The students who have aptitude in ideation, design, and product development will be cultivated into innovative professionals.

The Office of National Economics and Social Development (2016) emphasizes that both the present society and the future are significantly influenced by science, as science pertains to the daily lives and professions of individuals. Various tools, products, and conveniences utilized for living and working which are the combination of scientific knowledge, creative thinking and other disciplines. Scientific knowledge provides human cognitive development, including causal and creative thinking, analytical thinking, critical evaluation, and skills crucial for systematic inquiry and comprehensive problem-solving. Moreover, the development of the labor market skills and life skills in the 21st century which is essential for individuals of all age groups. For instance, children, adolescents, and young adults need to have skills such as systemic analytical thinking and creative thinking, while also emphasizing preparedness for the skill development in various domains, work skills, and the ability for entering in the labor market, this is accordance with the ideas of Pacharee, Nakphong, Siriwan, Wanichawattanaworachai, Rujiraporn, Rammasiri, and Montchai Pongsakornnaruewong (2021). In the context of science education, it is imperative to foster the following qualities among the modern Thais: 1) effective communication skills, analytical thinking, problem-solving abilities, and creative thinking; 2) self-learning propensity, an inclination towards reading, and a lifelong commitment to learning, as demonstrated by the findings of Rewadee, Namthongdee (2015), which indicated that the labor requirements of employers and organizations with a transformation in 2014 by the organization for economic

cooperation and development (OECD) analysis presented that the most anticipated skills for employers in the new organizational era are analytical and creative thinking skills.

Based on the evaluation of the assessment of students' skills at the international level conducted by the Organization for Economic Cooperation and Development (OECD: PISA, 2018), it is presented that the evaluation of the aptitude of 15-year-old students in terms of knowledge application and essential competencies for real-life challenges, consisting of three aspects: reading, mathematics, and science. This assessment emphasizes analytical thinking and interpretation. The PISA 2020 assessment reported the performance of Thailand in the international arena, ranking 68th in reading, 59th in mathematics, and 55th in science in 2018. In the Asian-Pacific region, Thailand only surpassed Indonesia and the Philippines, with around 60% of students scoring below the minimum of proficiency level in reading, 53% scoring below the basic proficiency level in mathematics, and 44% scoring below the baseline proficiency level in science. This result indicates a declining proficiency in reading and also decrease continuously in scores of both mathematics and science for Thai students. This correlates with resource allocation and education development investment in various Thai schools.

From the problems mentioned above, the researchers intend to implement for problem resolving by organizing learning activities using project-based learning that integrate the disciplines of science, technology, engineering, and mathematics (STEM). These four competencies are essential for children and youth in contemporary and future societies as they foster experiential learning and practical engagement, nurturing analytical and creative thinking for problem-solving. This approach diverges from traditional methods that emphasize on memorization rather than practical application. Learning through project-based approaches encourages students to engage in hands-on experimentation and emphasizes the development of creative and analytical thinking skills. This correspond with the perspective of Israsena Na Ayudhya (2018), who proposes that design thinking must be practiced to truly understand. The main goal is to focus on fostering an understanding of design thinking through experiential learning, comparing outcomes derived from employing different tools or methods.

Then, summarized the content including the actual working method and illustrative examples. The purpose of organizing learning through project-based approaches is to enhance thinking and learning processes via practical engagement, instilling an appreciation of science, technology, engineering, and mathematics (STEM) education, and recognizing their applicability in daily life, as presented by Porntip Siripattrachai (2013). This approach characterized by project-based learning that is not only emphasized on content memorization of scientific and mathematical but also to understand the theories or laws via practical implementation with skill development in critical thinking, questioning, problem-solving, information retrieval, and analysis of discovered findings. Furthermore, students have the opportunities for problem analysis and innovation design for problem solving. Students are also recognize their weaknesses or limitations which this process enables them to successfully achieve their objectives and facilitates effective communication. It reflects their progress and accomplishments that demonstrated via the presentations and their contributions to enhancing problem-solving processes in subsequent endeavors.

From the circumstances and reasons outlined above, the research team aims to develop teaching and learning methodologies to enhance creative thinking skills via project-based learning for first-year preparatory engineering students at Rajamangala University of

Technology Lanna, Chiang Rai. This research focus on students' ability to create and develop knowledge via hands-on practice rather than content memorization. Moreover, students are encouraged to apply the knowledge in their daily lives with Re-Skilling, Up-Skilling for technological advancements and the changing era that leads to a transformative learning process which prepare the students for industry labor market.

Research Objectives

1. To integrate teaching and learning for enhancing knowledge and creative thinking skills via project-based learning.
2. To compare the progress of student learning outcomes via project-based learning.
3. To assess creative ability via the organization of learning activities based on projects.
4. To investigate student satisfaction to project-based learning.

Research Framework

The study investigates the creative capabilities within the framework of project-based learning for students of the vocational certificate program in engineering preparation. The relationships between independent and dependent variables are depicted in the following Figure 1.

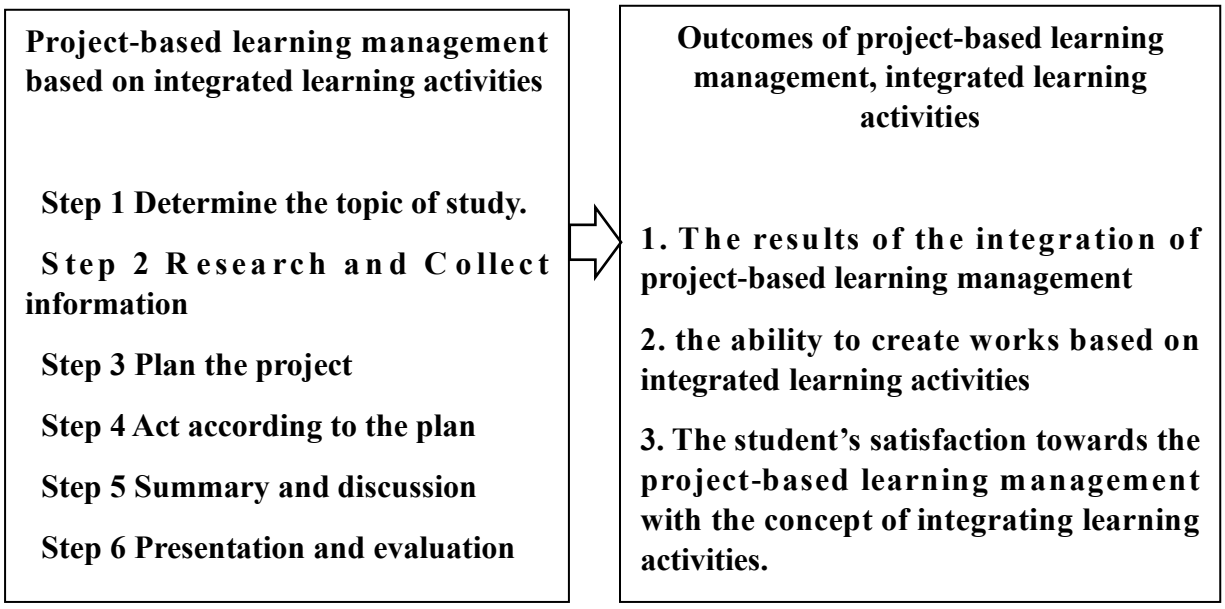

Figure 1: Depicting the relationship between independent and dependent variables

Benefits Derived From the Research

1. The learning outcomes which create the collaborative learning between instructors and students by stimulating the students' self-learning.
2. The study enables students to transfer knowledge to new experiences.
3. The research generates learning for developmental outputs through systematic and continuous thinking and analysis.
4. The study provides experiential learning via the scientific methodological learning process.
5. The research engenders effective learning via students' collaborative work that achieved by analyzing, interpreting, and accepting the perspectives of others.

Research Methodology

This research employs a combination of research methods and pre-experimental research design in the form of the One-Group Pretest-Posttest Design, and quantitative research. The aim is to integrate learning and enhance creative thinking and knowledge using project-based learning, it also figures out the satisfaction to learning activities involving project-based learning.

Population

The population consists of 14 students enrolled in the first semester of the vocational certificate program in engineering preparation for the academic year 2023.

Research Instruments

The research instruments for data collection are as follows:

1. Five learning activities integrated with the project-based learning which are:
   1.1 Ice Cream Stick Bridge
   1.2 Robotic Arm
   1.3 MBOT
   1.4 Application of Robotics and Automation Systems in CNC Machining
   1.5 Controlling Light via Smartphone, which serves as extracurricular activities as curriculum supplementing. The instructors have less role in guidance while assign more roles for the students, as shown in Figure 2.
2. Assessment questionnaire for measuring the level of creative abilities via project-based learning activities.
3. Progress assessment test for measuring learning progress via project-based learning activities.
4. Satisfaction survey questionnaire for measuring student satisfaction with learning activities that integrate project-based learning with learning integration concepts.

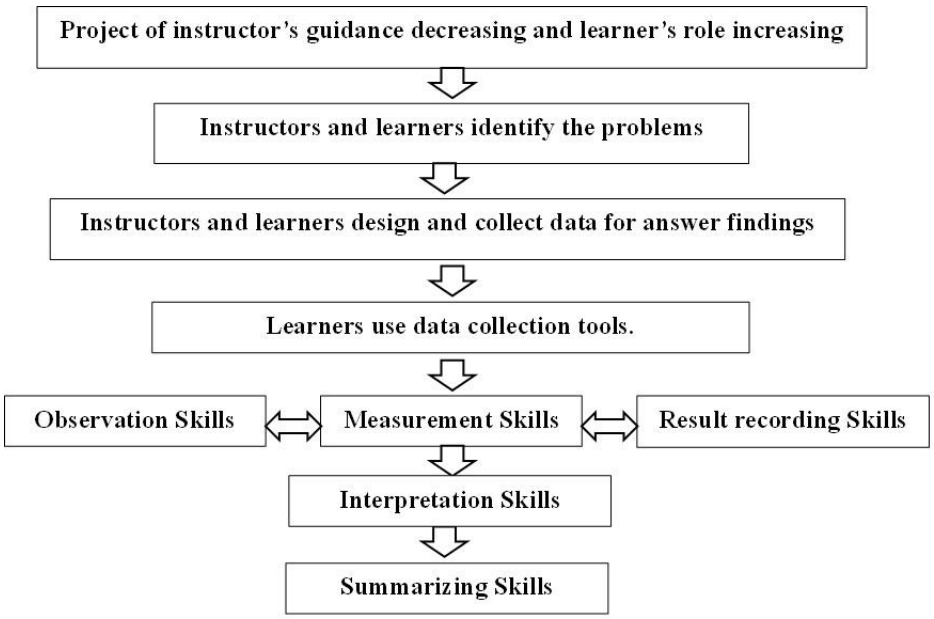

Figure 2: Project-based learning approach decreasing, Student's Role increasing

Steps for Developing Research Instruments

1. Literature Review and Research Exploration: Conduct a review of relevant literature, documents, and research related to organizing learning activities using project-based learning and integrating learning integration concepts. This is used for creative output and the evaluation process.

2. Development of Learning Activity Plan: Develop a learning activity plan by using project-based learning with learning integration concepts. This plan comprises of 24 class sessions.

3. Development of Creative Abilities Measurement Instrument: Design a measurement instrument for creative abilities based on learning activities that integrate project-based learning and learning integration concepts. This measurement assesses creative output across four aspects: 1) Project Execution Skills, 2) Innovative and Creative Thinking, 3) Application of Concepts and Knowledge in Relevant Sciences, and 4) Appreciation and Pride for individual and Group Achievements. This measurement employs a 5-point Likert scale, including "Very High," "High," "Moderate," "Low," and "Very Low."

4. Creation of Learning Outcome Assessment Test: Create a pre-test and post-test assessment test for learning outcomes of the organized learning activities using project-based learning. This multiple-choice test consists of 30 questions. Scoring criteria are set as follows: 1 point for a correct answer and 0 points for an incorrect answer.

5. Development of Satisfaction Survey Questionnaire: Develop a questionnaire to measure student satisfaction with the learning activities based on project-based learning used in this research. The researcher designs a closed-ended questionnaire using a 5-level evaluation scale:
   5: Very Satisfied
   4: Satisfied
   3: Moderately Satisfied
   2: Less Satisfied
   1: Not Satisfied

For the interpretation of the satisfaction score meaning regarding student satisfaction with learning activities based on project-based learning, the scores are interpreted as follows:

4.50 – 5.00: Very Satisfied
3.50 – 4.49: Satisfied
2.50 – 3.49: Moderately Satisfied
1.50 – 2.49: Somewhat Satisfied
1.00 – 1.49: Not Satisfied

Quality Verification of Research Instruments

Research instruments comprising diverse data collection in this study. These instruments spanned the spectrum of learning activity organization utilizing project-based learning as a foundation. These instruments were:

1. A measure of integrative creative thinking skills in project execution.
2. A measure of creative output abilities.

3. A pre- and post-test assessment of learning outcomes based on project-based learning.
4. A satisfaction questionnaire regarding the learning activities for project-based learning.

The verification process involved three specialized experts: 1) innovation and invention development, 2) content and learning activity organization, and 3) assessment and educational evaluation. This panel of experts assessed the content validity and completeness of the instruments. The instruments' appropriateness was established by determining the Index of Congruence (IOC) falling between 0.65 and 1.00, alongside determining the level of difficulty ranging from 0.20 to 0.80 and the discrimination power more than 0.20. Furthermore, the instruments' reliability was established using the Cronbach's Alpha Coefficient, resulting in a reliability of 0.89.

These research instruments were tested with a non-sample group of 20 students from the Professional Certificate in Engineering Preparation Course under the Education Equitable Fund (EEF). The data collected from this preliminary testing was refined based on expert feedback and adjustments, culminating in the development of an authentic research instrument. This refined instrument will be employed with the actual target group.

Data Collection

1. Pre-experiment Stage: During this stage, the research team prepared various aspects, including:

1.1 Creation of research instruments.

1.2 Conducting orientation to introduce the learning approach based on project-based learning.

1.3 Administering a pre-test assessment of learning outcomes before implementing the learning activities, involving 5 activities with 30 multiple-choice questions to measure fundamental knowledge.

2. Experiment Stage: The research team implemented the learning activity plan utilizing project-based learning over 12 weeks, with two 60-minute sessions per week, totaling 24 sessions, for the target group of students.

3. Post-Experiment:

3.1 Post-Experiment Data Collection:

Post-experiment data was collected by using a post-test assessment of learning outcomes that related to learning activities of project-based learning. The assessment included 5 learning activities with 30 multiple-choice questions. Then, the test results were analyzed, and the differences in scores before and after the experiment were calculated.

3.2 Student Satisfaction Questionnaire:

Students were asked to complete a satisfaction questionnaire regarding their experience with the learning activities based on project-based learning. This questionnaire was used for research data analysis.

Research Data Analysis

The process of analyzing research data includes the following steps:

1. Analyzing Learning Outcomes:

Data analysis was conducted to study learning outcomes based on learning activities utilizing project-based learning. Pre- and post-test assessments were performed, and the results were used to calculate means, standard deviations, and a dependent samples t-test.

2. Analyzing Creative Abilities and Integration:

Data analysis was conducted to assess creative abilities and integration in accordance with the learning activity organization approach based on project-based learning. This analysis was conducted based on the mean and standard deviation of the results obtained from learning activities.

3. Analyzing Student Satisfaction:

Data analysis was carried out to measure student satisfaction with the learning activities organized using project-based learning. This involved calculating the mean and standard deviation of the results obtained from the satisfaction questionnaire.

Research Results

1. Integration of Teaching and Learning

The study focused on enhancing knowledge, creative thinking skills, and practical abilities via learning activities based on project-based learning. Topics included wooden bridge construction, ice cream making, robotic arms (MBOT), applying robotics, and automated systems in Computer Numerical Control (CNC) and remote control of lighting. The results indicated that students possessed knowledge, understanding, and learning skills that could be applied and transferred, facilitating the integration of prior and new knowledge and experience. See Table 1 for details.

Items	**integrated learning ability**	**μ**	**σ**	**level learning progress**
1	Cognitive	3.42	0.58	moderate
2	Thinking and analytical skills	3.60	0.55	high
3	Operational and integration skills	3.78	0.50	high
4	Communication skills	3.90	0.44	high
5	Applying and knowledge and practice linking	3.80	0.47	high
Average all aspects		**3.90**	**0.94**	**high**

Table 1: Integration of teaching and learning to promote knowledge creativity and work skills according to learning activities

2. Comparative Learning Outcomes

Comparative analysis of student learning outcomes was conducted by employing project-based learning in combination with various learning activities, such as wooden bridge construction, ice cream making, robotic arms (MBOT), applying robotics, automated systems in CNC, and remote control of lighting. Statistical analysis showed significant improvement in learning outcomes at a significance level of .01. Refer to Table 2 for specifics.

Learning outcomes	**No. of students**	**Total score**	**μ**	**σ**	**t**	**p**
Pretest	14	30	15.50	2.17	13.00	.00
Posttest	14	30	26.78	1.92		

$\rho \leq .01$

Table 2: Comparison of student learning outcomes using project-based learning management

3. Creative Abilities Enhancement

The enhancement of creative abilities via project-based learning integrated with learning concepts. The topics are wooden bridge construction, ice cream making, robotic arms (MBOT), applying robotics, automated systems in CNC, and remote control of lighting, was evaluated in four aspects: 1) project execution skills, 2) creative thinking, 3) application of ideas and knowledge in related disciplines, and 4) recognition and pride in group and individual accomplishments. Results showed overall improvement in creative abilities in all dimensions. See Table 3 for details.

The ability of creative learning activities	**Assessment result**		**Progress difference μ**	**Skill level**
	pretest μ	**posttest μ**		
1. The ability to do projects	1.14	3.64	2.50	progressive
2. Creativity	1.50	3.57	2.07	progressive
3. Applying concepts and knowledge to relevant studies	1.21	3.21	2.00	progressive
4. Appreciation and pride of group and individual work	1.50	3.93	2.43	progressive
Average of all aspects	**1.33**	**3.59**	**2.25**	**progressive**

Table 3: Creative abilities using project-based learning management

4. Student Satisfaction

Student satisfaction regarding learning activity organization and perceived benefits of project-based learning was found to be high overall. This satisfaction encompassed both the learning activity structure and the benefits derived from the learning process. Refer to Table 4 for more information.

Items	Assessment Items	μ	σ	Level satisfaction
1	Learning activities	**4.13**	**0.47**	high
2	Benefits of learning management	**4.40**	**0.54**	high
Total average		**4.26**	**0.46**	high

Table 4: Student satisfaction towards project-based learning management

Conclusion

The usage of project-based learning as a foundation stimulates learners' potentials in knowledge acquisition, critical thinking, collaborative teamwork, and practical skills development. This approach involves engaging learners in scientific method to develop knowledge, thinking processes, and effective teamwork skills, leading to the creation of high-quality outcomes. This process also entails systematic self-monitoring and evaluation of progress at both individual and group levels. Therefore, teaching via project-based learning encourages observation, questioning, hypothesis formulation, and self-directed knowledge seeking, enabling students to answer their own inquiries, consolidate their learning outcomes, and comprehend their discoveries.

Project-based teaching methods can be integrated within or beyond regular class hours, adaptable to both individual and group settings. If aligned with specific subjects or content, it's referred to as a subject-based project, such as projects in Science or Mathematics. This is the concept of Nattaya Sareeto (2022), proposing that project-based learning, which involves experiential learning through investigation, empowers students to explore, leading to holistic solutions. This approach encourages systematic problem-solving, planning, and various levels of thinking, all facilitated by teachers who inspire, guide, and closely advise students throughout the learning process – from topic selection, data gathering, project planning, execution, to application.

Project-based teaching helps develop learners in terms of knowledge and attributes by involving them in activities that entail investigation, problem-solving, and real-world application of knowledge. This cultivates creative thinking and continuous development. Learners engage in genuine pursuits driven by their interests and aptitudes, leading to innovative outcomes derived from their learning experiences. Furthermore, they bridge learning experiences to novel creations and experiences, fostering personal pride and value recognition in their work. This aligns with the views of Pakawat Kwankaew et al. (2016), suggesting that project-based learning nurtures creativity and encourages learners to innovate, connecting learning to new experiences and creations.

Recommendations for Future Research

1. Research should focus on establishing a comprehensive link between various fields of knowledge through continuous interdisciplinary integration.
2. Short-term professional development courses centered based on project-based learning should be designed for all educational levels to cultivate teamwork, skills, thinking processes, and collaborative work.
3. Further studies should investigate the implementation of project-based learning in different subjects, enhancing analytical and critical thinking skills.
4. Research should focus on developing teaching methodologies that emphasize practical application across all levels and disciplines within universities.

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