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Enhancing Innovation Ability Through Design Thinking and Project-Based Learning: A Study of Second-Year Students at Sanming University

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Abstract

Background and Aims: With the continuous deepening of China's basic education reform, higher requirements have been imposed on students' innovation ability. As universities that aim to cultivate students' innovation ability, due to the limitations of traditional teaching models, they have been unable to meet the demands for cultivating innovation ability. This study aims to explore the effectiveness of the Design Thinking with Project-Based Learning in enhancing the innovation ability of second-year students at Sanming University, and to evaluate whether this intervention measure can help students reach the 70% passing standard.

Methodology: This study involved a sample of 30 second-year students, selected through cluster random sampling, from Sanming University in Sanming City, Fujian Province, China. The research employed the following instruments: The research instruments were 1) lesson plans were at a high level of appropriateness (M=4.40, SD=0.54), 2) an innovation ability test with a reliability of 0.88, and 3) a students' satisfaction questionnaire with a reliability of 0.95. The data were analyzed by using mean, standard deviation, t-test for dependent samples, and t-test for one sample. The qualitative data were analyzed using content analysis. There are 7 lesson plans (3 hours for 1 lesson plan: Total is 21 hours).

Results: The findings indicated that: 1) students' innovation ability consisted of 5 key aspects: Creative Thinking, Problem Identification, Idea Generation, Practical Application and Reflective Improvement, and 2) the results of implementation of comprehensive Foundation of Innovation Course indicated that (1) after learning through this course, the students' Innovation ability (M=39.90, SD=3.15) with the statistical significance of .01 level, (2) the students' satisfaction toward Foundation of Innovation Course based on Design Thinking combined with Project-Based Learning was higher than the criterion of 70%(M=4.64, SD=0.67,t_{29}=7.76, p<.01, indicating a large effect size.) with the statistical significance of .01 level.

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Conclusion: This study contributes to curriculum innovation by showing how the Foundation of Innovation Course can enhance students' innovation abilities.

Keywords: Foundation of Innovation Course; Design Thinking; Project-Based Learning; Innovation Ability

Introduction

In recent years, the Chinese government has placed strong emphasis on innovation-driven development and education reform. The "Outline of the National Medium- and Long-Term Education Reform and Development Plan (2010–2020)" clearly articulated that cultivating innovative talents is a cornerstone of national development (State Council of China, 2010). The "National Innovation-Driven Development Strategy" further highlighted the need to improve higher education's role in fostering creativity, problem-solving, and entrepreneurial capabilities (State Council of China, 2016). In addition, the "Implementation Opinions on Deepening the Reform of Innovation and Entrepreneurship Education in Higher Education Institutions" issued by the Ministry of Education emphasized the integration of professional learning with innovation education, advocating for new teaching approaches such as design thinking combined with project-based learning to enhance students' abilities in real-world contexts (Ministry of Education of China, 2019).

These policies reflect a clear governmental intention: universities should not only impart knowledge but also cultivate the innovative and entrepreneurial competencies required for the 21st-century workforce. However, despite these efforts, many universities, particularly local institutions such as Sanming University, still face challenges in aligning their curricula with these national mandates. The gap between policy expectations and actual teaching practices provides a compelling rationale for course innovation.

Sanming University, as a local undergraduate institution, admits a large number of students from diverse social and academic backgrounds, many of whom come from rural or semi-urban areas in Fujian Province. Research shows that students in such contexts often demonstrate strong diligence but lack exposure to innovative learning environments and interdisciplinary collaboration (Wang & Liu, 2021). Traditional lecture-based teaching methods still dominate, and assessment tends to focus on knowledge reproduction rather than creativity or problem-solving skills (Zhang, 2019).

The Foundation of Innovation Course focuses on "awakening innovation awareness, cultivating systematic thinking, and empowering practical transformation," following the principles of "problem-oriented, value-led, and integration of knowledge and action." Through integrating

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PBL (Problem-Based Learning) with real problem-driven methods (such as optimizing shared campus equipment), Synectic analogy (a technique for generating creative ideas through analogies, often applied in innovation contexts) innovation (biological imitation, reconstruction of pain points through life metaphors), and Process Learning with process monitoring (three-dimensional log recording of cognitive iteration), a closed-loop system of "theory - thinking - practice - value" is constructed. The courses are supported by tools such as TRIZ theory (a problem-solving methodology used to find innovative solutions to engineering and technical problems) and mind maps, and are carried out in the campus environment through the entire process training from "problem definition (such as courier congestion) to prototype implementation (intelligent disinfection cabinet)".

They incorporate elements of curriculum ideological education, such as elderly-friendly design and low-carbon projects, guiding students to master innovation methods in user research, prototype production, and presentation and defense. The teaching relies on the case library of the national smart education platform, the on-campus flash laboratory, and the logistics pilot base. It adopts a multi-dimensional assessment of "process log (30%) + creative metaphor (30%) + feasibility of implementation (40%)", ultimately helping students form an "identify problems - cross-border connection - optimization and iteration" innovation thinking system, laying a "willing to innovate and able to innovate" ability foundation for lifelong development. (Zhao et al., 2021).

Research Questions

The research probes into the question of how effective the implementation of the Foundation of Innovation Course, utilizing Design Thinking combined with Project-Based Learning, is in enhancing students' Innovation ability and students’ satisfaction.

Research Objectives

To evaluate the effectiveness of the Foundation of Innovation Course implemented through Design Thinking combined with Project-Based Learning.

1) To compare the students' innovation ability after implementing the Foundation of Innovation Course based on Design Thinking combined with Project-Based Learning to enhance the innovation Ability of Second-Year Students at Sanming University, with the criterion of 70%.

2) To compare the students' satisfaction with the Foundation of Innovation Course based on Design Thinking combined with Project-Based Learning to enhance the innovation ability of Second-Year Students at Sanming University, with the criterion of 70%.

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Literature Review

This literature review critically examines the application of Design Thinking (DT) combined with Project-Based Learning (PBL) in the Foundation of Innovation Course, with a specific emphasis on its implications for students' innovation ability and course satisfaction.

1) Information about the Current Foundation of Innovation Course

The current Foundation of Innovation Course is a professional core course for second-year undergraduates at Sanming University. The course integrates classroom instruction, group collaboration, hands-on activities, and reflective learning to maximize the enhancement of innovation ability (Zhang & Li, 2023). Its structure includes six components: teaching principles, objectives, contents, instructional strategies, media/resources, and evaluation methods. Assessments focus on measuring students' innovation ability, collaboration, and application of DT and PBL methods (Larmer & Mergendoller, 2015). However, while the course claims to be student-centered, preliminary observations suggest that students often struggle to internalize the iterative mindset, tending to treat the design process as a linear checklist—a common implementation pitfall that will be addressed later.

2) Design Thinking Combined with Project-Based Learning: A Critical Synthesis

The theory underlying Design Thinking (DT) is grounded in constructivist and human-centered paradigms, viewing learners as active participants who develop solutions through iterative experimentation and reflection (Razzouk & Shute, 2012). Project-Based Learning (PBL), in contrast, originated from John Dewey's (1938) progressive education philosophy, which argued that learning should be experiential and connected to real-life problems. PBL was later formalized as a pedagogical model characterized by extended inquiry, student autonomy, and interdisciplinary collaboration (Thomas, 2000; Krajcik & Blumenfeld, 2006).

While DT and PBL are often presented as complementary, a closer examination reveals significant conceptual tensions and unresolved critiques that are frequently overlooked in the literature.

Critique 1: The "Black Box" of Design Thinking's Stages

The DT process is typically described as involving five stages: empathize, define, ideate, prototype, and test (Brown, 2009). Proponents argue that these stages encourage learners to first understand users' needs, then define problems, generate ideas, create prototypes, and test solutions, thereby enhancing innovation ability through divergent and convergent thinking (Plattner, Meinel, & Leifer, 2011). However, a growing body of criticism questions whether this staged model is universally applicable or even pedagogically sound.

For instance, Kimbell (2011) argues that the neat, sequential representation of DT is a "post-hoc rationalization" of a much messier, non-linear process. When taught rigidly, students may

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become fixated on completing each stage (e.g., “finishing the empathy map”) rather than genuinely engaging with users or iterating based on feedback. Furthermore, some researchers contend that DT’s emphasis on rapid prototyping and “failing fast” can inadvertently discourage deep theoretical analysis in fields like engineering or social policy, where premature solutions may overlook systemic complexities (Tonkinwise, 2014). Thus, the very structure that makes DT accessible may also limit its depth.

Critique 2: The Implementation Gap in Project-Based Learning

Similarly, while a PBL cycle often includes defining a driving question, planning, inquiry, developing a product, presenting, and reflecting (Larmer, Mergendoller, & Boss, 2015), research has consistently documented a significant implementation gap. Kokotsaki, Menzies, and Wiggins (2016) note that in practice, PBL often devolves into “dessert projects” — superficial activities tacked onto the end of a unit — rather than serving as the core pedagogical engine. This is particularly problematic when teachers lack training in facilitation, reverting to traditional lectures while students work on projects independently. Moreover, the claim that errors in PBL are viewed “not as failures but as opportunities for iteration” (Kokotsaki et al., 2016) is an idealistic aspiration. In reality, high-stakes grading systems and students’ fear of poor evaluations can create a risk-averse culture where teams avoid genuine experimentation, thus undermining the very innovation ability the course aims to foster (Condliffe et al., 2017).

Critique 3: The Unresolved Tensions in DT-PBL Integration

The integration of DT and PBL is often advocated as a natural synergy: DT provides the creative problem-solving stages, while PBL offers the broader project structure. However, contradictions exist. DT’s user-centered empathy phase requires deep, qualitative immersion, which may conflict with PBL’s emphasis on timely project completion and deliverable production. For example, spending weeks on genuine user research might derail a semester-long PBL timeline. Conversely, rushing through empathy to reach prototyping can render DT superficial. Furthermore, the assessment of integrated DT-PBL remains a major gap in the literature. While rubrics exist for collaboration and final products, there is little consensus on how to validly assess process-oriented skills like “empathy” or “iteration mindset” without introducing excessive subjectivity (Larmer & Mergendoller, 2015).

Conclusion of the Literature Review

In summary, while DT and PBL are widely endorsed as complementary approaches for cultivating innovation ability, the literature reveals substantial critiques and unresolved challenges. These include the risk of ritualistic adherence to DT’s staged model, the persistent implementation gap in authentic PBL, and the conceptual tensions when integrating two distinct pedagogies. Moreover, most existing studies report positive outcomes without critically

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examining under what conditions or for which student populations DT-PBL integration actually works (or fails). This study aims to address these gaps by not only developing a DT-PBL integrated course but also systematically investigating the specific barriers students encounter, particularly their superficial use of innovation resources and difficulties with iterative thinking, as observed in the current course at Sanming University.

This literature review examines the application of Design Thinking combined with Project-Based Learning in the Foundation of Innovation Course, with a specific emphasis on its implications for students' innovation ability and course satisfaction.

1) Information about the current Foundation of Innovation Course

The current Foundation of Innovation Course is a professional core course for second-year undergraduates at Sanming University. This course aims to help students understand the fundamental concepts and processes of innovation, as well as develop the ability to apply innovative thinking in academic, professional, and real-life contexts.

The course content is comprehensive, including the foundations of innovation theory, the principles of design thinking, project-based learning processes, creativity tools and techniques, problem identification and framing, idea generation, prototyping, testing, evaluation, and project implementation. The course is designed to integrate classroom instruction, group collaboration, hands-on activities, and reflective learning to maximize the enhancement of innovation ability (Zhang & Li, 2023).

The current Foundation of Innovation Course course structure includes: 1) Teaching Principles, 2) Teaching Objectives, 3) Teaching Contents, 4) Teaching Instructional Strategies, 5) Teaching Media and Resources, 6) Evaluation Methods. Assessments focus on measuring students' innovation ability, collaboration, and application of design thinking and PBL methods (Larmer & Mergendoller, 2015).

2) Design Thinking combined with Project-Based Learning

The theory underlying Design Thinking is grounded in constructivist and human-centered paradigms, viewing learners as active participants who develop solutions through iterative experimentation and reflection (Razzouk & Shute, 2012).

Project-Based Learning, in contrast, originated from the progressive education philosophy of John Dewey (1938), who argued that learning should be experiential and connected to real-life problems. It was later formalized in the 1990s and 2000s as a pedagogical model in K–12 and higher education, characterized by extended inquiry, student autonomy, and interdisciplinary collaboration (Thomas, 2000; Krajcik & Blumenfeld, 2006). The Design Thinking process typically

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involves five stages: empathize, define, ideate, prototype, and test (Brown, 2009). These stages encourage learners to first understand users' needs, then define problems, generate creative ideas, create tangible prototypes, and test solutions. Through this process, students not only develop problem-solving skills but also enhance their innovation ability by practicing divergent and convergent thinking (Plattner, Meinel, & Leifer, 2011).

Project-Based Learning, while distinct, complements Design Thinking by providing a broader pedagogical structure. A PBL cycle often includes (1) defining a driving question, (2) planning and designing the project, (3) conducting inquiry and research, (4) developing a product or solution, (5) presenting the outcome, and (6) reflecting on learning (Larmer, Mergendoller, & Boss, 2015). Errors are viewed not as failures but as opportunities for iteration and improvement, which is essential for innovation ability development (Kokotsaki, Menzies, & Wiggins, 2016).

The integration of Design Thinking combined with Project-Based Learning directly contributes to the cultivation of innovation ability in higher education. Innovation ability involves the capacity to identify opportunities, generate novel ideas, and implement creative solutions in real-world contexts (Zhou, 2012). By applying Design Thinking's empathize and prototype stages within a PBL framework, they not only acquire subject knowledge but also strengthen innovation ability through real-world problem-solving, teamwork, and reflection (Condliffe et al., 2017).

In summary, Design Thinking combined with Project-Based Learning are complementary pedagogical approaches that combine creative problem-solving with experiential, project-driven inquiry. Their integration equips students with the innovation ability needed to thrive in complex, uncertain environments.

3) Students' Satisfaction

Students' satisfaction refers to students' recognition and psychological perception of the cultivation of innovation ability in the Foundation of Innovation Course. The theory of customer satisfaction was first proposed by American scholar Cardozo in 1965. Customer satisfaction refers to the emotional state generated by customers after comparing their expectations with the perceived effect of a product or service (Bai & Liao, 2001). Influenced by the theory of customer satisfaction, student satisfaction theory assumes that students are consumers of educational products. Therefore, student satisfaction refers to the psychological feeling of satisfaction or dissatisfaction generated by students when they compare the perceived effectiveness of the educational process with their expectations during the delivery of teaching services (Lin, 2007).

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The theory of student satisfaction began to be applied in the field of education after 1990, especially in student evaluations of teaching quality and learning effectiveness, and has since been widely recognized. In this study, a 5-point Likert scale was adopted to evaluate students' satisfaction with the Foundation of Innovation Course. The survey mainly focuses on the evaluation of teaching objectives, teaching content, instructional strategies, teaching resources, and assessment methods. Measuring students' satisfaction with the Foundation of Innovation Course not only promotes classroom teaching reform and teachers' professional growth but also enhances communication between teachers and students. It is an indispensable part of school quality management. In the Foundation of Innovation Course satisfaction questionnaire, the following response options were used: (a) very satisfied, 5 points; (b) fairly satisfied, 4 points; (c) satisfied, 3 points; (d) not satisfied, 2 points; (e) very dissatisfied, 1 point (Zhu, 2012).

4) Innovation Ability

In today's rapidly changing and knowledge-driven society, innovation ability is considered a crucial driver for personal development, organizational competitiveness, and national progress. Without sufficient innovation capability, individuals may struggle to adapt to uncertainty and complexity, while societies may face stagnation. As Drucker (1985) argued, innovation is the specific tool of entrepreneurship through which individuals and organizations exploit change as an opportunity. Similarly, Florida (2002) emphasized that innovation capability is central to the "creative class," which fuels economic growth and social transformation.

Scholars have highlighted different dimensions of innovation ability. Sternberg and Lubart (1999) described innovation as a confluence of intellectual skills, knowledge, thinking styles, personality, motivation, and environment. According to Amabile (1996), innovation ability involves the intersection of expertise, creative-thinking skills, and intrinsic task motivation. In the educational context, Craft (2005) proposed that innovation requires learners to exercise "possibility thinking," namely, asking "what if" and "as if" questions that challenge conventional patterns. Meanwhile, Dyer, Gregersen, and Christensen (2011) identified five key discovery skills that foster innovation: associating, questioning, observing, experimenting, and networking.

Other researchers have further associated innovation ability with adaptability and resilience. Anderson, Potočnik, and Zhou (2014) defined innovation as the intentional introduction and application of ideas, processes, and procedures that are new to a particular work role or organization. Mumford et al. (2002) stressed the role of problem construction and idea evaluation as critical components of innovative performance. In the same vein, Glover, Ronning, and Reynolds (2013) suggested that innovation ability reflects the integration of divergent thinking with convergent evaluation, allowing individuals to balance originality with usefulness.

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Indicators of innovation ability include open-mindedness, curiosity, risk-taking, and collaboration. Puccio, Mance, and Murdock (2011) pointed out that innovative individuals demonstrate a tolerance for ambiguity, persistence in the face of obstacles, and the capacity to synthesize diverse perspectives. Likewise, Robinson (2011) emphasized that innovation thrives in environments that encourage autonomy, creativity, and constructive challenge to norms. Thus, innovation ability should be understood not only as an individual skill set but also as a socially and contextually embedded capacity.

Conceptual Framework

In developing an innovation foundation course, the researcher draws upon established curriculum development theories, including Tyler's (1949) objective model, Taba's (1962) grassroots model, and Oliva's (1999) comprehensive model, which collectively provide the theoretical basis for systematic curriculum design, implementation, and evaluation. For the instructional strategy, this study employs design thinking combined with project-based learning (PBL), both of which emphasize problem identification, creativity, collaboration, and iterative solution development, thereby placing students at the center of the learning process and promoting their comprehensive development (Brown, 2009; Thomas, 2000).

Innovation ability of students refers to their capacity for creative problem-solving, critical and logical thinking, collaboration, and adaptability, which are essential competencies in both academic and real-world contexts. Through the implementation of a foundation course grounded in design thinking and PBL, students' innovation ability can be enhanced by providing opportunities for authentic problem-solving, interdisciplinary integration, and reflective learning. Therefore, the conceptual framework of this study situates the independent variable as the innovation foundation course based on design thinking combined with project-based learning, and the dependent variable as the innovation ability of second-year students at Sanming University.

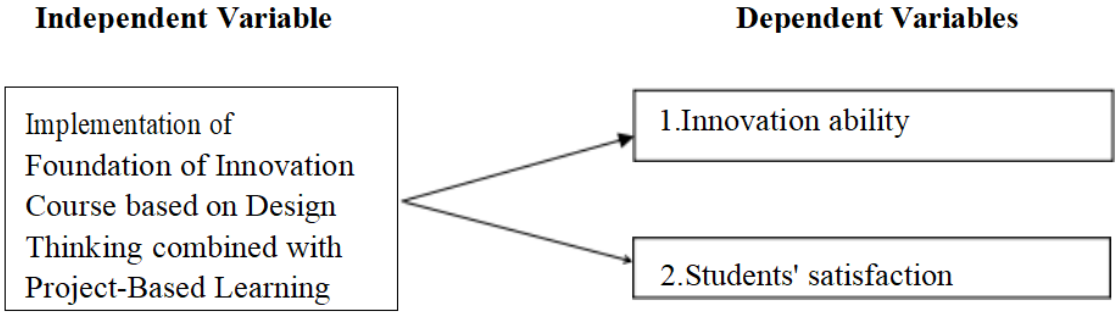


Figure 1 The relationship between the independent variable and the dependent variable

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Methodology

Population and Samples: The population of this study is 210 Second-Year students (7 classrooms) of Sanming University, Sanming City, Fujian Province, China. The sample of this study is 30 Second-Year students (1 classroom) of Sanming University, Sanming City, Fujian Province, China, which was derived by using the cluster random sampling method

Research Instruments: Research instruments were essential tools for data collection. The instruments utilized in this study included:

Instruments for the experiment

The Foundation of Innovation Course consists of six major components: (1) Principles, (2) Objectives, (3) Content, (4) Teaching Strategies, (5) Materials, and (6) Evaluation.

Five experts—two curriculum experts, two content instruction specialists, and one measurement and evaluation expert—evaluated the draft course using a 20-item evaluation form with 5-point rating scales. The mean score was 4.38 (SD=0.56), indicating that the course was rated at a high level.

1) Lesson plans

The researcher developed an evaluation form for lesson plans, which underwent rigorous assessment by the same panel of five specialists. The panel evaluated seven lesson plans designed for the course using 5-point scales. The mean scores ranged from 4.24 to 4.53 (SD=0.50-0.63). Based on these results, the lesson plans were deemed suitable for implementation, with a focus on nurturing students' innovation ability.

Instruments for Data Collection

The data collection instruments included a post-test for assessing innovation ability and a satisfaction questionnaire.

Test Paper and Scoring Rubric for Students' Innovation Ability

The examination paper contained items evaluating five aspects of innovation ability: 1) Creative Thinking, 2) Problem Identification, 3) Idea Generation, 4) Practical Application, and 5) Reflective Improvement. The Item-Objective Congruence (IOC) values for these items ranged from 0.60 to 1.00, confirming their relevance to the course objectives. The difficulty level (p) was optimal (0.50–0.70), and item discrimination (r) exceeded 0.20, meeting established criteria.

The scoring rubric's quality was validated through content validity and reliability checks. Content validity, assessed via IOC by five experts, yielded values between 0.60 and 1.00. Inter-rater reliability, tested during a trial phase, was 0.88, exceeding the threshold of 0.70.

Satisfaction Questionnaire

The satisfaction questionnaire was reviewed by five experts for content validity. Each item's IOC ranged from 0.60 to 1.00, with 20 items identified as appropriate for evaluating the

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blended learning course. The questionnaire's reliability coefficient was 0.89, surpassing the acceptable threshold of 0.70, confirming its internal consistency.

Data Collection

The data collection was implemented in the procedures as follows:

1) The sample was given the pretest for measuring students' innovation ability with constructed instruments.

2) After finishing the instruction, the samples received the post-test by using the same instrument as the pretest.

3) The samples were given the students' satisfaction questionnaire to express their opinion on the course.

Data Analysis

The collected data were analyzed by using statistical methods aligned with the research objectives:

1) The scores from the pre-test and post-test of the Chinese modern literature course were compared by using a t-test for dependent samples.

2) The data of students' satisfaction with the course were analyzed to determine the different scores of satisfaction with the criterion of 70% by using a t-test for one sample.

Research Results

The results were presented by the research objectives:

A comparison of students' innovation ability scores after participating in the Foundation of Innovation Course, which utilized Design Thinking combined with Project-Based Learning, was conducted using a paired-sample t-test.

Table 1 The result of comparing the different scores of students' Innovation ability scores toward the course after course implementation, with the criterion of 70%

Group	n	Full score	The criteria score of 70%	*M*	*SD*	t	p
Experimental group	30	50	35	39.9	3.15	8.52**	.001

***p*< .01

As presented in Table 1, the mean scores of the students' Innovation Ability test after learning through the Foundation of Innovation Course were 39.9 out of possible full marks of 50, and the standard deviation was 3.15, which was statistically higher than the determined criterion of 70% at the .01 level of statistical significance (t_{29}=8.52, p<.01)

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As indicated in Table 1, students reported high Innovation Ability test levels with the course delivery format following their engagement with the Foundation of Innovation Course based on Design Thinking combined with Project-Based Learning.

Table 2 Mean score and satisfaction level of students' satisfaction with the Foundation of Innovation Course based on Design Thinking combined with Project-Based Learning

Question number of the satisfaction questionnaire		M	SD	Satisfaction level
Section	Question number			
Section 1: Course Objectives	1. The course objectives clearly define the innovation ability students should gain.	**4.67**	**0.61**	Very high level
	2. The course objectives are aligned with students' needs and current trends in innovation and creativity.	**4.60**	**0.62**	Very high level
	3. The course objectives adequately cover knowledge. skills and attitudes related to innovation.	**4.63**	**0.56**	Very high level
	4. The course objectives are realistic and achievable within the given time frame.	**4.60**	**0.72**	Very high level
	Total	**4.63**	**0.62**	Very high level
Section 2: Course Content	5. The course content was well-organized and easy to follow.	**4.70**	**0.47**	Very high level
	6. The course content appropriately supports the development of innovation skills such as have practical significance.	**4.67**	**0.48**	Very high level
	7. The course content appropriately supports the development of innovation skills such as idea generation and creativity.	**4.63**	**0.49**	Very high level
	8. The course content can provide theoretical concepts and practical application for improving students' innovation ability.	**4.73**	**0.45**	Very high level
	Total	**4.68**	**0.47**	Very high level
Section 3: Instructional strategy	9. The teaching strategies helped me apply concepts to real-world situations.	**4.73**	**0.45**	Very high level
	10. The instructor encouraged student participation and discussion.	**4.77**	**0.43**	Very high level
	11. The teaching strategies helped students apply concepts to real-world situations.	**4.73**	**0.45**	Very high level

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Question number of the satisfaction questionnaire		M	SD	Satisfaction level
Section	Question number			
	12. The instructor used teaching methods that supported students' learning.	**4.53**	**0.63**	Very high level
	13. Classroom activities encouraged creativity and problem-solving.	**4.70**	**0.53**	Very high level
	Total	**4.69**	**0.50**	Very high level
Section 4: Teaching resources	14. The media and learning materials used in the course supported students' understanding.	**4.57**	**0.50**	Very high level
	15. The digital tools and resources provided were easy to access and use.	**4.60**	**0.62**	Very high level
	16. The learning environment (online or physical) supported effective learning.	**4.57**	**0.63**	Very high level
	Total	**4.58**	**0.58**	Very high level
Section 5: Evaluation	17. The assessments reflected the key concepts taught in the course.	**4.57**	**0.63**	Very high level
	18. The feedback from the teacher to improve their performance. helped students	**4.57**	**0.68**	Very high level
	19. Students received timely and helpful feedback on their work.	**4.63**	**0.67**	Very high level
	20. The evaluation methods were fair and appropriate for an innovation course.	**4.63**	**0.56**	Very high level
	Total	**4.60**	**0.63**	Very high level
	Total/Overall	**4.64**	**0.56**	Very high level

The result of Table 2 showed that the students' satisfaction with the Foundation of Innovation Course based on Design Thinking combined with Project-Based Learning was very high level (*M= 4.64, SD=0.56*). In the 20 items of satisfaction questionnaire, the lowest mean score was (*M=4.53, SD=0.63*), which is the 12 items, which are issues related to teaching materials. The highest mean score was (*M=4.77, SD=0.43*), it is the 11items, which are issues related to teaching content.

The finding of the comparison of students' satisfaction after learning through the Foundation of Innovation Course, with the criteria set at 70 percent.

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The result of comparing the different scores of students' satisfaction after learning through the Foundation of Innovation Course with the criteria set at 70 percent. The table below shows descriptive statistics and t-test as analyzed by the statistical package program. This table aims to answer the research objective of whether the implementation of the Foundation of Innovation Course based on Design Thinking combined with Project-Based Learning can improve students' satisfaction.

Table 3 The result of comparing the different scores of students' satisfaction after learning through the Foundation of Innovation Course based on Design Thinking combined with Project-Based Learning, with the criteria set at 70 percent

Group	n	Criteria	M	SD	t	p
Experimental group	30	3.51	4.64	0.67	7.76**	0.001

**p < .01

As presented in Table 3, the mean scores of students' satisfaction after learning through Foundation of Innovation Course based on Design Thinking combined with Project-Based Learning was (*M=4.64, SD=0.67*) which was statistically higher than the criterion of 3.51 at .05 level of statistical significance (t_{29}=7.76, $p < .01$). It can be seen that the students' satisfaction of the students who through Foundation of Innovation Course based on Design Thinking combined with Project-Based Learning are higher than 70%.

Discussion

The purpose of this study was to develop and evaluate a Foundation of Innovation Course based on the integration of Design Thinking (DT) and Project-Based Learning (PBL) for second-year students at Sanming University. The results demonstrated significant improvements in students' innovation ability and high levels of course satisfaction. This section interprets these findings in light of existing literature, discusses unexpected outcomes, acknowledges limitations, and proposes implications for educational practice and future research.

1. Interpretation of Findings on Innovation Ability

The first key finding is that students' post-course innovation ability scores (M = 39.9 out of 50, SD = 3.15) significantly exceeded the 70% benchmark, t_{29}= 8.52, p <.01, with a large effect

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size (r = 0.85). This result provides strong empirical evidence that the DT-PBL integrated course effectively enhances multidimensional innovation competence.

2. Interpretation of Findings on Student Satisfaction

The second key finding is that student satisfaction (M = 4.64/5, SD = 0.67) significantly exceeded the 70% benchmark, t_{29}=7.76, p<.01. This high level of satisfaction is noteworthy because innovation courses often face student resistance due to the ambiguity and risk of failure inherent in open-ended projects (Zhang & Li, 2023).

A cautionary note on satisfaction. However, high satisfaction should not be equated with deep learning. Some educational researchers warn that students may rate "fun" or "low-effort" courses highly even when cognitive gains are modest (Hattie, 2009). In this study, satisfaction was measured immediately after course completion, which may capture affective reactions rather than long-term value. Future research should employ delayed satisfaction surveys (e.g., one semester later) to assess whether students perceive the course as useful after applying innovation skills in other contexts.

3. Implications for Practice

Despite the limitations, the findings offer practical guidance for educators designing innovative courses in higher education.

Adopt a structured DT-PBL cycle, not just "projects." Many innovation courses claim to be "project-based" but lack a clear process model. This study demonstrates that explicitly teaching and enforcing the five-step DT-PBL cycle helps students navigate ambiguity and reduces the anxiety associated with open-ended tasks. Instructors should provide checklists, templates, and milestone check-ins for each step, especially for the "Define & Plan" phase, where students often struggle.

Address the "Practical Application" gap. The relatively lower score in Practical Application indicates a need for more implementation support. Possible solutions include: (a) inviting industry mentors to provide feasibility feedback during the prototyping phase; (b) extending the course duration or offering a follow-up "implementation lab"; (c) integrating low-code/no-code digital tools to lower technical barriers; and (d) forming interdisciplinary teams (e.g., business + engineering) to simulate real-world innovation contexts.

4. Suggestions for Future Research

Building on the present study, several directions for future research are recommended.

Comparative studies of DT-PBL vs. traditional methods. A randomized controlled trial comparing the integrated DT-PBL course with a traditional lecture-based innovation course would provide stronger causal evidence.

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Moderator and mediator analyses. Future research should examine whether the effectiveness of DT-PBL differs by student characteristics (e.g., prior innovation experience, academic discipline, gender) and what mediating mechanisms (e.g., increased collaboration, improved metacognitive awareness) explain the effects.

Conclusion

The author developed and implemented a new course on the Foundation of Innovation Course. The course development process included 1) establishing guiding principles; 2) defining objectives; 3) selecting content; 4) adopting instructional strategies; 5) selecting media and resources; and 6) designing assessment tools.

The statistical results revealed that students' Innovation ability significantly improved after participating in the new course. The post-test mean score (M = 39.9, SD = 3.15) was higher, with t_{29}=8.52, p< .01 at the .05 significance level. This demonstrates that the intervention had a strong positive impact on students' Innovation ability.

The results indicated that students' satisfaction with the new Foundation of Innovation Course significantly exceeded the 70% criterion. The mean satisfaction score across all dimensions was M = 4.32, SD = 0.48, surpassing the benchmark with a statistically significant margin (t_{29} = 8.27, p < .001). This demonstrates that students not only developed their innovation abilities but also found the learning process highly engaging, relevant, and rewarding.

In summary, the findings from the satisfaction analysis robustly affirm the effectiveness and positive reception of the new Foundation of Innovation Course. Quantitative results confirmed that student satisfaction significantly surpassed the 70% benchmark. Qualitative data revealed that students highly valued the active, hands-on steps of ideation, prototyping, and iterative testing, which empowered them to translate creativity into actionable solutions. The transformation of the teacher's role into that of a facilitator and coach, coupled with the use of authentic digital resources, created a supportive and professional learning environment. Students reported increased motivation, confidence, and a strong sense of ownership over their learning.

This discussion has interpreted the main findings of the study, placing them in the context of prior literature and highlighting both consistencies and unexpected patterns. The significant improvements in innovation ability and high levels of student satisfaction support the value of an integrated DT-PBL approach. However, the limitations—particularly the single-group design and small sample—caution against overgeneralization. The study advances the field by providing a replicable five-step teaching cycle and a multi-dimensional rubric for innovation ability assessment. With careful attention to the "Practical Application" gap and with more rigorous

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experimental designs in future research, the DT-PBL framework holds promise as a scalable model for innovation education in Chinese universities and beyond.

Recommendation

Based on the findings and implementation outcomes of this study, the following recommendations are proposed to enhance the effectiveness, scalability, and sustainability of the Foundation of Innovation Course based on Design Thinking and Project-Based Learning:

1. Deepen Process-Oriented Assessment and Feedback

As Bereczki and Kárpáti (2021) note, assessment in creative domains must move beyond judging final products to evaluating the quality of the exploratory process itself. Developing and validating a set of "innovation process indicators" (e.g., quality of problem reframing, diversity of ideation, depth of user testing analysis) will provide teachers with more precise tools to guide and support student development in real-time.

2. Refine and Contextualize the Innovation Ability Framework

The framework and its associated rubrics should be adapted for different university contexts (e.g., research-intensive vs. application-oriented universities) and regional economic foci to enhance their ecological validity and practical utility (Wiek et al., 2020).

3. Systematically Integrate Advanced Digital Collaboration and Prototyping Tools

As argued by Cheng et al. (2022), it transforms abstract methodologies into tangible practice, making the innovation process more efficient, collaborative, and professionally relevant.

4. Expand Implementation and Conduct Cross-Institutional Comparative Research

This will allow for comparative analysis of effectiveness, identification of contextual moderating factors, and refinement of the model. Such large-scale, cross-institutional research is essential for developing a robust, nationally relevant model for innovation education that can inform broader policy and curriculum reforms (Brundiers & Wiek, 2013).

Building this professional ecosystem is vital for moving beyond isolated course success to fostering a lasting culture of innovation teaching within and across institutions.

Recommendations for Further Research

Based on the implementation and outcomes of this study, the research findings are summarized in accordance with the two core research objectives as follows:

1. Findings Related to Course Development

The study successfully developed a Foundation of Innovation Course by systematically integrating the Design Thinking (DT) framework with Project-Based Learning (PBL) pedagogy. The course was structured around six core components—principles, objectives, content, teaching strategies, materials, and evaluation—and operationalized into a five-phase teaching cycle: (1)

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Driving Question & Empathy, (2) Define & Plan, (3) Ideation & Creation, (4) Prototyping, Reflection & Revision, and (5) Testing, Presentation & Evaluation. The development process was grounded in the theoretical frameworks of Tyler's Objective Model, Taba's Grassroots Model, and Constructive Alignment Theory, ensuring coherence between learning objectives, instructional activities, and assessment methods. Expert validation confirmed the appropriateness and comprehensiveness of the course design.

2. Findings Related to Course Effectiveness

The implemented Design Thinking combined with Project-Based Learning integrated course demonstrated significant effectiveness in enhancing second-year students' innovation ability and received highly positive student satisfaction.

Innovation Ability Enhancement: Post-intervention assessment using a five-dimensional rubric (Creative Thinking, Problem Identification, Idea Generation, Practical Application, Reflective Improvement) revealed strong student performance, with a total mean score of 39.9 out of 50 (SD = 3.15). Single-sample t-test results showed that student performance significantly exceeded the 70% benchmark (35 points), with t_{29}= = 8.52, $p < .01$. All five dimensions scored above 7.4 out of 10, with "Problem Identification" (M = 8.3) and "Creative Thinking" (M = 8.2) demonstrating the highest gains, confirming the course's efficacy in cultivating comprehensive innovation competencies.

Student Satisfaction: Student satisfaction with the new course significantly exceeded the 70% criterion, with a mean score of 4.32 out of 5 (SD = 0.48) and t_{29}= = 8.27, $p < .01$. Students particularly valued the hands-on, collaborative steps of "Ideation & Creation" and "Prototyping, Reflection & Revision," which fostered engagement, confidence, and a sense of ownership over their learning. Qualitative feedback confirmed that the shift from traditional lectures to facilitative, project-based instruction created a supportive and motivating learning environment.

In summary, the newly developed Design Thinking, combined with Project-Based Learning, integrated Foundation of Innovation Course, not only significantly enhanced students' multidimensional innovation abilities but also generated high levels of student satisfaction, validating its effectiveness as a student-centered, practice-oriented pedagogical model.

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