SAHABAT CENDEKIA INDONESIA

Journal of Learning and Instruction Innovation

DOI: https://dx.doi.org/10.xxxxx/jolii.v1i1.9

Journal homepage: https://journal.sahabat-cendekia.com/index.php/jolii

A Study of Self-Efficacy, Interest, and Performance in STEAM Activity Design Exhibited by Elementary Preservice Teachers in Taiwan

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article info

Article history:
Received: February 27, 2026
Received in revised form: March 08, 2026
Accepted: March 08, 2026
Available online: March 30, 2026

Keywords:
Preservice teachers;
STEAM;
Interdisciplinary;
Scientific inquiry;
Self-efficacy.

Published by Sahabat Cendekia Indonesia Publisher in Collaboration with the Center for Scientific Publications and Rankings Universitas Islam Negeri Siber Syekh Nurjati Cirebon, Indonesia.

abstract

Background: Nowadays, science education trends increasingly emphasize the integration of disciplines worldwide, and Taiwan's new curriculum guidelines simultaneously address multidisciplinary teaching and learning. Since scientific inquiry and interdisciplinary integrated learning remain challenges for most Taiwanese students.
Aims: The purpose of the study was to examine elementary preservice teachers' self-efficacy, interest, and performance in designing STEAM activities.
Methods: The study included 17 preservice teachers majoring in science enrolled in a three-semester-hour course focused on elementary science teaching and learning. Participants were invited to complete a sequence of guided inquiry-based learning activities that emphasized cross-subject and scientific inquiry. At the end of the study, they presented their interdisciplinary activity design, which focused on scientific inquiry across science, technology, engineering, art, and mathematics. Data were collected from questionnaires and from preservice teachers' performance and feedback for further analysis.
Results: Results indicated that preservice teachers expressed more interest in scientific inquiry and the STEAM interdisciplinary design of elementary science. Personal self-awareness, scientific inquiry skills, and self-confidence in designing scientific and interdisciplinary instructional activities need to be enhanced.
Conclusion: The findings provide some insights into the implementation of STEAM education in science teacher preparation.

How to cite this article: Wang, Y. F. (2026). A Study of Self-Efficacy, Interest, and Performance in STEAM Activity Design Exhibited by Elementary Preservice Teachers in Taiwan. *Journal of Learning and Instruction Innovation*, *1*(1), 19-36. https://dx.doi.org/10.xxxx/jolii.v1i1.9

1. Introduction

STEAM education is a global trend in science education reform that emphasizes cross-domain curriculum design. In the context of STEAM education, it is an "interdisciplinary education" composed of the initials of the five subjects, including science, technology, engineering, art, and mathematics. The rationale for STEAM education is to break down disciplinary barriers and integrate STEM fields with the arts and humanities, encouraging students to create and experiment, learn through the process, consider solutions to real-life problems, and incorporate artistic elements to nurture learners' creativity, thinking skills, and imagination. Since the world needs innovative problem-solving skills, STEAM education places great importance on students' active learning, practical participation, independent creation, and problem discovery. Hands-on learning, problem-solving, art, and innovation are also emphasized in STEAM education. It also breaks down disciplinary barriers and combines STEM fields with the arts and humanities. To cultivate learners' mathematical and logical thinking in science and engineering, education must also nurture artistic beauty and integrate rationality and sensibility, thereby becoming a whole-person education.

1.1. The Development of STEM / STEAM Education

STEM education is particularly important for promoting economic growth, technological progress, and addressing global challenges of the 21st century in the Asia-Pacific region (Deehan et al., 2024). Many countries in this region recognize the transformative power of STEM and prioritize quality education in these fields to cultivate a generation of innovators and critical thinkers (Jamaluddin et al., 2025). In Singapore, research findings from the implementation of the STEM applied learning programme revealed that teachers perceived a conflict between examination demands and the programme's designed learning outcomes (Wen et al., 2021). The integration of arts with science, technology, engineering, and mathematics (STEM) education has increased significantly in recent years (Perignat & Katz-Buonincontro, 2019). Davies and Trowsdale (2021) propose a new framework for multi-subject curricula that focuses on the "culture of disciplines," arguing that the arts and sciences can coexist within the same curricular space-time. Many researchers have attempted to elucidate a more positive perspective by integrating art with science, technology, engineering, and mathematics. The perspectives move beyond viewing art merely as an instrumental tool for enhancing STEM outcomes and instead explore the essence and nature of art in learning. They consider STEAM a collective term for an educational system shaped by comprehensive, interdisciplinary humanities practices (Davies & Trowsdale, 2021; Meijas et al., 2021).

In Taiwan, the implementation of STEAM education and the competency-oriented approach of the 108 curriculum guidelines emphasize interdisciplinary knowledge integration rather than the quantification of exam scores. Project-based learning (PBL) starts with real-life challenges, and student-centered learning encourages students to complete projects from scratch. Students learn through hands-on experiences, solving problems by building with blocks, assembling robots, and programming. The integration of art and humanities aims to incorporate artistic elements, cultivate aesthetic awareness in design, and enhance logical and creative thinking skills. Science curriculum reforms aim to encourage teachers to collaborate with industry and academia to develop a new curriculum that shifts teachers' roles from instructors to facilitators and moves toward student-centered learning. Yang, Liu, and Hsueh (2024) found that research trends in master's and doctoral dissertations in Taiwan had gradually increased attention to STEAM education since 2018. STEAM education research largely focuses on curriculum and teaching models, frequently employing the 6E model, project-based learning, and creativity. Current STEAM education research in Taiwan focuses on K-12 students, but there is relatively little research on university students and teachers (Yang et al, 2024). An analysis of literature on STEAM courses in Taiwanese elementary schools published between 2018 and 2021 revealed that information technology and art were most often treated as supplementary courses to science, while the diverse expressions of art were not emphasized

(Tang, 2022). In general, the concepts of science, engineering, and mathematics (STEM) are relatively rigid and difficult for students to understand. Incorporating art elements into STEM can transform the learning of difficult concepts into fun, hands-on art activities and explorations. This can enhance students' learning and exploration of complex interdisciplinary concepts and principles, increase their interest, and cultivate their creativity. Focusing too heavily on the arts in STEAM courses may oversimplify STEM concepts, while maker STEAM programs in engineering design often neglect artistic expression (Glass & Wilson, 2016). It is important to consider the balance in STEAM courses, specifically how to integrate science and art into the curriculum. Therefore, strengthening diverse artistic expression and creativity, and integrating them with interdisciplinary STEM learning, warrants in-depth exploration.

1.2. Taiwan's 108 Curriculum Guidelines

As science education trends increasingly integrate disciplines worldwide, Taiwan's 108 curriculum guidelines align with global trends and present a forward-looking vision that emphasizes scientific inquiry and interdisciplinary learning. The spirit of the new curriculum encourages learners to raise questions, design experiments, collect and analyze data, and draw conclusions across different disciplines. Scientific learning emphasizes critical and creative thinking rather than rote memorization. Students are encouraged to learn through interdisciplinary, guided, and inquiry-based activities. The guided inquiry approach emphasizes student-centered, constructivist teaching and learning that scaffolds learning, fosters critical thinking and independent research, and deepens understanding, with students actively constructing knowledge rather than passively receiving it. The importance of active exploration and learning lies in students' ability to construct their own knowledge through hands-on, minds-on, interdisciplinary activities. A diversified focus on teaching and learning can help learners construct their own knowledge and integrate discrete and interdisciplinary concepts. An educational philosophy emphasizing interdisciplinary curricula and integrating knowledge and skills across disciplines has emerged. It has led to a trend toward hands-on and project-based learning, which, combined with the maker movement, has become a core concept of educational reform in Taiwan.

1.3. The Challenges for Implementing STEAM Education in Taiwan

The global trend in science education reform advances constructivist principles, advocates scientific inquiry, and implements these in the classroom. Students are capable of constructing knowledge through experiencing in scientific inquiry. If learners can take the initiative to explore and learn, they should be able to improve science learning outcomes. In fact, the pressure of getting into good schools has always existed in Taiwan. Many students study hard to earn good grades and gain admission to highly ranked academic schools to pursue their careers. Hence, academic performance is highly valued in high school and university entrance examinations, as these exams are extremely competitive for Taiwanese students. When implementing the new curriculum guidelines, teachers often face the dilemma of balancing the need to guide students' learning interests and the need to teach scientific concepts directly to achieve high scores. Many students prioritize memorization over other aspects from elementary school through high school, and strive to achieve high scores and gain admission to top-ranked high schools and universities. It usually leads school teachers to provide more practice exercises and exams to enhance students' learning achievement, but there are few opportunities for reflective learning. Meanwhile, due to time constraints in the school curriculum, the limited integration of inquiry and science practice remains a long-standing problem of science educational reform in Taiwan.

1.4. Self-efficacy, STEM / STEAM, and Teacher Education

STEM and STEAM education have received considerable attention in education reform, and teachers' key role is widely recognized (Al Salami et al., 2017; Chen & Chen, 2021; Lee et al., 2019; Kilty et al., 2021). Dira and Carr (2023) noted calls for scientific inquiry experiences in primary school undergraduate science curricula and in all primary school teacher training programs. Many primary school teachers have not received training in effective science teaching methods, which leaves them feeling uncomfortable and lacking confidence. Therefore, this study focuses on cultivating preservice teachers' cross-domain designing abilities, which is very important. The concept of self-efficacy, as defined by Albert Bandura, refers to a person's belief in their ability to execute the behaviors necessary to achieve specific outcomes. It also means confidence in someone's ability to influence and control the events and environment. Bandura (1986, 1997) articulated the self-efficacy model and its antecedents from the perspective of scientific self-efficacy. Qualities include mastery experience in science, vicarious scientific experience, forms of scientific persuasion, physiological components (physical indicators), and four other sources of performance information. Bandura further pointed out that self-efficacy. The level of ability will affect not only the individual's thinking style but also the choice of behavior, the amount and persistence of effort, and emotions. Lazarides and Warner (2020) define self-efficacy as individuals' beliefs about their ability to organize and execute the actions needed to reach specific goals, and it is essentially task- and context-specific rather than a general feature. Self-efficacy is typically defined as teachers' confidence in their ability to carry out instructional tasks that support student learning, and syntheses of the field link teacher self-efficacy to classroom practice and teacher well-being.

Four primary informational sources were emphasized as shaping efficacy beliefs: mastery experiences, vicarious experiences, verbal/social persuasion, and physiological/affective states, helping explain why practice preparation and timely feedback can enhance preservice teachers' confidence in their teaching (Lazarides & Warner, 2020). Science teachers' perceived ability to create an effective and productive learning environment and to increase student success and motivation is expressed as science teaching self-efficacy (Durak et al., 2023). Self-efficacy refers to an individual's perceived ability to plan and act to achieve goals (Bandura, 1986). It is a key component of teachers' competence and confidence in iSTEM teaching (Johnson et al., 2021). Extensive literature indicates that elementary school teachers generally lack strong self-efficacy in teaching science, mathematics, or engineering (Hammack & Ivey, 2017; Knaggs & Sondergeld, 2015; Webb & LoFaro, 2020). In the United States, pre-service elementary school teachers' comprehensive STEM teaching self-perception is often seen as a significant achievement of methodological curriculum reform and modeling approaches; research consistently shows that pre-service teachers' self-perception is enhanced when they experience coherent integration, well-formed implementation, and significant support that reduces content anxiety and confirms the feasibility of integration opportunities (Johnson et al., 2021; Webb & LoFaro, 2020, Menon, 2023; Menon, 2025).

In South Asia, Mehddi, Kazi, and Butt. (2025) explored how STEAM professional development training grounded in design thinking influences primary school teachers' beliefs and teaching practices. Four teachers participating in the 12-week training program showed that the training enhanced their self-efficacy, promoted interdisciplinary collaboration, and encouraged the use of inquiry-based and student-centered teaching strategies (Mehddi et al., 2025). In the Asia-Pacific region, despite vigorous efforts to promote STEM or STEAM education, schools at all levels, from kindergarten to university, still face many challenges. The issues for promoting STEAM include teaching practices (Li et al., 2023; Arlinwibowo et al., 2023; Karpudewan et al., 2022), learning methods (Way et al.,2022; Beruin, 2022; Manoharan & Kaur, 2023), geographical location (Murphy, 2023), and gender differences (Wang, 2024). These issues indicate the complexity of implementing STEM education in the Asia-Pacific region. Across Taiwan and other countries, preservice elementary teachers' self-efficacy in designing STEAM activities is also increasingly recognized as a design-for-practice capacity. A recent study on teacher education interventions offers a clear pathway: technology-rich, project-based design experiences, such as micro:bit, physical computing, and game design. It enhances preservice teachers' confidence in creating integrated activities. It improves related outcomes, such as computational thinking, domain knowledge, and positive orientations toward programming competencies, which are increasingly relevant to STEAM lesson design in Taiwan's new curriculum (Tsai et al., 2022; Tsai, 2023; Tsai, 2024). The previous study indicates that preservice teachers often lack the self-efficacy needed to implement STEM education effectively in their classrooms (Pearce, Brock, & Bunch, 2022). Webb and LoFaro (2020) stated that an integrated STEAM curriculum could support elementary preservice teachers' participation, perspectives on integrated STEM and STEAM, and the development of teaching self-efficacy, while also revealing structural barriers that complicate interdisciplinary implementation in schools. However, direct evidence of STEAM-design self-efficacy remains comparatively little in Taiwan.

Preservice teachers' self-efficacy in designing STEAM activities needs further enhancement. It is important to implement STEAM educational objectives for preservice teachers that encourage active learning and participation, foster independent creation and problem discovery, and prepare students for future societal and technological changes. Therefore, the purposes of this study were to explore preservice teachers' self-efficacy, interest, and performance in STEAM cross-field inquiry and implementation design. Two research questions were designed to guide the study as follows.

1. How did the pre-service teachers hold their self-efficacy and interest in the science activity and interdisciplinary instructional design?
2. How did the pre-service teachers perform in designing STEAM activities?

2. Methods

2.1. Research design

It was a six-week-long study. The study aimed to explore preservice teachers' self-efficacy, interests, and performance in interdisciplinary instructional design, with 17 science majors enrolled in a three-semester-hour course on elementary science teaching and learning. During the course periods, participants were invited to voluntarily complete a sequence of inquiry-based learning activities that emphasized cross-subject and theme-based content. All participants provided informed consent for inclusion before participating in the study. The researcher developed the training courses with an emphasis on guided inquiry. All the participants needed to work on the reading materials and hands-on activities related to scientific inquiry and the STEAM interdisciplinary field. The researcher served as an instructor to progressively increase the levels of scientific inquiry: from confirmation inquiry to structured inquiry, guided inquiry, and open inquiry. The guided-inquiry process involves posing questions and hypotheses, designing experiments and collecting data, analyzing evidence and interpreting it, explaining and drawing conclusions, and communicating and evaluating the findings.

2.2. Research procedure

The instrument was created by the researcher and validated by 10 experts in science education to assess preservice teachers' self-efficacy in scientific inquiry and cross-disciplinary work. The instrument was a questionnaire that included five domains: self-awareness and scientific inquiry abilities; interest in scientific inquiry; interest in designing scientific experiments or activities; interest in designing science and interdisciplinary science teaching activities; and confidence in designing scientific and interdisciplinary teaching activities. Before the study, 17 preservice teachers were invited to complete questionnaires from the previous semester to establish the instrument's reliability. Cronbach's alpha was used to assess reliability. Although the sample size was small, Cronbach's alpha was 0.72, indicating acceptable reliability. In the study, seventeen preservice teachers enrolled in the course volunteered to complete the questionnaire at the beginning and end of the study. They completed questionnaires developed by the researcher to assess preservice teachers' self-efficacy and capability in designing interdisciplinary, inquiry-based science instruction. Meanwhile, student work, questionnaires, and feedback were collected from the participants for the analysis. At the end of the study, they presented their interdisciplinary instructional design that integrated science, technology, engineering, art, and mathematics. They used scientific knowledge as core concepts and integrated multiple disciplines to design STEAM activities. Then they designed variables for scientific experiments, including manipulated, control, and dependent variables, and developed a rubric to measure learners' performance.

2.3. Participants

Participants were selected using purposive sampling methods. The purposive sampling approach allowed the researcher to invite participants who fit the phenomenon under examination or the case (Patton, 2015). Seventeen (17) preservice teachers enrolled in the course of science teaching and learning were science majors, mostly second-year undergraduates, with a smaller number of third- and fourth-year undergraduates and graduate students. Before conducting this study, the researcher solicited the opinions of students who had taken the course and invited them to participate voluntarily.

2.4. Data collection

The instructional guidance activities lasted six weeks, with questionnaires administered one week before and one week after implementation. Qualitative and quantitative data were collected for analysis. A pre- and post-test questionnaire was developed by the researcher and validated by the ten science education experts. Students' work for the interdisciplinary activity design was collected for analysis. Seventeen preservice teachers were invited to complete the questionnaire at the beginning and end of the course. Student work, questionnaires, and feedback were collected from the participants for the analysis.

2.5. Data analysis

Quantitative analysis of questionnaire results was applied to explore relationships between pre- and post-test scores, including the Paired Samples t-test and Cohen's d. Qualitative analysis was based on preservice teachers' reports and feedback to supplement the explanation of the questionnaire data. Data triangulation was conducted using the pre-test and post-test questionnaires, preservice teachers' work, and their reports.

3. Results

During the study, 17 pre-service teachers participated in a sequence of interdisciplinary activities, including inquiry-based reading materials and guided activities such as parachute design and landing experiments, simple pendulum design, exploration of the oscillation period, building-block assembly, and experiment design. At the end of the study, they have to complete the inquiry-based STEAM activity design.

The findings indicated that post-test scores were higher than pre-test scores in Dimensions 1, 2, 3, and 4, and confidence in designing such activities decreased slightly. The mean score, standard deviation, and effect size of the pre-test and post-test are shown in Table 1.

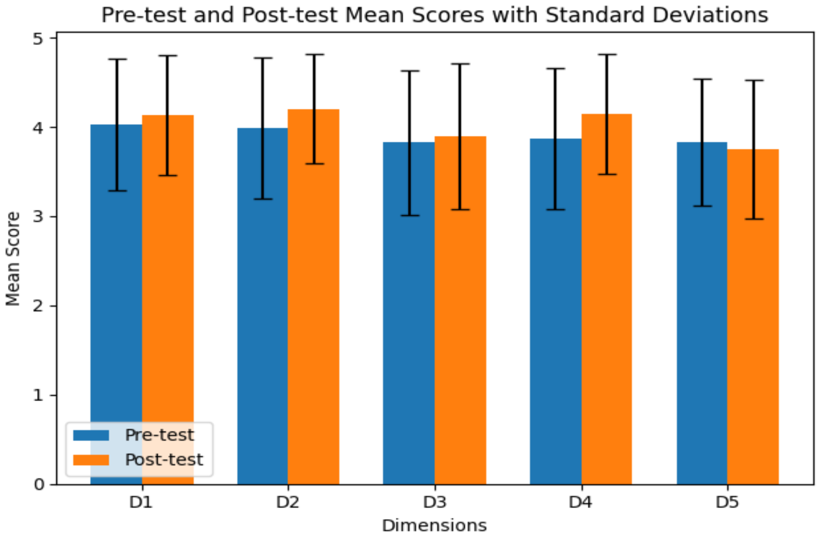
Table 1. Paired-samples t-test results for pre-test and post-test scores across five dimensions (N=17)

Dimension	Pre-test M (SD)	Post-test M (SD)	T	p	Cohen's d
D 1	4.02 (0.74)	4.13 (0.67)	-0.97	.338	0.11
D 2	3.99 (0.79)	4.20 (0.61)	-2.02*	.046	0.22
D 3	3.82 (0.81)	3.90 (0.81)	-0.51	.612	0.06
D 4	3.87 (0.79)	4.15 (0.68)	-2.04*	.046	0.25
D 5	3.82 (0.71)	3.75 (0.78)	0.53	.600	-0.06

N=17; $^*p < .05$

D 1: Self-awareness and scientific inquiry skills
D 2: Interest in scientific inquiry
D 3: Interest in designing scientific experiments or activities
D 4: Interest in designing science and interdisciplinary science teaching activities
D 5: Confidence in designing scientific and interdisciplinary teaching activities

The results indicated statistically significant improvements in Dimension 2, t = -2.02, p = .046, d = 0.22, and Dimension 4, t = -2.04, p = .046, d = 0.25. No significant differences were found in Dimension 1 (t = -0.97, p = .338), Dimension 3 (t = -0.51, p = .612), or Dimension 5 (t = 0.53, p =.600). Seventeen pre-service teachers showed a positive interest in interdisciplinary knowledge and self-efficacy. T-tests and Cohen's d analyses revealed significant differences between pre- and post-test results in Dimemsion 2 and 4. The 6-week intervention increased pre-service teachers' interest in designing scientific inquiry, scientific activities, and interdisciplinary activities, with variation between pre- and post-test responses. No significant differences were found between pre-test and post-test results regarding self-awareness and scientific inquiry skills.



Graph 1. The comparisons between the pre-test and post-test

As it's clearly shown in Graph 1, the mean score of D1, D2, D3, and D4 increased, and D5 decreased slightly in the post-test compared to the pre-test. In other words, data collected and analyzed from the questionnaire showed that pre-service teachers exhibited a slight increase in interest in scientific inquiry skills and in designing interdisciplinary science and STEAM activities. However, their confidence in designing such activities decreased slightly (Graph 1).

3.1. The performance of preservice teachers' work

Preservice teachers complete many interesting STEAM activity designs. All the STEAM educational activities designed by the preservice teachers incorporated scientific inquiry, including manipulated, control, and dependent variables, in their experimental designs. Their individual final reports presented a variety of interesting and fun projects, including catapults, paper tracks, gear tracks, floating boats, creative water filters, and springs. Pre-service teachers completed numerous engaging interdisciplinary activities, including a catapult, a building-block gear track, a float boat, a creative water filter, a spring, a bubble design, a toy racing car, and more. The STEAM educational activities designed by the participants incorporated scientific inquiry into the manipulation of independent and dependent variables and the use of control variables in their experimental design. Following the training, the participants gained confidence, reported higher self-efficacy, and expressed interest in interdisciplinary instructional design. Seventeen preservice teachers demonstrated strong affirmation of STEAM learning and teaching, as well as technical skills in designing cross-field activities. The findings indicated that preservice teachers considered how to integrate science, technology, engineering, and mathematics and to make the work both functional and aesthetically pleasing. Some of the students' work is listed as follows.

An example of a preservice teacher's STEAM activity design was presented in Tables 2 and 3. The preservice teacher, Grace, presented a basic design of STEAM activity and performance assessment strategies for elementary students. This activity design presented the control variables, manipulated variables, and dependent variable. She mentioned that she would guide students in designing the paper track, taking into account interactions between marbles and the track. The rationale of activity design is listed in Table 2. The science domain guides students in learning about the relationship between friction and the paper track. Discuss how the trace speed affects the final drop point on the paper track. The technology domain is computer simulation. The engineering domain involves designing and building the track, as well as addressing any problems that may arise. The art domain tries to make the work aesthetically pleasing. The mathematics domain involves calculating the rolling trajectory most suitable for the marble (e.g., see Table 2). Grace mentioned that elementary students can learn from the play and figure out the relationships between marbles and the paper track. The skills for computer simulation and slope calculation are beyond the reasoning of elementary students. It is more appropriate for junior high school students to explore friction, run computer simulations, and calculate the slope of the paper track. Grace's work on the paper track design is listed in Table 2.

Table 2. Grace's work-paper track design

Science	Explore the friction: Different paper materials have different friction levels, which affect the marble's rolling speed and, in turn, its final landing point.
Technology	Computer simulations can be used to calculate the optimal track design by modeling friction and the marble's trajectory.
Engineering	The actual track was made of paper, and potential problems (such as slope, stiffness, and height) were addressed by reinforcing it with different media.
Art	Beautify the track. Paper tracks are only white or gray. You can use techniques such as cutting and pasting colored paper to design the entire track into the style of an amusement park.
Mathematics	Since the track is 3D, there is a slope issue, which requires mathematical calculations to determine the most suitable rolling trajectory for the marble.

The scoring rubric designed by Preservice teacher Grace was used to measure student performance in track design, as listed in Table 3.

Table 3. Grace's work-assessment for STEAM activity design

Science	2	The effects of two or more different frictional forces on marbles can be calculated in detail.
	1	The effect of a single type of frictional force on a marble can be calculated.
	0	Cannot be calculated.
Technology	2	It can use computers to simulate the track and calculate the optimal design to ensure the best score every time.
	1	A computer can be used to draw the track, but it cannot calculate the optimal score track.
	0	It is impossible to simulate the derailment pattern using a computer.

Engineering	2	It can be used to build tracks from computer simulations, and the experiments can be repeated without the tracks breaking or collapsing.
	1	It is possible to create a track, but there may be discrepancies between the actual track and the computer simulation. Alternatively, it may be possible to create a track, but the experiment cannot be repeated, and it may collapse.
	0	Unable to create a track.
Art	2	It can beautify the tracks into interesting shapes, adding creativity and color so they are not just plain white and gray.
	1	The tracks are beautified with simple colors; there is no special creativity, just color used for aesthetics.
	0	The tracks are not aesthetically pleasing.
Mathematics	2	The slope calculation is correct and is indeed the optimal method; it can be applied in a computer simulation to compute the optimal trajectory.
	1	It can calculate the slope, but the resulting slope is not necessarily optimal for the trajectory, and it cannot be applied to computer simulations.
	0	Unable to calculate the slope.

The marble-and-track activity is fun for elementary and junior high school students. The STEAM activity is better suited for junior high school students to investigate concepts across the five STEAM domains. In reality, if STEAM activity design is limited to the primary school level, preservice teachers will face many restrictions when designing activities. Therefore, there are no restrictions on designing STEAM activities outside elementary school for preservice teacher training. An example from preservice teacher Chen is his introduction of a buoyancy activity. He designed the Algodoo physics simulation game for the STEAM activity's technology domain. The objective of this activity is to explore the buoyancy of different objects in the water. The objects include an apple, a table tennis, a toy car, and a coin. The leading question is “Which of the following items will float on the surface of water or sink in the water?”.

3.2. Preservice teacher Eric’s work

As shown in Figure 1, a catapult was made by preservice teacher Eric, a ballistic device used to launch a projectile a great distance without the aid of gunpowder or other propellants.

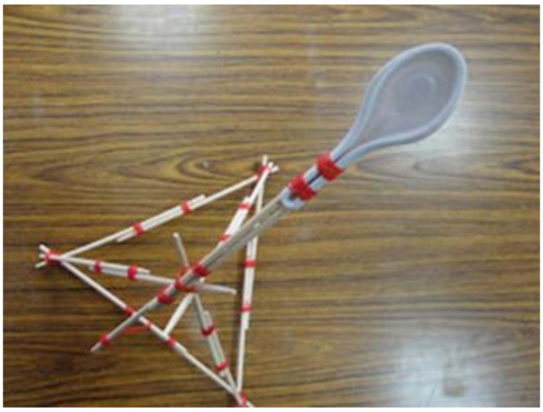


Figure 1. A catapult created by preservice teacher Eric

Eric pointed out that the catapult design considered one of many items as the control material, along with stick material, spoon material, the catapult structure, and the rubber band. The next step was to select the above items and take turns considering each as the manipulated variable. The range distance would be the dependent variable for the experimental design of the catapult activity. Eric's work and report provided a well-organized, concise design for the catapult activity within the domains of science, technology, engineering, art, and mathematics.

3.3. Preservice teacher Grace's work

Grace developed a falling activity to explore the relationships between different parachute designs and falling speed. She mentioned that the activity was designed to guide learners in exploring the principle that a parachute harnesses air resistance to extend the time required for objects to land; when air resistance is small, the falling speed increases. She tried to guide the students to explore whether, when the resistance is high, the speed decreases or increases. She guided students to figure out that the larger the umbrella's surface area, the greater the air resistance, and the slower the descent. The smaller the umbrella's surface area, the lower the resistance and the faster the descent. From Grace's work and report, she demonstrated a clear parachute design and an inquiry into the relationships among parachutes with different appearances, shapes, and descent speeds.

Another qualitative data point, collected from preservice teachers' reports on STEAM activity design, indicated that 17 preservice teachers (100%) completed the design, encompassing the disciplines of science, technology, engineering, art, and mathematics. Fifteen preservice teachers (88%) could clearly explain the content of their designs across different disciplines. Fourteen (82%) preservice teachers could clearly design an assessment rubric for STEAM activities. Overall, all the pre-service teachers presented numerous engaging interdisciplinary activities, including a catapult, a gear track, a float boat, a creative water filter, a spring, and many fantastic activity designs. The STEAM educational activities designed by the participants incorporated scientific inquiry into the manipulation of independent and dependent variables and the use of control variables in their experimental design. At the end of the study, the participants demonstrated positive self-efficacy and expressed interest in science and in designing interdisciplinary activities. However, the complexity of the STEAM activity designs might be why they feel unconfident at the end of the study when they have to implement them in a real classroom without any teaching practice. Finally, the preservice teachers showed slightly lower confidence in designing scientific and interdisciplinary teaching activities than at the beginning of the study.

4. *Discussion*

The results indicated that all seventeen preservice teachers strongly affirmed learning scientific inquiry and interdisciplinary instruction, particularly in STEAM learning and teaching activities. The participants were more interested in designing and implementing STEAM activities. Preservice teachers improved their technical skills for designing cross-field activities. Their interests in interdisciplinary knowledge and self-efficacy are positive. Further data analysis of the t-test and Cohen's d revealed significant differences between the pre-test and post-test in the dimensions 2 and 4. It demonstrated that preservice teachers showed differences in their pre- and post-test responses regarding their interests in designing scientific inquiry, scientific activities, and interdisciplinary activities. There were no significant findings regarding self-awareness and scientific inquiry skills between the pre-test and post-test. Based on their work and report, preservice teachers effectively designed the variables for STEAM activities. This might be because enhancing preservice teachers' scientific inquiry and interdisciplinary science instructional design skills within just six weeks is quite challenging. They need more training in integrating thinking skills across disciplines and more practice to build personal awareness and confidence in scientific inquiry skills. Similar research findings from an experiment-based intervention with pre-service primary school teachers emphasize that practical, hands-on experimental experiences are crucial for developing the professional competence and self-confidence of future primary teachers in science education (Beudels et al., 2022).

Due to time constraints and the need to keep pace with the course schedule, the individual teaching demonstrations of preservice teachers were not executed in the study. When pre-service teachers consider how to translate their designed STEAM activities into actual teaching, they may encounter problems and uncontrollable factors that can undermine their confidence. It might be the reason why preservice teachers' confidence decreased at the end of the study (e.g., Table 1, Graph 1). Hence, microteaching is a good pedagogical practice for transforming the activities they developed into teaching. Microteaching is recommended for future training and research design in teacher preparation for STEAM education. It meant they showed greater interest at the end of the study in the domains of scientific inquiry and in designing science and interdisciplinary science teaching activities. On the other hand, there were no significant differences between the pre-test and post-test in Dimensions 1, 3, and 5. It was evident that preservice teachers did not perform much better in the domains of self-awareness and scientific inquiry skills, interest in designing scientific experiments or activities, or confidence in designing scientific and interdisciplinary teaching activities. However, the preservice teachers expressed greater interest in the post-test than in the pre-test in the domains of self-awareness and scientific inquiry, as well as in designing scientific experiments or activities. On the other hand, pre-service teachers' confidence in designing cross-disciplinary STEAM activities decreased. Lee and Shea (2016) studied pre-service elementary school teachers' views on inquiry-based teaching. The starting point of this study was that if elementary school teachers lacked confidence in their ability to teach science, they were likely to give up teaching the subject altogether (Lee & Shea, 2016). In Taiwan, many students are accustomed to being passive recipients of knowledge, striving to achieve high exam scores through rote memorization without engaging in deep critical thinking. In reality, they may not feel particularly interested in learning. A similar learning style is used by many students from elementary school through university. Hence, it was encouraging to find that the preservice teachers showed growth in their interest in scientific inquiry and in designing science and interdisciplinary science teaching activities. Preservice teachers may lack sufficient training in designing open-ended interdisciplinary science investigations. Meanwhile, due to time constraints in the curriculum schedule, they conduct science work and follow cookbook-style protocols rather than engage in exploratory practice. Pre-service teachers generally expressed uncertainty about how to convert specific teaching objectives tailored to individual abilities into concrete lesson plans. Training periods could be extended to strengthen preservice teachers' capacity to design cross-field science activities.

Lazarides and Warner (2020) stated that teachers with high levels of self-efficacy are more open to new instructional approaches, set more challenging goals, exhibit greater planning and organization, put forth effort to solve problems, seek assistance, and modify their instructional approaches when encountering difficulties. Hence, more training is needed to strengthen the preservice teachers' self-efficacy in STEAM interdisciplinary activities and instructional design. In Taiwan, design-based strategy of intervention that combines programming like maker educational tools with project-based learning, such as Scratch, Arduino, Micro: bit game design, has repeatedly shown the preservice teachers' computational thinking, relevant science content, and attitudes toward computer programming with positive implementation and satisfaction outcomes (Tsai et al., 2022; Tsai, 2024). It is important to deepen and broaden the interdisciplinary nature of scientific, critical, and creative inquiry. It could positively impact preservice teachers' self-efficacy and future science teaching capabilities. Meanwhile, more support and encouragement are effective ways to help preservice teachers build confidence, positive self-efficacy, and interest in interdisciplinary instructional design. Because this study did not delve into the design and implementation of cross-disciplinary STEAM instruction for elementary science teacher preparation, the next study, in addition to exploring the design of scientific inquiry activities for pre-service teachers, will need to further examine their ability to teach cross-disciplinary inquiry activities.

Preservice-focused interventions stated that structured practicum experiences can facilitate elementary teachers toward more complex forms of inquiry and help them apply inquiry into practice (Contreras et al., 2024), while practice-based science methods coursework enhances preservice teachers' notice about student sensemaking during practice, which will facilitate evidence-based discussions emphasized by both Taiwan's 108 curriculum guidelines and NGSS (Arias et al., 2024). Hence, not only the design of activities but also the pedagogical practice of instructional design is important for preservice teachers. For future studies, preservice teachers are encouraged to express their ideas and demonstrate their teaching skills during their microteaching after completing the STEAM activity design. Li and Chiu (2019) compared the similarities and differences between Taiwan's new curriculum guidelines and the NGSS in science. The results showed slight differences in teaching methods, the content of inquiry and practice, and model construction. NGSS helps students develop competence in understanding models and modeling processes more than in Taiwan. Experiencing modeling-based inquiry could help students develop stronger systematic problem-solving skills (Li &

Chiu, 2019). Scientific inquiry, combined with an interdisciplinary instructional approach, is an effective way for preservice teachers to build on their disciplinary knowledge. Inquiry-based teaching and learning strategies will be adapted to reflect preservice teachers' learning diversity and progress.

Menon and Sadler (2016) studied 18 participants and divided them into low, medium, and high groups based on their initial self-efficacy levels. Quantitative results showed that participants' science-teaching self-efficacy and scientific-concept comprehension improved significantly. The improvement in scientific concept comprehension was moderately positively correlated with improvements in individual science teaching self-efficacy, suggesting that enhanced subject knowledge may be an important potential mechanism for improving teaching confidence. Menon and Sadler (2018) continued to investigate the factors contributing to the development of preservice elementary school teachers' science-teaching self-efficacy in physics classes. They found that four major curriculum factors significantly influence the development of preservice teachers' self-efficacy, including enhanced conceptual understanding, active learning experiences, teaching strategies modeled by instructors, and the instructor as a role model. Therefore, a conceptual understanding of the course content is very important for learners, especially in cross-field STEAM teaching and learning. It would be a key concern in enhancing preservice teachers' self-efficacy in STEAM instructional design.

To sum up, the cross-contextual model suggests that research on the self-efficacy of pre-service STEAM teachers in Taiwan needs more explicit STEAM design efficacy measurement indicators beyond attitudes and critical thinking, practice-based implementation, such as: microteaching and rehearsals to provide the strongest international evidence on how design experience transfer into lasting confidence, promoting integrated and standards instruction (Johnson et al., 2021; Menon, 2023; Ribeirinha & Correia, 2025). Nowadays, Taiwan's measurement development and survey research have also begun to incorporate activity design-related behaviors, such as adopting teaching practices that promote students' scientific autonomy and integrating sustainable development goals into science learning activities. These concepts align with STEAM design, which emphasizes exploration, evidence-based reasoning, cooperation, and social science problem-solving skills (Smith, 2024). Therefore, more specific assessment strategies will be developed to measure preservice teachers' work, such as microteaching and instructional design for future study.

5. Limitations and future research

Methodological limitations include observing and analyzing preservice teachers' performance in designing interdisciplinary science activities and collecting their work, as well as a lack of prior research findings for comparison. Future research will collect preservice teachers' outcomes from their interdisciplinary activity design before the research. Since only a subset of the preservice teachers in our department need to take this course, the participation of a few people limited the generalizability of this study. A larger sample size is recommended to increase the reliability of the estimate and generalizability. Meanwhile, the research findings can be applied to university courses and science teacher education programs to implement STEAM activities.

6. Conclusion

This study showed that preservice teachers' self-efficacy in scientific inquiry and interest increased, while their confidence in designing STEAM interdisciplinary activities decreased slightly. It is not only about acquiring knowledge but also about developing the procedural knowledge required for scientific inquiry, including operational skills and logical thinking. Furthermore, to implement STEAM education, teaching strategies, and assessment strategies are considered for intervention to support the instructor's action research in higher education settings. It is also worth integrating STEAM education into the curriculum, including encouraging students to explore interdisciplinary concepts, build greater self-efficacy, and develop confidence in designing cross-field instructional activities. For further study, efforts should focus on strengthening pre-service teachers' capacity to design cross-field science activities and on raising the level of thinking in design with respect to student background. More diversified, cross-domain professional activity skills training courses are recommended for implementing elementary science teacher preparation. Especially for elementary preservice teachers, the interdisciplinary implementation of STEM education is an effective way to enhance their scientific inquiry and problem-solving skills and to motivate them to develop higher levels of creative and critical thinking. It is also worth considering how to guide preservice teachers toward deeper levels of thinking in STEAM interdisciplinary activity design, and how to integrate activity design with instruction remains a topic for future research.

Acknowledgments

I want to express my sincere gratitude to the anonymous reviewers for their valuable comments, which helped improve this paper. I would also like to thank all the preservice teachers involved in the research for their cooperation; their contributions made this research possible.

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