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UNIVERSITY STUDENTS' ATTITUDES TOWARDS STEAM VIA A THEMATIC 3D DESIGN PROJECT

Tsai-Yun Mou

Abstract. *The development of STEAM education has captured researchers' attention due to its advantages for students' learning and interest in related subjects, specifically in kindergarten to grade 12 (K-12) educational settings. However, there is limited research on the inclusion of STEAM in higher education, and what university students think as they are on the professional training track. This study aimed to examine university students' attitudes towards STEAM via a 3D design project. Twenty-seven college students participated in this study. A questionnaire and focus group interviews were administered at the end of the course to uncover the students' learning enjoyment, conceptions of STEAM learning, and intentions of STEAM future design/work involvement. The results show that the students enjoyed the 3D STEAM project regardless of their performance. High-performance students had higher conceptions of STEAM learning after the project. All of the students highly agreed that they could integrate interdisciplinary knowledge into their 3D designs. With regard to future intentions, they generally did not show an active attitude towards STEAM involvement. The students' learning enjoyment in the STEAM project did not have a strong positive correlation with their future intentions. Findings from this study could offer inspiration for art-oriented courses that look for potential interdisciplinary integration and expression in STEAM.*

Keywords: *attitudes towards STEAM, university students, STEM, 3D design*

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Introduction

The development of STEAM education has become a trend in recent years. The original term STEM, which emerged at the beginning of the 1990s, is often defined by including disciplines of Science, Technology, Engineering, and Mathematics in order to develop human capital in these fields (Martín-Páez et al., 2019). While there are different definitions of STEM education among researchers (Sanders, 2009; Shaughnessy, 2013), a broadly supported idea is that STEM education is a meta-discipline in which particular subject content is undivided, and integrated teaching and learning approaches are used to understand and solve real-world problems (Bybee, 2013; Merrill & Daugherty, 2010). The evolution of STEM education was later extended to a broader domain through the integration of arts into a cohesive learning paradigm (Liao, 2019). Therefore, in STEAM education, art plays an important role in transforming and reshaping the profound knowledge of STEM into a more approachable and pleasant form for people of different ages (Land, 2013; Madden et al., 2013; Yakman, 2010). Based on this viewpoint, this research attempted to adopt art and design to interpret and reshape STEM-related issues. Moreover, it is known that nowadays educational training has shifted its focus to diverse competency, or what is called the 21st-century skills, which include life and career skills, learning and innovation skills, and information, media, and technology skills (Bellanca, 2010; Griffin & Care, 2015). All of these skills have to be obtained in interdisciplinary learning settings for better outcomes or achievements, and art plays a unique and irreplaceable role in this tendency (Liao, 2016; Madden et al., 2013).

There are plenty of studies on STEM or STEAM education in kindergarten to grade 12 (K-12) educational settings (Davis et al., 2019; Kennedy et al., 2016; Lange et al., 2019; Sahin, 2019; Schroth & Daniels, 2020). These studies adopted various approaches, materials, and forms to enhance students' interest in the STEAM domains. The success and implementation of these studies are unquestionable. In a STEAM study in middle school classrooms, the researchers pointed out that by remixing education in the context of STEAM, instead of offering new instruction, they altered existing practices and introduced STEAM education into the classrooms (Herro & Quigley, 2016). Previous research also shows that an integrative approach among STEAM could have positive effects on students' learning of related subjects (Becker & Park, 2011). Shahali et al. (2016), in their research on

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secondary school students, found that integrating engineering design in the context of STEAM could increase their level of interest in those subjects and in related careers as well. Besides, the role of art in STEAM education cannot be ignored either. Quigley et al. (2017) used art as an expression of STEM issues in marine science teaching, and their project-based learning approach further triggered students' exploratory attitude towards other academic subjects, such as mathematics, social studies, music, English, and social services. Therefore, STEAM's transdisciplinary approach can introduce students to multiple ways of thinking, and allow them to participate in related fields (Savage et al., 2008). Nevertheless, the research on STEAM is mostly focused on the K-12 educational settings (Chen & Lo, 2019; Liao, 2016; Ng, 2017; Taylor, 2016), while there is limited information about students' attitudes or points of view, specifically those of university students.

It is regarded that learning in university is mainly about professional training. Students in specific programs acquire related professional skills and knowledge in order to contribute to related domains. Nevertheless, learning at university does not mean that students learn only domain-specific knowledge; interdisciplinary learning is also important in higher education. The 21st-century skills are not only diverse but also dynamic. Therefore, it is necessary for university students to expand their learning experiences so as to face the ever-changing future. STEAM education at the university level needs to have a well-designed model for teaching practices (Quigley et al., 2017). Discipline integration is one of Quigley et al. (2017) proposed models to connect content and synthesize disciplines for STEAM education. It is critical for university students to accumulate interdisciplinary learning experiences for their life and future careers (Frodeman et al., 2010; Zhan et al., 2017). Therefore, this study examined university students' attitudes towards STEAM via a thematic 3D design project.

Literature Review

The Role of Arts in STEAM

The inclusion of arts in STEM means that it plays a special role in STEAM education. Art and design are often considered creative aspects of expression. While science, technology, engineering, and mathematics emphasize logic and convergent thinking, art and design highlight divergent thinking or so-called creativity (Clinton & Hokanson, 2012; Land, 2013). It is the creative element that distinguishes art and design from other academic fields. Hence, when Yakman (2010) proposed the idea of STE@M, the researcher regarded that science and technology were interpreted through engineering and arts and were based on mathematical elements. However, this viewpoint was not widely supported in academia at that time. Years later, John Maeda, the previous president of the Rhode Island School of Design, interpreted the definition of STEAM and promoted it at different educational levels so that it gradually became mainstream in education (Maeda, 2012). The researcher pointed out that it is through the expression of arts that conventional science, technology, engineering, and mathematics can be integrated and can be made approachable to students. The design process that is adopted in the art and design field is now introduced to STEM classrooms, and the creative process is used in and becomes part of STEM education (Bequette & Bequette, 2012). As a matter of fact, art education often adopts problem-based learning or project-based learning (PBL) to develop students' higher-order thinking skills as they investigate ill-defined problems (Costantino, 2002). Previous studies acknowledged the advantages of utilizing arts as a presentation of STEM content (Bass et al., 2016; Bequette & Bequette, 2012; Chen & Lo, 2019; Costantino, 2018; Ng, 2017; Rolling Jr, 2016). Arts can help with the evolution of learners' understanding of scientific concepts and contribute to STEAM practice in education (Dhanapal et al., 2014; Knochel, 2013). Hence, the role of arts in STEAM can be treated as an integrative representation of different disciplines.

STEAM Works in Higher Education

As mentioned earlier, STEAM education is mostly adopted in K-12 educational settings. Nevertheless, there are still some studies on STEAM in higher education. Radziwill et al. (2015), in their senior capstone course, prototyped a zonohedral dome with 3D printing to visualize an interactive learning space. This work involved interactive, participatory, and dialogic design. The students had interdisciplinary experiences in the capstone project. Keefe and Laidlaw (2013) adopted an interdisciplinary collaboration between art and science students to visualize human blood flow through a branching coronary artery on a virtual reality (VR) platform. The data visualization provided an interesting platform for teaching, as well as a great experience for students with dif-

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ferent majors. Guyotte et al. (2014) arranged a collaboration among art education, engineering, and landscape architecture students, conceptualizing STEAM as a social practice, and reflecting concerns for the community and environment. The art installations revealed creativity in transdisciplinary spaces. In some cases, these experiences have even impacted students' career paths. With the development of technology, STEAM education has also been practiced in robot design. Lavicza et al. (2018), in their robotics workshops which utilized Arduino-based ReBOT Kit, 4Dframe, and GeoGebra mathematics software, found that working with robots increased students' motivation, engagement and attitude towards learning. Moreover, they pointed out that the students further developed their creative problem-solving skills and had authorship through the design of aesthetic aspects of the robots. Besides, STEAM learning activities have also gained broad attention in many maker-center projects. Some educators further regard the maker movement as an opportunity for STEAM education (Gerstein, 2013; Peppler & Bender, 2013). The "Traditional cigar box guitar" by Frauenfelder (2010) is a good example. As Clapp and Jimenez (2016) in their review of maker projects indicated, the guitar project demonstrated an incorporation of the arts into STEM education. It provided young makers with the opportunity to understand the mechanics and musical qualities of string instruments through the creation of a customized guitar. It was an appealing project because it took arts as a core focus, while also deepening STEM knowledge learning (Liu et al., 2021). All of the above-mentioned studies demonstrate that art can be integrated into diverse disciplines and can even provide deep reflections and experiences for students. These STEAM studies in higher education were a milestone for further research. However, besides the advantages of STEAM education for students, it is also important to know students' attitudes towards STEAM. In other words, to what degree do students experience enjoyment in class and to what degree does the experience affect their future interdisciplinary careers? These questions need to be further examined and, in this study, we probe this aspect from the point of view of art and design students.

Research Questions

The purpose of this study was to examine university students' attitudes towards STEAM from their experiences of a thematic 3D design project. By conducting a questionnaire and focus group interviews at the end of the project, this study aimed to find out their thinking about combining art with STEM. Below are the research questions which guided this study.

1) What is the correlation between students' learning enjoyment and project performance in a 3D design STEAM project?
2) What are the students' attitudes towards STEAM learning through thematic 3D design?
3) What are the students' intentions to be involved in future STEAM design/work?

To examine the correlation between students' learning enjoyment and project performance, their final project grades and self-reported enjoyment levels were compared and analyzed. Moreover, through the examination of their project grades and their conceptions of STEAM learning, this study expected to identify the differences among students. Finally, to find out to what extent a 3D design STEAM project could influence students' intentions of future STEAM design/work involvement, both their questionnaire and interview responses were analyzed. Through the collected data, this study expected to uncover more of the university students' attitudes towards STEAM.

Research Methodology

This exploratory research was conducted in a 3D course in the year 2020. Because the participants had no previous experience of STEM-related topics for 3D design, no specific hypothesis was proposed beforehand. The project-based learning approach was adopted, and the class was a blended learning environment with in-class teaching and post-class online materials. Since the sample size was small, a non-experimental study was chosen. Notwithstanding, the study adopted both qualitative (focus group interviews) and quantitative (questionnaire) methods to obtain more comprehensive information from the participants.

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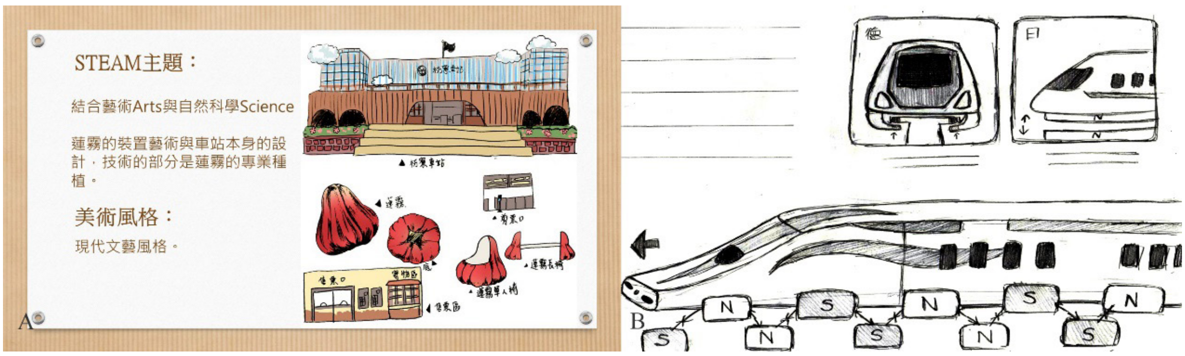
Research Design

The project-based learning approach was adopted in this study. The teacher introduced the course outline and requirements at the beginning of the semester. The class was 3 hours per week and the semester was 16 weeks, during which the teacher and students had face-to-face teaching and feedback. Each student had to complete a 3D design that illustrated a STEM concept of his/her choice. The teacher introduced the STEAM concepts based on the explanations from Maeda (2012). Practices of STEAM work from around the world were also brought to the class for stimulating discussion and motivation. The students selected a STEM topic that interested them and proposed their design ideas to the class. Two examples of students' design proposals are shown in Figure 1.

Figure 1
Examples of Students' Design Proposals



(A) The planting science and installation of wax apples in Fangliao train station; (B) The principle of the Maglev train

During the semester, the teacher provided 3D modeling techniques and design principles to assist the students with the practical creation of their works. The in-class learning materials were also offered online for post-class study in a blended learning environment. Besides training their hands-on skills, the teacher assisted students in resolving project problems and provided suggestions for project design. Hence, the students could collect feedback regularly to improve their final projects in a positive learning environment. Besides their project proposals, the students' project progress and final designs were also required to be submitted via the online platform as assignments throughout the semester. Each of the students was also asked to set his/her schedule to complete the project by the end of the semester. Knowing one's own design progress is advantageous to time management and planning. This way of arrangement was to assist the students in developing active learning attitudes and behaviors. Through the class requirements and self-monitoring of their project progress, the students could learn to take responsibility for their project, which is essential in project-based learning. A previous study also pointed out that students' awareness of their learning process is important, and can intensify their performance as well (Warburton & Volet, 2013).

At the end of class, an assessment was conducted to examine the students' 3D STEAM design performance. The students presented their work and the teacher provided feedback to them in class. The teacher used a rubric which included the clarity of the STEM content (STEM clarity and STEM correctness) and the technical performance of the 3D design (3D completeness, 3D elaboration, and 3D layout) to grade their performance. Moreover, the questionnaire and interviews were administered to obtain the students' learning enjoyment in the course, their conceptions of STEAM learning, intentions of future STEAM design/work involvement, and their attitudes towards and experiences of the 3D design STEAM project. The structure of the course design and the weekly curriculum are shown in Figure 2 and Table 1 respectively.

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Figure 2
Structure of the Course Design

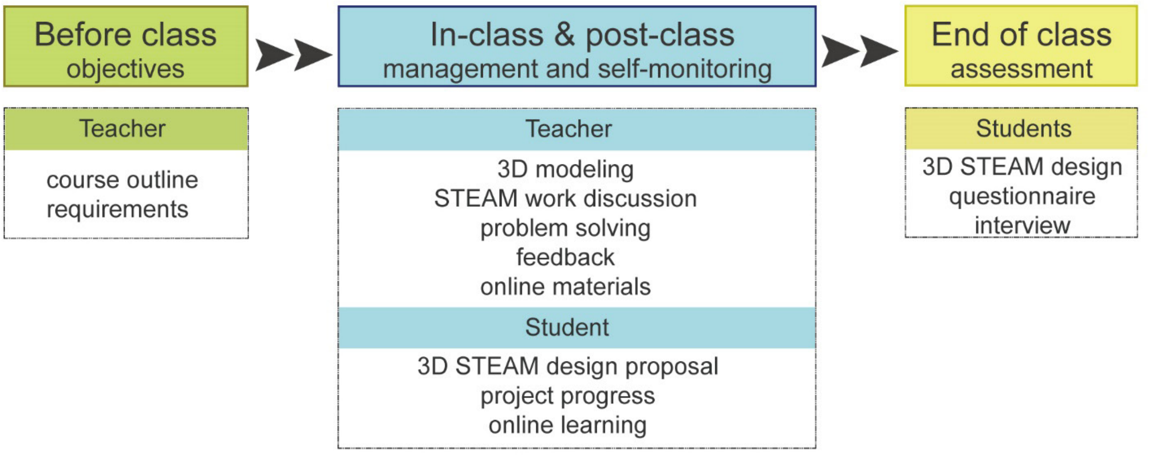

Table 1
The Weekly Curriculum

Week	Week 1	Weeks 2-5	Weeks 6-7	Weeks 8-14	Weeks 15-16
In-class activity	• Course introduction	• STEAM work discussion • 3D modeling practice	• 3D STEAM proposal	• Project progress • Problem solving • 3D modeling practice	• Project presentation • Feedback

Participants

Since this exploratory study aimed to examine students' attitudes towards STEAM through a thematic 3D design project, the number of participants was limited. A total of 27 university students (9 males, 18 females) from a Visual Arts department participated in this study. Their average age was 20. The study was conducted in a selective 3D modeling course in the curriculum. All of the participants had basic 3D software skills and had taken the Introduction to 3D Animation course. However, none of the participants had previous experience of STEAM-related projects. The students were notified of the class objectives and understood the research procedure for the semester. All students consented to join the research and finish their 3D design projects.

Focus Group

Focus group interviews were administered at the end of the semester to obtain the students' thinking and experiences in the 3D design STEAM project. The teacher guided the semi-structured discussion topics, and the students answered with their perspectives and opinions. With the element of synergy and interaction between the group members, this study hoped to synthesize a common view from the university students (Basch, 1987; Dilshad & Latif, 2013; Green & Thorogood, 2018). The interview questions were examined by two experts to confirm the validity of the questions. Five focus groups were formed in this study and each group consisted of three students. Each group session lasted for approximately one hour. All of the discussion responses were recorded for further analysis. Two experienced teachers coded the same text to ensure consistency of judgment. Some samples of the open-ended questions are listed below.

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1) What was your experience in the 3D STEAM project?
2) What were the challenges in your 3D STEAM project?
3) What did you think about the project in terms of your learning and future STEAM involvement?

Questionnaire

The questionnaire was administered at the end of the semester to obtain the students' attitudes towards the project. Data from the questionnaire were collected using the self-report survey method (Eppes et al., 2012). The questionnaire was based on a previously validated instrument which included three elements: interest, ability, and value (Mahoney, 2010). In this study, the survey items were modified to fit the context and comprised nine items collecting information on students' learning enjoyment (Cronbach's alpha = .82), interdisciplinary knowledge (Cronbach's alpha = .85), and future intention (Cronbach's alpha = .87). Students were asked to respond on a 5-point Likert scale from *strongly agree* (5) to *strongly disagree* (1). Two advisors were invited to preview the items to ensure the validity of the instrument. Table 2 shows the items in the questionnaire.

Table 2
The Questionnaire Items

	Items
Learning enjoyment	• I think the curriculum design of this class is interesting. • I enjoy doing the STEAM design project. • The class increases my interest in 3D design.
Interdisciplinary knowledge	• The STEAM project enhances my interdisciplinary knowledge. • The STEAM project provides me with opportunities to integrate interdisciplinary knowledge. • The STEAM project promotes my application ability in interdisciplinary knowledge.
Future intention	• I will continue engaging in STEAM design/creation. • I will encourage other people to participate in STEAM. • I am interested in a STEAM career in the future.

Data Analysis

In this study, data were collected at the end of the course. Descriptive and correlational analyses were used to analyze the quantitative data. To determine correlations between the variables, Spearman's rho was used since the data did not have a normal distribution. Regarding the qualitative data, a research assistant recorded and transcribed the interview responses without the participants' names or project grades attached to ensure non-biased coding. The conceptual analysis method was adopted to examine the participants' narratives. The transcripts were analyzed by two experienced teachers to code and determine themes related to the research questions. By sifting the data, sorting out quotes and making comparisons, they finalized the thematic content based on the three elements: learning enjoyment, interdisciplinary knowledge, and future intention. The inter-coder reliability of an interview sample was .85.

Research Results

Students' Self-Reported Enjoyment Level and Project Performance

At the end of the class, all of the students completed the 3D design STEAM project and participated in the survey. Their project performance was graded by the teacher based on the clarity of the STEM content (50%) and the technical performance of the 3D design (50%). The students did not know their grades when they completed the survey. Table 3 shows the students' project performance.

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Table 3
Descriptive Results of the Students' Project Performance

N = 27	Project performance		
	M	*SD*	%
High (6)	88	1.67	22
Medium (12)	83.67	1.44	45
Low (9)	77	5.57	33
ALL	82.41	5.39	100

From Table 3, we can see that six of the students were categorized as having high performance, while 12 and nine students respectively were ranked as having medium and low performance. Only 22% of the students clearly presented the STEM concepts and revealed their 3D skill proficiency in their projects, while 78% could only express part of the STEM knowledge and showed medium or basic 3D skills.

Regarding their enjoyment of the 3D design STEAM project, the students generally responded with positive attitudes. Table 4 illustrates the students' self-reported enjoyment level.

Table 4
The Students' Self-Reported Enjoyment Level

	Project performance			
Enjoyment level	High %	Medium %	Low %	Total %
Strongly agree	17	33	23	26
Agree	83	50	33	52
Slightly agree	0	17	44	22
Disagree	0	0	0	0
Strongly disagree	0	0	0	0
Total	100	100	100	100

As shown in Table 4, 78% of the students reported that they strongly agreed or agreed that they experienced enjoyment during the project, while only 22% slightly agreed, and none felt negative about it. This implies that integrating STEM topics into the 3D design course is feasible since all of the students had a certain level of enjoyment of the project. The students enjoyed the 3D design STEAM project regardless of their project performance.

Examining the differences among students, it was found that students with high and medium performance had higher agreement levels than the low-performance students. All of the high-performance students reported strongly agree or agree, and 83% of the medium-performance students had the same responses. The low-performance students obviously revealed less enjoyment than others. Nevertheless, in general, the students enjoyed the 3D design STEAM project.

To examine whether there is a correlation between students' learning enjoyment and project performance, Spearman's rho was adopted to calculate the relationship. Table 5 shows the results. The value of r_s is 0.28. This means that the association between learning enjoyment and project performance is considered as low. This corresponds to the findings presented in Table 3, in which the students enjoyed the 3D design STEAM project regardless of their project performance.

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Table 5
Spearman's Rho Correlation Coefficient Between Variables

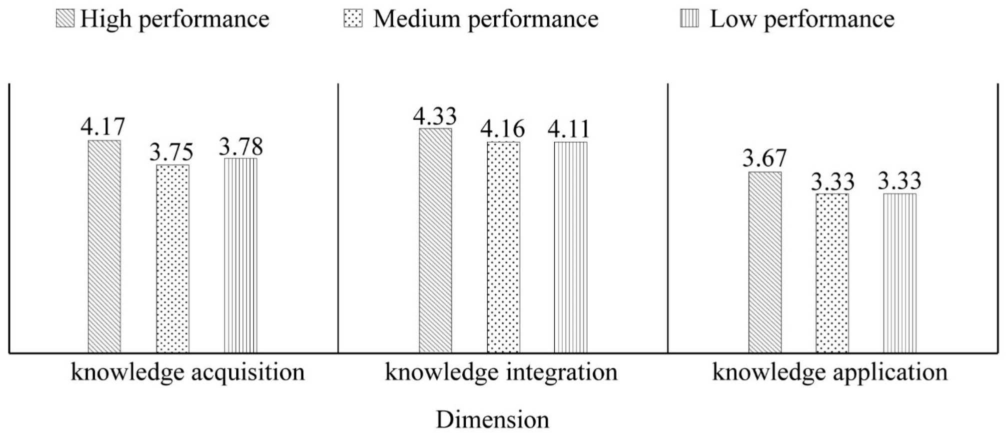
	Learning enjoyment	Project performance
Learning enjoyment	1	.28***
Project performance	.28***	1

p = .14

Students' Attitudes Towards STEAM Learning

To find out to what extent the students learned interdisciplinary knowledge through the project, we inquired into their responses and compared them with their performance. Three dimensions of STEAM learning were examined: knowledge acquisition, knowledge integration, and knowledge application. Figure 3 presents the students' self-reported STEAM learning from different levels of student performance.

Figure 3
Students' Self-Reported Attitudes Towards STEAM learning



As demonstrated in Figure 3, compared with others, students with high performance had more positive attitudes towards STEAM learning after this project. They believed their STEAM knowledge acquisition and integration increased after the design project. Besides, it is noticeable that in the knowledge integration dimension, all of the students highly agreed that they could integrate knowledge into their 3D design representation. However, concerning interdisciplinary knowledge application, it seems that most of the university students only held a slightly positive attitude, within which high-performance students held slightly higher agreement.

Students' Intentions of Future STEAM Involvement

In this study, the participants did not have previous experience with STEAM-related design/work. Therefore, their attitudes towards future STEAM project involvement were analyzed. Their responses to the survey are shown in Figure 4.

As revealed in Figure 4, most of the students had only slightly positive intentions regarding joining future STEAM design or work. The mean score of all students was 3.35. Among the responses, high-performance students had slightly higher intentions than other groups. To further find out whether there were differences among students, we conducted a simple *t*-test. The *t*-value was -.78, and the *p*-value was .22 (> 0.05). There was no significant difference among students. This means that the students had a similar level of intention regarding future STEAM involvement.

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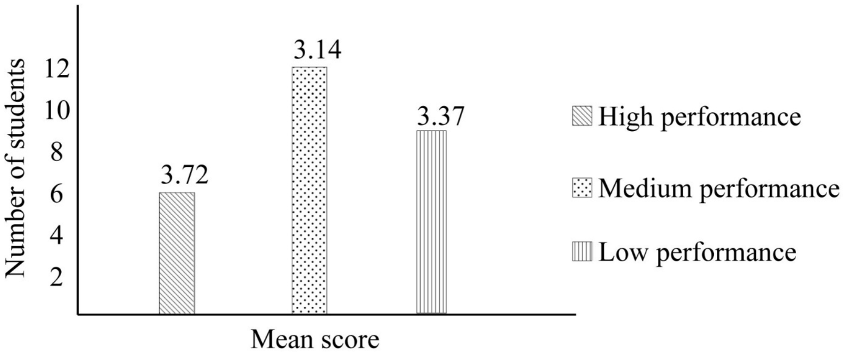
Figure 4
Students' Intentions of Future STEAM Involvement



To further understand the university students' intentions concerning specific STEAM involvement, we examined each survey question. Table 6 presents the descriptive results of the students' intentions regarding different types of STEAM involvement. As shown in Table 6, in terms of continuing to engage in STEAM design/creation, most of the students did not reveal an active attitude toward this survey item. The average score was 3.22. This means that they would not be actively involved in related design themselves. With regard to encouraging others to participate, they showed a slightly stronger intention to promote STEAM design/creation. As for career choice, although the mean score was 3.48, it appeared to be the highest response in the survey. Therefore, we further calculated the Spearman's correlation coefficient to determine whether there was a correlation between learning enjoyment and career choice. Table 7 shows the results. The value of r_s is .27, p (2-tailed) = .17. This means that the association between learning enjoyment and career choice cannot be considered statistically significant. This indicates that the enjoyment the students had in the project did not have a strong positive correlation with their future career selection.

Table 6
Descriptive Results of Different Types of STEAM Involvement Intention

STEAM involvement	High performance		Medium performance		Low performance		Total	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
I will continue engaging in STEAM design/creation	3.50	0.55	3.00	0.60	3.33	1.22	3.22	0.80
I will encourage other people to participate in STEAM design/creation	3.83	0.41	3.08	0.67	3.33	1.32	3.33	0.83
I am interested in a STEAM career in the future	3.83	0.41	3.33	0.78	3.44	1.01	3.48	0.77

Table 7
Spearman's Rho Correlation Coefficient Between Learning Enjoyment and Career Choice

	Learning enjoyment	Career choice
Learning enjoyment	1	.27***
Career choice	.27***	1

p = .17

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Students' Qualitative Feedback on the STEAM Design Project

At the end of the class, qualitative responses through semi-structured focus group interviews were collected to obtain the university students' thinking and experiences in the 3D design STEAM project. Their responses were coded and categorized into themes as learning enjoyment, attitudes towards STEAM learning, and intentions of future STEAM involvement. Table 8 displays the students' main viewpoints. Positive and negative replies are both presented to reveal the students' true attitudes.

Table 8
Students' Interview Feedback

	Learning enjoyment
+	• I chose the cocoa beans topic because I love chocolate and I did find interesting facts and history about cocoa beans. • The design process of the theme is enjoyable. I can learn how to visualize the STEM concept and practice my 3D skills at the same time. • It's my first time conducting a STEAM project. I'm excited to learn new things that open up a window for 3D design.
-	• I prefer to create my 3D design with imagination and fantasy. The STEAM project is too restrictive. • It is difficult for me to connect STEM content with art. It took me a long time to search for and decide on which theme to develop for the project.
	Attitudes towards STEAM learning
+	• This project reminds me of my high school science class. Now I feel upgraded because I can transform STEM knowledge into a more approachable form with 3D design. • It is through this project that I learned science knowledge of cane sugar refining. I think it's a good approach to integrate science and art and interestingly acquire new knowledge.
-	• It's good to acquire interdisciplinary knowledge with the 3D design project. However, I do not think it's useful to me at this stage. • I don't know how to apply the STEM knowledge I learned to other aspects or domains. Besides knowledge acquisition, it is hard to relate learning to other fields.
	Future intentions
+	• STEAM is a brand new domain for me. I've never thought that art skills can be applied to science. I may think about this direction for future work. • I've noticed that STEAM is growing vigorously in recent years. Since art is an indispensable part of STEAM, I will definitely consider engaging in related work or creation.
-	• The project is fun. However, I will not engage in STEAM-related creation in the future because I prefer more artistic expression of imagination. • For me, it's like an assignment to accomplish at the end of the class. I fulfilled the request and probably will not encourage others to participate in STEAM-related design. I couldn't find much fun in it.

From the students' feedback shown in Table 8, we can see that in the learning enjoyment aspect, students who expressed positive feedback chose topics of interest to them and thus could find pleasure in the creation process. They enjoyed learning new things, whether it was knowledge or skills, and had an open attitude towards STEAM. In contrast, students who expressed negative feedback tended to be more art-oriented and had a somewhat limited vision in terms of 3D creation. They liked the 3D design but only in the context of the art field. As we have shown in Tables 4 and 5, most of the students regarded the project as pleasurable, and they enjoyed the 3D design STEAM project. Although the students had different levels of performance, their enjoyment levels did not have a significant difference. Therefore, synthesizing the quantitative and qualitative data presented above, we could infer that most of the students had a positive attitude towards the project and enjoyed the learning experiences regardless of their project performance.

In the attitudes towards STEAM learning aspect, as we can see above, the students thought they had acquired new knowledge through the project and developed the ability to combine science and art in the form of 3D design. However, it seems that the knowledge they learned did not have a direct link to them, nor was it helpful to them. They did not think the knowledge could be applied or related to other fields either. These positive and negative responses correspond to the survey results in Figure 3. The students revealed slightly higher cognitions of knowl-

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edge acquisition but lower cognitions of knowledge application. Concerning knowledge integration, it showed the highest score compared with the other dimensions. This implies that most of the students believed that they were capable of embodying STEM knowledge with 3D design, regardless of their performance.

In the future intentions aspect, some students had positive thinking about continuing in related creation or work. They believed that their art skills had the potential for development in STEAM. These responses are in line with the survey item in which the students showed slightly higher intention (score 3.48) in future creation/work compared with other items. Regarding the negative feedback, whether the students had fun or not, their reasons for not engaging in STEAM creation/work lie in the limitations of the design theme and assignment request. They would not proactively take part in related design themselves nor encourage others to participate. As we can see from the results in Table 6, the students only had a slight agreement with the survey items. Overall, although most of the university students experienced enjoyment while working on the projects, they did not reveal strong aspirations for future STEAM creation. Some final designs from the students are shown in Figure 5.

Figure 5
Some Final Designs by the Students

Note. (A) The structure of a green roof; (B) The principle of the Maglev train; (C) The process of cane sugar refining; (D) The structure and principle of an airfoil

Discussion

This study examined university students' attitudes towards STEAM through a 3D design project. The results indicated that the students enjoyed the project regardless of their project performance. There was a low correlation between students' learning enjoyment and project performance (r_s = .28). This finding suggests that combining STEM topics with 3D art creation is workable for curriculum design. Similar suggestions were also provided in previous research which found that visualization was a way to connect art and science and could constitute STEAM practice in art education (Dhanapal et al., 2014; Knochel, 2013). The students found pleasure in exploring interdisciplinary themes, selecting the topics, and visualizing the concepts with 3D design. The findings on students' interest and pleasure through art expression of STEM issues are in line with the literature (Ahn & Choi, 2015; Guyotte et al., 2014; Quigley, Harrington, et al., 2017). This process of project-based learning (PBL) is helpful for students to probe into topics of interest to them and further polish their 3D skills. Hence, they thought the project was enjoyable and they had pleasure in the learning process.

However, as revealed in other results, their intentions regarding future STEAM involvement were relatively low. This result is contradictory to previous research which found positive attitudes toward related subjects or careers (Engelman et al., 2017; Ifenthaler et al., 2015; Shahali et al., 2016; Thuneberg et al., 2017). Having fun in STEAM learning is not supportive enough for students to engage in STEAM design or work in the future. There are some possible reasons for this situation. First, the students were new to STEAM in this study. Although they knew that art is an integrated part of STEAM, they would still choose a related career based on their professional training experiences. Second, the STEAM project was a course assignment, and thus, despite experiencing enjoyment while working on the project, the students would not actively pursue or participate in STEAM creation themselves. As presented in Table 7, the analysis of the relationship between learning enjoyment and career choice also revealed a low correlation (r_s = .27). Although in the interview some students revealed positive thinking about continuing

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with STEAM-related design/work, if we probe into these responses, their considerations were based on pragmatic concerns. They regarded STEAM as a trend or as having potential development for art involvement. In other words, while most of the university students would choose a professional-oriented career, some would premeditate joining the STEAM domain based on practical considerations. Notwithstanding, this practical viewpoint actually echoed the perspective of Maeda (2013) who advocated that the aim of STEAM was to cultivate people to use the skills and creativity in art with STEM knowledge in order to devote themselves to social progress and economic growth (Liao, 2019). Therefore, in this study, whether their enjoyment in the STEAM domain would be sustained and would continue in their career development needs to be investigated in the future.

Another interesting finding in this study is the students' attitudes towards STEAM learning. High-performance students, compared with others, generally had higher cognitions of knowledge acquisition, integration, and application after the project. Although the acquisition and application aspects may not show distinctly high scores, their self-reported beliefs reflected their confidence in the 3D design STEAM project. Therefore, we can see a little higher future intention of STEAM involvement in high-performance students as well (Table 6).

For the knowledge integration aspect, students at all levels of learning performance highly agreed that they could integrate STEM knowledge into their 3D design representations. This phenomenon is interesting since not all of the students performed well in the project. There are some possible explanations. First, as we have discussed above, most of the students experienced pleasure in doing the project. This phenomenon corresponds to previous studies that found students' interest and enjoyment in related subjects (Chen & Lo, 2019; Shahali et al., 2016; Thuneberg et al., 2017). In this study, the PBL procedure that they experienced offered the students opportunities to explore the STEM domain, select topics, and visualize the concepts with their 3D design skills. It was through this process that they gained enjoyment. As the correlation analysis is shown in Table 5, the association between learning enjoyment and project performance is considered as low ($r_s = .28$). This means that the students enjoyed the project regardless of their performance. Therefore, it is understandable that they regarded themselves as capable of integrating STEM with 3D design since they enjoyed the project. Second, the completion of the project could have enhanced the students' beliefs. Since all of the students finished the design project, they could have mistaken their knowledge integration ability that was being developed. As a result, the students generally showed high agreement in the knowledge integration dimension.

Conclusions and Implications

This study examined students' attitudes towards STEAM through a 3D design project. The results implied that the students enjoyed the project regardless of their project performance. Their affirmatory project experiences showed a positive linkage between art and STEM, as well as a potential field for exploration. Through the 3D design project, the students at all levels of learning performance revealed high agreement in STEM-related knowledge acquisition and integration of their interests. However, they did not consider that the knowledge could be applied to other fields, nor that they would engage in future STEAM work. They generally did not show an active attitude towards STEAM involvement.

The inclusion of STEM content in other disciplines is an inexorable trend in education and learning. Arts, as a form of creative expression, play specifically unique roles in linking interdisciplinary domains. As previous art educators advocated, art making could be an important element of the STEAM curriculum. The findings from this research offer some inspiration for art-oriented courses that look for potential interdisciplinary integration and expression. In this study, the 3D design of the STEAM project is achievable in curriculum design to enhance university students' interest. Nevertheless, there still remains a gap between a feasible course implementation in educational settings and a beneficial course design for the need of interdisciplinary talents in various industries. Future research could further explore how to adopt proper pedagogical approaches or curriculum design to develop university students with not only professionality but also an open mind to join the STEAM domains actively. In addition, to strengthen the intersection among STEAM disciplines and increase university students' future intentions, it is also suggested that their perspectives on different STEM domains be collected. This information could provide educational researchers and practitioners with a thorough and sound understanding of their views which is important for the interdisciplinary pedagogical design. Finally, to achieve the goal of cultivating students with 21st-century skills in this transdisciplinary era, individual educators can originate with small strategies and class projects to evaluate the potentiality and advantages of the practice of STEAM education.

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Scope and Limitations

This exploratory study on university students' attitudes towards STEAM through thematic 3D design is a preliminary attempt to reveal perspectives from the art side. Although the number of participants is small, the initial findings from this study could shed some light on the integration of STEAM topics for university students. Developing university students with open thinking and willingness to join interdisciplinary work should be a continuous endeavor for both teachers and students. More studies on STEAM education from the art/design point of view will be needed in the future.

Ethics Approval

This study was approved by the National Cheng Kung University research ethics committee and was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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References

Ahn, H.-S., & Choi, Y.-M. (2015). Analysis on the effects of the augmented reality-based STEAM program on education. *Advanced Science and Technology Letters*, *92*(1), 125-130.

Basch, C. E. (1987). Focus group interview: An underutilized research technique for improving theory and practice in health education. *Health Education Quarterly*, *14*(4), 411-448. https://doi.org/10.1177/109019818701400404

Bass, K. M., Dahl, I. H., & Panahandeh, S. (2016). Designing the game: How a project-based media production program approaches STEAM career readiness for underrepresented young adults. *Journal of Science Education and Technology*, *25*, 1009-2004. https://doi.org/10.1007/s10956-016-9631-7

Becker, K., & Park, K. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education: Innovations & Research*, *12*(5), 23-27.

Bellanca, J. A. (2010). *21st century skills: Rethinking how students learn*. Solution Tree Press.

Bequette, J. W., & Bequette, M. B. (2012). A place for art and design education in the STEM conversation. *Art Education*, *65*(2), 40-47. https://doi.org/10.1080/00043125.2012.11519167

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. National STEM Teachers Asociation.

Chen, C. W. J., & Lo, K. (2019). From teacher-designer to student-researcher: A study of attitude change regarding creativity in STEAM education by using Makey Makey as a platform for human-centred design instrument. *Journal for STEM Education Research*, *2*(1), 75-91. https://doi.org/10.1007/s41979-018-0010-6

Clapp, E. P., & Jimenez, R. L. (2016). Implementing STEAM in maker-centered learning. *Psychology of Aesthetics, Creativity, and the Arts*, *10*(4), 481-491. https://doi.org/10.1037/aca0000066

Clinton, G., & Hokanson, B. (2012). Creativity in the training and practice of instructional designers: The design/creativity loops model. *Educational Technology Research and Development*, *60*(1), 111-130. http://www.jstor.org/stable/41415020

Costantino, T. (2018). STEAM by another name: Transdisciplinary practice in art and design education. *Arts Education Policy Review*, *119*(2), 100-106. https://doi.org/10.1080/10632913.2017.1292973

Costantino, T. E. (2002). Problem-based learning: A concrete approach to teaching aesthetics. *Studies in Art Education*, *43*(3), 219-231. https://doi.org/10.1080/00393541.2002.11651720

Davis, B., Francis, K., & Friesen, S. (2019). *STEM Education by Design: Opening Horizons of Possibility*. Routledge.

Dhanapal, S., Kanapathy, R., & Mastan, J. (2014). A study to understand the role of visual arts in the teaching and learning of science. Asia-Pacific Forum on Science Learning & Teaching, Hong Kong.

Dilshad, R. M., & Latif, M. I. (2013). Focus group interview as a tool for qualitative research: An analysis. *Pakistan Journal of Social Sciences (PJSS)*, *33*(1), 191-198. http://pjss.bzu.edu.pk/index.php/pjss/article/view/189

Engelman, S., Magerko, B., McKlin, T., Miller, M., Edwards, D., & Freeman, J. (2017). Creativity in authentic STEAM education with EarSketch. 2017 ACM SIGCSE Technical Symposium on Computer Science Education, Seattle, USA.

Eppes, T. A., Milanovic, I., & Sweitzer, H. F. (2012). Strengthening capstone skills in STEM programs. *Innovative Higher Education*, *37*(1), 3-10. https://doi.org/10.1007/s10755-011-9181-0

Frauenfelder, M. (2010). Traditional cigar box guitar. *Make*, *21*, 76-85.

Frodeman, R., Klein, J. T., & Mitcham, C. (2010). *The Oxford handbook of interdisciplinarity*. Oxford University Press.

https://doi.org/10.33225/jbse/23.22.294

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Gerstein, J. (2013). STEAM and maker education: Inclusive, engaging, self-differentiating. https://usergeneratededucation.wordpress.com/2013/07/23/steam-and-maker-education-inclusive-engaging-self-differentiating/
Green, J., & Thorogood, N. (2018). *Qualitative Methods in Health Research 4th Edition*. Sage Publications.
Griffin, P., & Care, E. (2015). *Assessment and Teaching of 21st Century Skills: Methods and Approach*. Springer.
Guyotte, K. W., Sochacka, N. W., Costantino, T. E., Walther, J., & Kellam, N. N. (2014). STEAM as social practice: Cultivating creativity in transdisciplinary spaces. *Art Education*, *67*(6), 12-19. https://doi.org/10.1080/00043125.2014.11519293
Herro, D., & Quigley, C. (2016). Innovating with STEAM in middle school classrooms: remixing education. *On the Horizon*, *24*(3), 190-204. https://doi.org/10.1108/OTH-03-2016-0008
Ifenthaler, D., Siddique, Z., & Mistree, F. (2015). Designing for open innovation: Change of attitudes, self-concept, and team dynamics in engineering education. In *Emerging Technologies for STEAM Education* (pp. 201-215). Springer. https://doi.org/10.1007/978-3-319-02573-5_11
Keefe, D. F., & Laidlaw, D. H. (2013). Virtual reality data visualization for team-based STEAM education: Tools, methods, and lessons learned. In R. Shumaker, *Virtual, Augmented and Mixed Reality. Systems and Applications* Berlin, Heidelberg.
Kennedy, J., Lee, E., & Fontecchio, A. (2016). STEAM approach by integrating the arts and STEM through origami in K-12. In. 2016 IEEE Frontiers in Education Conference (pp. 1-5). Eire, USA. https://doi.org/10.1109/FIE.2016.7757415
Knochel, A. (2013). Histochemical seeing: Scientific visualization and art education. *Studies in Art Education*, *54*(2), 187-190. https://doi.org/10.1080/00393541.2013.11518892
Land, M. H. (2013). Full STEAM ahead: The benefits of integrating the arts Into STEM. *Procedia Computer Science*, *20*, 547-552. https://doi.org/10.1016/j.procs.2013.09.317
Lange, A. A., Brenneman, K., Mano, H., & Zan, B. (2019). *Teaching STEM in the Preschool Classroom*. Teachers College Press.
Lavicza, Z., Fenyvesi, K., Lieban, D., Park, H., Hohenwarter, M., Mantecon, J. D., & Prodromou, T. (2018). Mathematics learning through Arts, Technology and Robotics: Multi-and transdiscpilinary STEAM approaches. In. *8th ICMI-East Asia Regional Conference on Mathematics Education*. Taipei.
Liao, C. (2016). From interdisciplinary to transdisciplinary: An arts-integrated approach to STEAM education. *Art Education*, *69*(6), 44-49. https://doi.org/10.1080/00043125.2016.1224873
Liao, C. (2019). Creating a STEAM map: A content analysis of visual art practices in STEAM education. In M. S. Khine & S. Areepattamannil (Eds.), *STEAM Education: Theory and Practice* (pp. 37-55). Springer International Publishing. https://doi.org/10.1007/978-3-030-04003-1_3
Liu, C.-Y., Wu, C.-J., Chien, Y.-H., Tzeng, S.-Y., & Kuo, H.-C. (2021). Examining the quality of art in STEAM learning activities. *Psychology of Aesthetics, Creativity, and the Arts*. https://doi.org/10.1037/aca0000404
Madden, M. E., Baxter, M., Beauchamp, H., Bouchard, K., Habermas, D., Huff, M., Ladd, B., Pearon, J., & Plague, G. (2013). Rethinking STEM education: An interdisciplinary STEAM curriculum. *Procedia Computer Science*, *20*, 541-546. https://doi.org/10.1016/j.procs.2013.09.316
Maeda, J. (2012). *STEM to STEAM: Art in K-12 is key to building a strong economy*. https://www.edutopia.org/blog/stem-to-steam-strengthens-economy-john-maeda
Maeda, J. (2013). STEM + Art = STEAM. *The STEAM Journal*, *1*(1), Article 34. https://doi.org/10.5642/steam.201301.34
Mahoney, M. P. (2010). Students' attitudes toward STEM: Development of an instrument for high school STEM-based programs. *The Journal of Technology Studies*, *36*(1), 24-34. https://doi.org/10.21061/jots.v36i1.a.4
Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J., & Vílchez-González, J. M. (2019). What are we talking about when we talk about STEM education? A review of literature. *Science education*, *103*(4), 799-822. https://doi.org/10.1002/sce.21522
Merrill, C., & Daugherty, J. (2010). STEM education and leadership: A mathematics and science partnership approach. *Journal of Technology Education*, *21*(2), 21-34. https://digitalcommons.usu.edu/ncete_publications/59/
Ng, O.-L. (2017). Exploring the use of 3D computer-aided design and 3D printing for STEAM learning in Mathematics. *Digital Experiences in Mathematics Education*, *3*, 257-263. https://doi.org/10.1007/s40751-017-0036-x
Peppler, K., & Bender, S. (2013). Maker movement spreads innovation one project at a time. *Phi Delta Kappan*, *95*(3), 22-27. https://doi.org/10.1177/003172171309500306
Quigley, C., Harrington, J., & Herro, D. (2017). Moving beyond STEAM. *Science Scope*, *40*(9), 32-39. https://www.jstor.org/stable/26389165
Quigley, C., Herro, D., & Jamil, F. M. (2017). Developing a conceptual model of STEAM teaching practices. *School Science and Mathematics*, *117*(1-2), 1-12. https://doi.org/10.1111/ssm.12201
Radziwill, N. M., Benton, M. C., & Moellers, C. (2015). From STEM to STEAM: Reframing what it means to learn. *The STEAM Journal*, *2*(1), 1-7. https://doi.org/10.5642/steam.20150201.3
Rolling Jr, J. H. (2016). Reinventing the STEAM engine for art+ design education. *Art Education*, *69*(4), 4-7. https://doi.org/10.1080/00043125.2016.1176848
Sahin, A. (2019). *STEM education 2.0: myths and truths – What has K-12 STEM education research taught us?* Brill | Sense.
Sanders, M. E. (2009). STEM, STEM education, STEMmania. *The Technology Teacher*, *68*(4), 20-27.
Savage, R., Chen, K., & Vanasupa, L. (2008). Integrating project-based learning throughout the undergraduate engineering curriculum. *Journal of STEM Education*, *8*(3-4), 15-27. https://eric.ed.gov/?id=EJ1096179
Schroth, S. T., & Daniels, J. (2020). *Building STEM Skills Through Environmental Education*. IGI Global.
Shahali, E. H. M., Halim, L., Rasul, M. S., Osman, K., & Zulkifeli, M. A. (2016). STEM learning through engineering design: Impact on middle secondary students' interest towards STEM. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(5), 1189-1211. https://doi.org/10.12973/eurasia.2017.00667a

https://doi.org/10.33225/jbse/23.22.294

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Shaughnessy, J. M. (2013). Mathematics in a STEM context. *Mathematics Teaching in the Middle School*, *18*(6), 324. https://doi.org/10.5951/mathteacmiddscho.18.6.0324

Taylor, P. C. (2016). *Why is a STEAM curriculum perspective crucial to the 21st century?* Australian Council for Education Research, Brisbane, Australia.

Thuneberg, H., Salmi, H., & Fenyvesi, K. (2017). Hands-on math and art exhibition promoting science attitudes and educational plans. *Education Research International*, *2017*. https://doi.org/10.1155/2017/9132791

Warburton, N., & Volet, S. (2013). Enhancing self-directed learning through a content quiz group learning assignment. *Active Learning in higher education*, *14*(1), 9-22. https://doi.org/10.1177/1469787412467126

Yakman, G. (2010). What is the point of STEM?–A Brief Overview. *Steam: A Framework for Teaching Across the Disciplines. STEAM Education*, *7*. https://www.academia.edu/8113832/What_is_the_Point_of_STEAM_A_Brief_Overview_of_STEAM_Education

Zhan, Y., So, W. W. M., & Cheng, I. N. Y. (2017). Students' beliefs and experiences of interdisciplinary learning. *Asia Pacific Journal of Education*, *37*(3), 375-388. https://doi.org/10.1080/02188791.2017.1301880

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