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From stereotype to reality: A pilot study on the use of science, technology, engineering, and mathematics and STEAM in design education in Taiwan

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Currently, STEAM interventions in design education are a relatively new phenomenon. A design education system derives from three major ideas from the Bauhaus: (1) art and technology: a new unity; (2) human-centered design; and (3) interdisciplinarity, which is the essence and connotation of STEAM. In the transition from STEM to STEAM, the concept and mindset of art connect the four disciplines within STEM, elevating these tools and methods into a strategy. It is urgently necessary for design educators to restructure their curriculum using STEAM models and thought. However, there is no evidence that the integration of these disciplines will improve design education for the public. Consequently, this study examines the perception of educators and the public regarding the use of STEAM in design education. Using expert interviews, six design schools were selected as samples, and questionnaires were used to collect and analyze the views of different groups of people. According to the results, the expert group scored fairly high; and other groups will form stereotypes based on the characteristics of the school, resulting in a polarized assessment of STEAM. All groups displayed cognitive differences in many aspects. It is evident from this study that the STEAM model should be incorporated into design education; however, it is necessary to determine objectively the relationship between the five attributes and their relative importance within different design fields. Under the premise of complying with policies, regulations, and the actual situation of the school, the design of the curriculum planning needs to be adjusted and supplemented in a timely manner according to the STEAM model. Specifically, it cannot be arranged arbitrarily for STEAM, but it should also let students understand what STEAM is about so that they can understand why these courses exist. Furthermore, researchers should examine the effectiveness of these courses over time by conducting a phased retrospective.

KEYWORDS

STEM and STEAM, design education, humanities and arts literacy, interdisciplinarity cooperation, cognitive ergonomics

1. Introduction

Recently, the academic community has been interested in the concept, scope, and core theory of STEM and STEAM, and these successive publications provide strong theoretical support (Babaci-Wilhite, 2018; Culén and Gasparini, 2018; Milner-Bolotin, 2018; Khine and Areepattamannil, 2019; Videla et al., 2021; Anabousy and Daher, 2022). We live in a designed world. STEAM by design presents a transdisciplinary approach to learning that challenges young minds with the task of making a better world. STEAM by design develops designing minds. Designing minds work across STEAM fields developing social, cultural, technological, environmental, and economic responses to existing and future conditions. STEAM by design positions designing as world pedagogy that connects students as citizen activists in the communities in which they live and learn.

Back to field of design and creativity, since the 20th century, the German model has always occupied a pivotal position in the global design field, forming the Bauhaus–Ulm System (Bredendieck, 1962; Phelan, 1981; Harrington, 1988; Lerner, 2005; Ascher, 2015). The German design education model has become the benchmark in many countries. In Taiwan, modern design education was also influenced by the Bauhaus. It is constantly adjusted according to the development of the times, and has gradually formed a design education model suitable for Taiwan (Lu and Lin, 2010; Tsao and Lin, 2011; Wu et al., 2012). Since the 21st century, although the energy of design has flourished with the advancement of science and technology, and the style and type of design have also been constantly updated with the evolution of artistic and cultural concepts and trends, it is controversial whether the essence of design is implemented in so many new designs. Looking to the future, Bauhaus's three propositions for modern design education: (1) art and technology: a new unity; (2) human-centered design; and (3) interdisciplinarity, their goals and values remain unchanged. This coincides with the philosophy of STEAM (Haider, 1990; Marshall, 2014; Liao, 2016; MacDonald et al., 2019; Malele and Ramaboka, 2020; Anabousy and Daher, 2022).

The philosophy of modern design emphasizes the importance of benefiting people over products, and human-centered design is prevalent in the design of products. Therefore, whether it is "product," "design" or "evaluation," the focus is always on humans. We also follow the above principles when evaluating products or designs (Lin, 2007). Similarly, the above points apply to the development and application of the model of design education (Hanington, 2010). To achieve benign and sustainable development, it is important to continuously adjust the design education model to meet the needs of the times. As far as design education is concerned, the goal is to implement the essence of design, and to adjust how design responds to technological development and social change (Norman, 2010, 2011, 2018).

The design of the 21st century and its educational model also face challenges, which necessitate self-reform. The STEAM model is also seen as an effective way to intervene (Haider, 1990; Marshall, 2014; MacDonald et al., 2019; Malele and Ramaboka, 2020). The definition of industrial design by ICSID has also undergone many revisions, but its statement of the essence of design has stood the test of time (WDO, 2022a,b). Lin (2011) further refines those definitions and summarizes them into the following four points, which further demonstrates the rationality and necessity of applying the STEAM model to design education. They are briefly described below, and their relationship is shown in Figure 1.

1. Design is a creative act that expresses high-quality creative results through products.
2. Design is a form-making activity that applies technology to express the aesthetic effects of forming.
3. Design is an economic activity that meets the different needs of users and producers.
4. Design is also cultural creativity, which creates a daily life culture through products.

Therefore, based on the above reasons, as a theoretical framework for this study, STEAM was used, along with questionnaires and analyses, to examine the current state of STEAM in design education as well as to understand the cognitive differences between individuals and which STEAM attributes they valued. Thus, the following hypothesis is further proposed by this study:

1. The experts (who are familiar with both the target university and STEAM) gave the school a higher rating than other subjects.
2. The subjects who answered intuitively (who were unfamiliar with either the target university or STEAM) rated the lowest out of all subjects.
3. Other subjects (the general group) provided more relevant responses and may be closer to expert assessments.
4. The subjects rated their university higher than the others.

2. Theoretical framework: From STEM to STE(A)M

Although the core of design education is still influenced by the Bauhaus, it is worth paying attention to how design education should develop in the future, and the concept and mode of design education also need to be dynamically adjusted, so that the essence and spirit of design can be fully reflected (Norman, 2010, 2011, 2018; Kaur Majithia, 2017). Additionally, the revision and improvement of the design education model also need to find answers from the industry. If there is a disconnect between teaching and practical application of the knowledge and skills required, it will be difficult for design schools to train students to achieve the competencies required as designers (Cross, 2011; Chiang et al., 2021).

Science, technology, engineering, and mathematics (STEM) is a broad term used to group together these academic disciplines. This term is typically used to address education policies or curriculum choices. The acronym STEM was suggested by Rita Colwell, Ph.D., a bacteriologist who was the director of NSF in the 1980s (Marshall, 2015). The framework of STE(A)M derived from STEM, adding the category of art to the original STEM, emphasizing that future students should develop their humanistic and artistic literacy (Humart = Human + Art) and interdisciplinary ability (Interdisciplinary). In short, it is to integrate art and humanity into "rationality and objectivity" (Lin et al., 2015), and use art, culture, and humanity to connect the rational STEM to form a strategy and thought (see Figure 2). Many designs have diverse styles, types and forms, and this replicable beauty brings a lot of inspiration to design innovation and is more likely to resonate with most people. In this study, "Arts" is critical to connecting the other four attributes in STE(A)M, and becomes the core of this system. The concept of art has a very broad meaning, and this study believes that it also has cultural implications (Leong and Clark, 2003; Moalosi et al., 2008).

The STEAM model has been applied to education and training, and there have been many mature achievements and theories. For example, the formulation and application of STEAM education policies allow STEAM to be quickly promoted in teaching in related fields, and in turn examine the rationality and appropriateness of policies (Boy, 2013; Allina, 2017; Khine and Areepattamannil, 2019; Liao, 2019; Martín-Páez et al., 2019). A large number of specific application examples, or critical thinking on the STEAM model, provide a solid foundation for selecting STEAM as the core theoretical framework in this study (Land, 2013; Henriksen, 2014, 2017; Rolling,

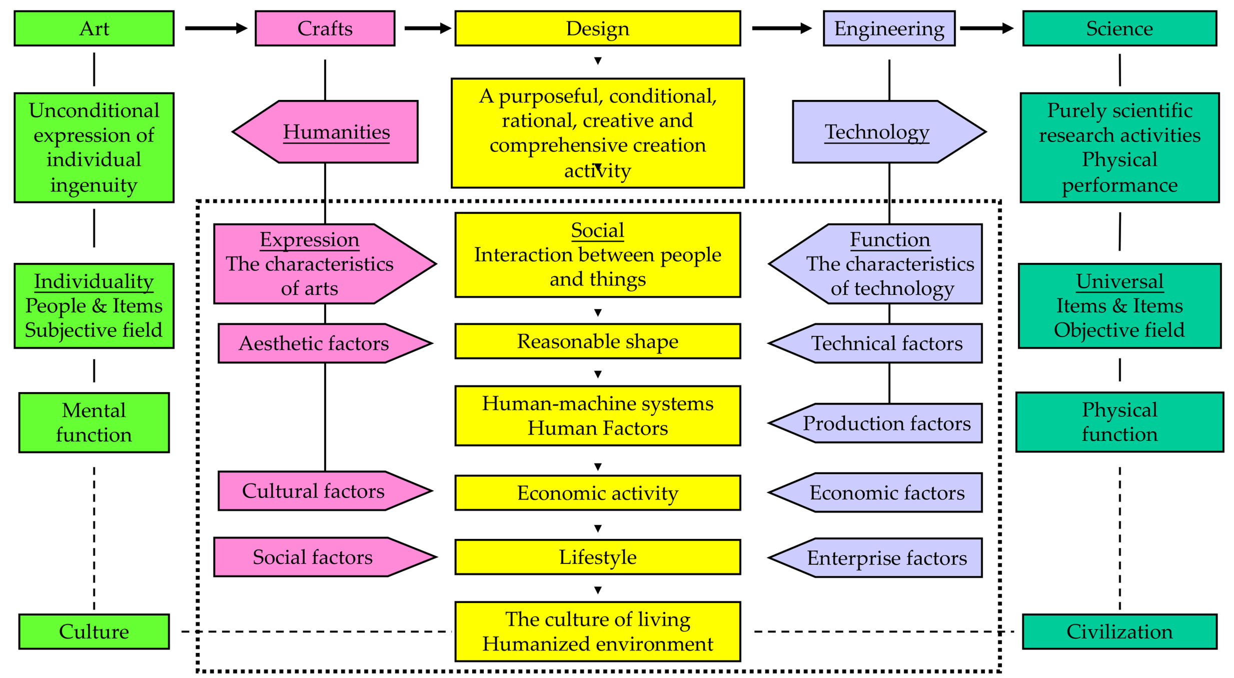

FIGURE 1
The essence of design: the balance between art and science (Source: this study).

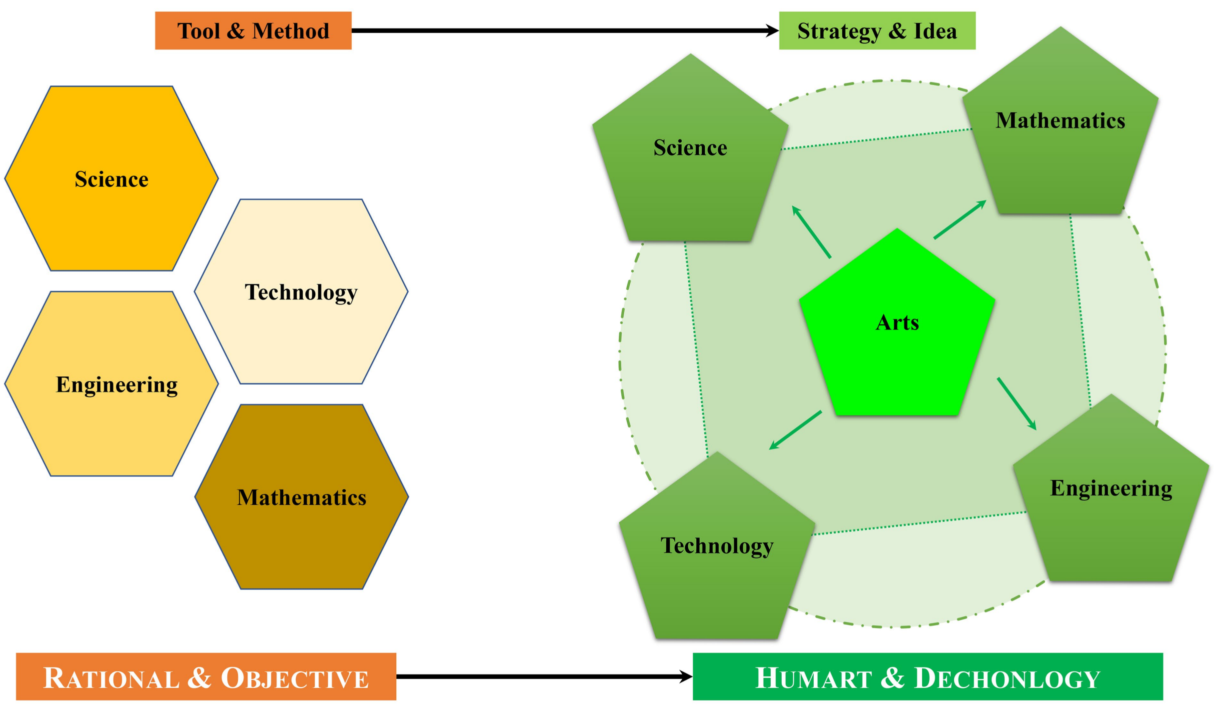

FIGURE 2
From STEM to STE(A)M: Humarts + Dechnology (Source: this study).

2016; Costantino, 2018; Colucci-Gray et al., 2019; Perignat and Katz-Buonincontro, 2019; Walshe et al., 2019; Li and Wong, 2020; Lin et al., 2021; Perales and Aróstegui, 2021).

Another reason for this study as a pilot study is to examine what are the cognitive differences between experts' and the public's perceptions of STEAM, and what is the relationship between the STEAM model and design education. How is the impact being made? STEAM, which is seen as a new driver, is also essential to ensure that it works as it is intended and can be corrected at any time based on audience feedback (Bequette and Bequette, 2012; Dahal, 2022).

In short, this study aims to understand the current status of the use of STEAM models in design education, further analyze the key points that need to be paid attention to when using STEAM models in design education by comparing the cognitive differences between subjects from different backgrounds, and provide a reference for the dynamic adjustment of STEAM models in design education in the future.

3. Methods

3.1. Procedures

Based on the previous studies, this study involved the use of questionnaire analysis to derive subjects' views on the use of STEAM in design education, as shown in Figure 3. The study can be divided into three sessions. In session I, a literature review is used to understand the difference between STEM and STEAM, and the relationship between STEAM and design education is explored. In session II, experts from the field of design were invited to conduct interviews, and design schools/laboratories from 6 universities around the world were selected as samples. The first draft of the questionnaire is analyzed and a small scale of forward testing is carried out to check the rationality of the questionnaire design. In session III, in addition to descriptive statistics, this study focuses on what is attributed to possible cognitive differences between subjects from two universities in Taiwan. Meanwhile, subjects' familiarity with the relevant university is regarded as self-variable, and the differences are analyzed after grouping, to better grasp the cognitive differences between different types of subjects.

3.2. Sample

This study argues that STEM focuses on the technical and methodological aspects, while STEAM is a strategy and idea, especially the formation of an art-centered theoretical framework. Therefore, we further selected six universities with design schools or laboratories as a sample for our studies: (1) Academic of Art & Design, Tsinghua University, (2) College of Design and Innovation, Tongji University, (3) College of Design, National Taiwan University of Arts, (4) College of Design, National Taiwan University of Science and Technology, (5) Rhode Island School of Design, RISD, and (6) MIT Media Lab (see Table 1).

Our selection of these six universities for this study is based on the fact that three of them concentrate on the arts, and the other three focus on the field of technology. This division will help this study better explore the use of the STEAM model and the current situation of design education in art or technical universities.

3.3. Questionnaire design and testing

In addition to the literature review, questionnaire was designed on the basis of several experts' insights. After the questionnaire was designed, we invited some scholars and students to fill it out and further revised the questionnaire based on their feedback. In this way, the validity and reliability of the questionnaire can be guaranteed. To better grasp their perspectives and facilitate data processing and analysis, we made copies of the questionnaires and provided them to the subjects from NTUA and NTUST. Additionally, we used online community to invite more subjects to participate. The questionnaire they filled out was named 'general edition'. Thus, 3 versions of the questionnaire were formed which are:

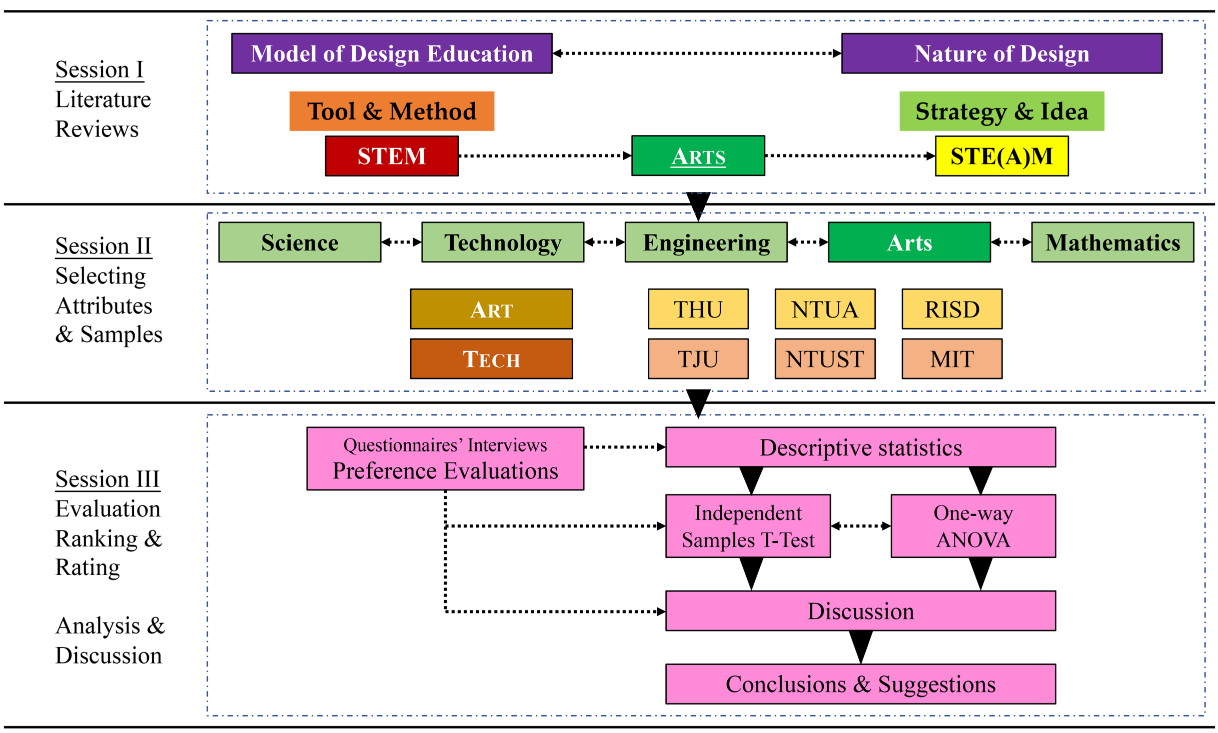

FIGURE 3
The procedures for deriving the effectiveness of the STEAM model which used in design education (Source: this study).

TABLE 1 Samples.

Group	College or laboratory of design in 6 universities
Art	Academic of Art & Design, Tsinghua University (THU)
	College of Design, National Taiwan University of Arts (NTUA)
	Rhode Island School of Design (RISD)
Science	College of Design and Innovation, Tongji University (TJU)
	College of Design, National Taiwan University of Science and Technology (NTUST)
	MIT Media Lab (MIT)

TABLE 2 The second part of the questionnaire (taking NUTA as example).

College of design, NTUA	
Are you familiar with this school?	Very low 1 2 3 4 5 Very high
Science	Very low 1 2 3 4 5 Very high
Technology	Very low 1 2 3 4 5 Very high
Engineering	Very low 1 2 3 4 5 Very high
Arts	Very low 1 2 3 4 5 Very high
Mathematics	Very low 1 2 3 4 5 Very high

general edition, NTUA edition, and NTUST edition. It should be noted that the questionnaires provided to subjects at NTUA and NTUST, we adjusted the options in age and education level, to allow those who have not yet graduated from college to answer the questionnaire.

The questionnaire is divided into two parts: the first part was the basic information of the subjects; in the second part, subjects were asked whether they were focused on STEAM at six universities, and then whether the target schools focused on the five dimensions of STEAM (see Table 2). In this study, a 5-Point Likert Scale was used for subjects with scores from 1 ("Very low") to 5 ("Very high").

The questionnaire was launched on October 26, 2022, and was created and delivered using Google Forms. The time to complete the questionnaire was limited to 2 weeks, and by November 8, 128, 115 and 60 questionnaires were received in the three editions. After analysis, all questionnaires were valid. SPSS 28.0 are used to process and analyze data. After the descriptive statistics are completed, the Independent Samples *t*-test and ANOVA are further used to analyze the data to discover what cognitive differences existed between the subjects.

4. Results and discussion

4.1. Descriptive statistics

This study focuses on whether there are cognitive differences among subjects. The variables were (1) whether the subject is familiar with the sample; (2) whether subjects knew STEAM. For the time being, we will not analyze other elements of the population variant (e.g., gender, age, education level, and experience of studying abroad), however, these data will continue to be used in future studies. The basic data of the subjects are shown in Table 3. The familiarity of subjects with the six universities in the three versions is shown in Table 4. Since the subjects are all from Taiwan, they are more familiar with NTUA and NTUST than the other four schools, which is reasonable.

The three versions of the subjects' assessments of whether these 6 universities whether to focus on STEAM are shown in Table 5:

1. The views of the general subjects and the NTUA subjects are more consistent. They all believe that MIT pays considerable attention to the four attributes of STEM. The most focused on Arts is NTUA. These assessments are based on subjects' intuitive reactions to the characteristics of the school, or they may be objective assessments that they actually know the school well.
2. Subjects from NTUST rated their schools relatively highly, with three attributes scoring first and two attributes ranking second. This may be an intuitive reaction to the subject's feelings about their own school, or it may be an assessment based on objective facts.

4.2. Differences in subjects' perceptions

After the three versions of the questionnaire were merged, we took "whether subjects know STEAM" as an independent variable, and used the Independent Samples *t*-test to grasp the cognitive differences between the subjects.

The results showed that in addition to THU, subjects had differences in cognition of some STEAM attributes for the other 5 universities. Subjects who "know STEAM" have a high average rating (see Table 6). Since the concept of STEAM is relatively professional, if subjects who do not know about it can only rely on intuition to make an assessment, a lower score is expected.

One-way ANOVA was used to determine whether there was any cognitive difference among the subjects of all three versions, and the results are shown in Table 7. It can be seen that in addition to MIT, other attributes with cognitive differences are rated higher by subjects from NTUA and NTUST. The possible reason is that because the subjects from NTUA and NTUST, which have a professional background in design, they will have a more comprehensive understanding and awareness of the relevant properties.

Subsequently, the study analyzed the feedback of subjects from NTUA and NTUST separately to understand the cognitive differences between subjects with professional backgrounds (e.g., art or technology). To facilitate statistical analysis, we divided the subjects' responses to "What do you know about the College" into three groups: subjects who ticked the 5-point were regarded as "expert groups"; Subjects who ticked 1-point are considered "intuitive group"; other subjects were considered "general group." The results of the one-way ANOVA analysis are shown in Tables 8, 9.

There were some differences in perception of some or all the attributes of the six schools between the three groups of subjects from the two schools. Next, we further analyzed the cognitive differences between subjects from NTUA and NTUST, and the results were as follows:

1. Among the three groups of subjects from NTUA, there was only a cognitive difference in the evaluation of NTUA at the level of "art," which may mean that these subjects all had artistic backgrounds and their interpretation of art may be very diverse. Their evaluation of NTUST showed cognitive differences in the

TABLE 3 Basic data of the subject.

Variables		General (*n*=128)	NTUA (*n*=115)	NTUST (*n*=60)
Gender	Female	47/36.7%	79/68.7%	14/23.3%
	Male	81/63.3%	36/31.3%	46/76.7%
Age	18–22	/	29/25.2%	11/18.3%
	23–35	/	18/15.7%	11/18.3%
	26–35	18/14.1%	17/14.8%	4/6.7%
	36–45	31/24.2%	31/27%	12/20%
	46–55	52/40.6%	17/14.8%	15/25%
	56–65	22/17.2%	3/2.6%	7/11.7%
	> 65	5/3.9%	17/14.8%	4/6.7%
Education level	University student	/	33/28.7%	8/13.3%
	Graduated from university	9/7%	8/7%	18/30%
	Master	47/36.7%	42/36.5%	25/41.7%
	Ph.D.	72/56.3%	32/27.8%	9/15%
Do you know STEAM?	Yes	98/78.4%	74/64.3%	37/61.7%
	No	27/21.6%	41/35.7%	23/38.3%
Do you have experience studying abroad (more than 1 year)	Yes	40/31.3%	26/22.6%	8/13.3%
	No (For the next question, please check "None")	88/68.8%	89/77.4%	52/86.7%
The country or region where you are studying abroad	United States, Canada	20/15.6%	14/12.2%	3/5%
	Europe	4/3.1%	6/5.2%	2/3.3%
	Asia	12/9.4%	5/4.3%	2/3.3%
	Australia, New Zealand	3/2.3%	1/0.9%	1/1.7%
	None	88/68.8%	89/77.4%	52/86.7%
	Other	1/0.8%	1/0.9%	1/1.7%

TABLE 4 The mean and standard deviation of subjects' familiarity with six universities.

	THU	TJU	NTUA	NTUST	RISD	MIT
General (*n* = 128)	2.18 (1.111)	2.27 (1.245)	3.95 (1.229)	3.43 (1.215)	2.34 (1.220)	2.91 (1.160)
	NTUA > NTUST > MIT > RISD > TJU > THU					
NTUA (*n* = 115)	2.10 (1.180)	1.77 (1.035)	3.75 (1.220)	2.83 (1.237)	1.93 (1.190)	2.34 (1.263)
	NTUA > NTUST > MIT > THU > RISD > TJU					
NTUST (*n* = 60)	1.65 (1.039)	1.58 (1.062)	2.88 (1.474)	3.42 (1.476)	1.87 (1.255)	2.63 (1.507)
	NTUST > NTUA > MIT > RISD > THU > TJU					

three attributes of "science," "technology" and "engineering" (see Table 8).

2. Among the three groups of subjects from NTUST, there were cognitive differences in the assessment of NTUST in all 5 attributes. The NTUA assessment shows cognitive differences in the three attributes of "science," "technology" and "engineering" (see Table 9).

4.3. Discussion

The characteristics presented by the data are basically in line with the expectations of the study. The first 3 assumptions can therefore be held for the following reasons:

1. All samples are highly specialized design schools, if the subjects do not know enough about them and do not know the connotation of STEAM, then the assessment is very subjective and prone to polarization, which will lower the average score. However, as a preliminary study, we believe that these subjective evaluation results can be used in subsequent studies to cross-compare with expert assessments.
2. In most cases, the STEAM model is developed and operated by professionals, who give high ratings reasonably. Meanwhile, the STEAM mode has a relatively mature operation, so it is reasonable to give it a high rating.
3. There was no significant polarization tendency among subjects who were defined as "general group." These results are more in line with the assessments made by the expert. Indirectly, this also proves the validity of the expert community's assessment.

TABLE 5 The mean and standard deviation of subjects' assessment of the STEAM model.

General (*n*=128)	THU	TJU	NTUA	NTUST	RISD	MIT
Science	3.23 (1.233)	3.14 (1.085)	2.88 (0.988)	3.88 (0.944)	3.26 (0.941)	4.44 (0.903)
	MIT > NTUST > RISD > THU > TJU > NTUA					
Technology	3.26 (1.186)	3.23 (1.103)	3.16 (1.007)	4.16 (0.903)	3.34 (0.891)	4.50 (0.939)
	MIT > NTUST > RISD > THU > TJU > NTUA					
Engineering	3.16 (1.200)	3.15 (1.065)	2.58 (1.024)	3.97 (0.922)	3.26 (0.982)	4.38 (0.940)
	MIT > NTUST > RISD > THU > TJU > NTUA					
Arts	3.69 (1.266)	3.51 (1.190)	4.57 (0.928)	3.36 (1.070)	3.88 (1.047)	3.62 (1.080)
	NTUA > RISD > THU > MIT > TJU > NTUST					
Mathematics	2.94 (1.228)	2.99 (1.112)	2.35 (0.977)	3.45 (0.971)	2.97 (0.922)	4.21 (0.993)
	MIT > NTUST > TJU > RISD > THU > NTUA					
NTUA (*n* = 115)	**THU**	**TJU**	**NTUA**	**NTUST**	**RISD**	**MIT**
Science	3.27 (1.15)	3.01 (1.158)	2.79 (1.039)	3.65 (0.937)	3.13 (0.996)	4.21 (1.055)
	MIT > NTUST > THU > RISD > TJU > NTUA					
Technology	3.36 (1.069)	3.27 (1.187)	3.20 (1.061)	4.00 (0.927)	3.37 (1.037)	4.26 (1.027)
	MIT > NTUST > RISD > THU > TJU > NTUA					
Engineering	3.22 (1.138)	3.14 (1.139)	2.80 (1.053)	3.77 (0.974)	3.08 (0.890)	4.19 (1.067)
	MIT > NTUST > THU > TJU > RISD > NTUA					
Arts	4.05 (1.083)	3.67 (1.212)	4.56 (0.797)	3.34 (1.075)	3.77 (1.071)	3.37 (1.151)
	NTUA > THU > RISD > TJU > MIT > NTUST					
Mathematics	3.10 (1.116)	3.01 (1.112)	2.42 (1.043)	3.41 (1.016)	3.06 (1.003)	4.10 (1.068)
	MIT > NTUST > THU > RISD > TJU > NTUA					
NTUST (*n* = 60)	**THU**	**TJU**	**NTUA**	**NTUST**	**RISD**	**MIT**
Science	3.28 (1.166)	3.20 (1.117)	2.73 (1.071)	4.08 (0.979)	3.17 (0.977)	4.02 (1.066)
	NTUST > MIT > THU > TJU > RISD > NTUA					
Technology	3.53 (1.171)	3.23 (1.079)	3.05 (0.982)	4.20 (1.054)	3.28 (1.043)	4.13 (1.112)
	NTUST > MIT > THU > RISD > TJU > NTUA					
Engineering	3.20 (1.286)	3.23 (1.079)	2.98 (1.157)	4.12 (1.010)	3.35 (1.087)	4.10 (1.130)
	NTUST > MIT > RISD > TJU > THU > NTUA					
Arts	3.60 (1.153)	3.27 (1.133)	4.25 (1.068)	3.98 (1.033)	3.52 (1.112)	3.52 (1.097)
	NTUA > NTUST > THU > MIT > RISD > TJU					
Mathematics	3.13 (1.270)	3.10 (1.040)	2.73 (1.150)	3.73 (1.250)	3.17 (1.080)	3.93 (1.150)
	MIT > NTUST > RISD > THU > TJU > NTUA					

Regarding hypothesis four, the subjects in this study are all from Taiwan, so the focus is on feedback from NTUA and NTUST subjects. Although the subjects of these two schools did give their own schools a higher evaluation since we did not invite subjects from the other four schools to make the same assessment, it is only an assertion that all subjects will make the same judgment. This is mainly because subjects still make more objective assessments based on the actual situation. Additionally, since most of the subjects have no experience studying abroad, their knowledge of universities in other countries or regions may only come from the websites of those schools and have not had real experience, which may be a reason why they can only give higher marks to the schools they have attended.

Since most of the subjects' feedback came from their intuition, in order to further verify whether it was consistent with the actual situation, this study further analyzed the curriculum of NTUA and NTUST. Since the use of the STEAM model in design education needs to be implemented through different courses, it is necessary to analyze and discuss the curriculum. These courses are mainly composed of two parts: the courses prescribed by the department, and the general courses offered by the college. The curriculum of these two universities is shown in Tables 10, 11.

From the curriculum of these two schools, this study makes the following inferences:

1. College of Design, NTUA, which has 4 departments. Courses are mainly focused on the "art and technology" level, while there are relatively few or no courses at the "science, engineering and mathematics" level, which may be related to the positioning of the art university. However, there are exceptions. For example, the Department of Multimedia and Animation Arts, which accounts for more than 60% of the courses at the technical level, may be related to the characteristics of this department, students must use various technical means to effectively complete the creation.

TABLE 6 Cognitive differences between subjects who were familiar or unfamiliar with STEAM.

Sample	Attribute	Self-variation	*N*	Mean	Standard deviation	*t*	Comparison
TJU	Science	Yes	209	3.24	1.115	3.343***	1 > 2
		No	94	2.79	1.066		
	Technology	Yes	209	3.38	1.116	3.124**	1 > 2
		No	94	2.95	1.101		
	Engineering	Yes	209	3.28	1.060	2.779**	1 > 2
		No	94	2.90	1.127		
	Arts	Yes	209	3.62	1.155	2.096*	1 > 2
		No	94	3.31	1.253		
	Mathematics	Yes	209	3.13	1.046	2.619**	1 > 2
		No	94	2.78	1.165		
NTUA	Science	Yes	209	2.92	1.041	2.653**	1 > 2
		No	94	2.59	0.944		
NTUST	Science	Yes	209	3.96	0.916	3.246**	1 > 2
		No	94	3.56	1.001		
	Technology	Yes	209	4.20	0.880	2.417*	1 > 2
		No	94	3.91	1.054		
	Engineering	Yes	209	4.00	0.930	1.979*	1 > 2
		No	94	3.76	1.023		
	Arts	Yes	209	3.60	1.057	2.959**	1 > 2
		No	94	3.20	1.122		
RISD	Science	Yes	209	3.30	0.935	2.989**	1 > 2
		No	94	2.95	0.999		
	Technology	Yes	209	3.45	0.909	2.956**	1 > 2
		No	94	3.10	1.078		
	Engineering	Yes	209	3.33	0.915	3.314**	1 > 2
		No	94	2.94	1.045		
	Arts	Yes	209	3.91	0.952	3.302**	1 > 2
		No	94	3.44	1.249		
	Mathematics	Yes	209	3.17	0.930	3.474***	1 > 2
		No	94	2.76	1.044		
MIT	Science	Yes	209	4.38	0.907	2.634**	1 > 2
		No	94	4.02	1.164		
	Technology	Yes	209	4.47	0.915	3.266**	1 > 2
		No	94	4.03	1.159		
	Engineering	Yes	209	4.37	0.927	2.761**	1 > 2
		No	94	3.99	1.196		
	Arts	Yes	209	3.73	1.008	5.338***	1 > 2
		No	94	3.02	1.182		
	Mathematics	Yes	209	4.24	0.967	3.055**	1 > 2
		No	94	3.82	1.182		

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Do you know STEAM: 1. Yes, 2. No.

2. College of Design, NTUST, which has two departments. In the Department of Design, there are no courses at the "Science and Mathematics" level; The Department of Architecture, on the other hand, does not offer courses at the "Science" level. Relatively speaking, the proportion of courses at the "art" level is relatively high, and the proportion of courses at the "technology and engineering" level is not much different from that at the "Art" level, which may be related to NTUST's philosophy of focusing on science and technology.

TABLE 7 The differences between subjects in the three versions.

Sample	Attribute	Source of variation	SS	df	MS	*F*	*Post hoc* tests
THU	Arts	Between groups	11.311	2	5.655	4.082*	2 > 1; 2 > 3
		Within groups	415.587	300	1.385		
		Total	426.898	302			
NTUA	Engineering	Between groups	7.319	2	3.659	3.242*	3 > 1
		Within groups	338.602	300	1.129		
		Total	345.921	302			
NTUST	Science	Between groups	7.837	2	3.918	4.355*	3 > 2
		Within groups	269.912	300	0.900		
		Total	277.749	302			
	Arts	Between groups	19.338	2	9.669	8.526***	3 > 1;3 > 2
		Within groups	340.226	300	1.134		
		Total	359.564	302			
MIT	Science	Between groups	1.029	2	0.514	0.547*	1 > 3
		Within groups	281.869	300	0.940		
		Total	282.898	302			
	Technology	Between groups	0.268	2	0.134	0.140*	1 > 3
		Within groups	287.719	300	0.959		
		Total	287.987	302			

*$p < 0.05$, ***$p < 0.001$; 3 versions of the questionnaire: 1. General, 2. NTUA, 3. NTUST.

TABLE 8 A comparison of NTUA and NTUST assessments by subjects from NTUA.

Sample	Attribute	Source of variation	SS	df	MS	*F*	*Post hoc* tests
NTUA	Arts	Between groups	15.167	2	7.584	14.845***	2 > 1; 3 > 1
		Within groups	57.215	112	0.511		
		Total	72.383	114			
NTUST	Science	Between groups	7.558	2	3.779	4.574*	2 > 1; 3 > 1
		Within groups	92.529	112	0.826		
		Total	100.087	114			
	Technology	Between groups	13.293	2	6.646	8.788***	2 > 1; 3 > 1
		Within groups	84.707	112	0.756		
		Total	98.000	114			
	Engineering	Between groups	9.858	2	4.929	5.618*	2 > 1; 3 > 1
		Within groups	98.264	112	0.877		
		Total	108.122	114			

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; Familiarity with the University: 1. Intuition, 2. Ordinary, 3. Expert.

For students, when choosing a university, they may not have a very detailed understanding of the curriculum of the relevant college or department, but more will use the attributes of the university as an important basis for selection. However, when students enter university, it is essential whether the curriculum is reasonable.

This study believes that the curriculum of design education is very related to the positioning and professional characteristics of the school, and may have different emphases, in addition to giving play to the established characteristics and advantages of the school, how to achieve a certain balance around the STEAM model needs to be further explored: the point is that the curriculum cannot be arbitrarily set up to meet the so-called STEAM model. Simultaneously, it is also necessary to let teachers and students understand the connotation of STEAM during the education process, to help teachers and students understand the intention of certain courses. From an educational perspective, the STEAM model and essence can only be realized through various courses.

5. Conclusion and suggestions

STEAM has been widely used in many fields, and the value and significance of this mindset have been proven many times. Since STEAM is a system and the focus will be different in different fields, it is necessary

TABLE 9 A comparison of NTUA and NTUST assessments by subjects from NTUST.

Sample	Attribute	Source of variation	SS	df	MS	*F*	*Post hoc* tests
NTUST	Science	Between groups	11.617	2	5.808	7.363**	2 > 1; 3 > 1; 3 > 2
		Within groups	44.967	57	0.789		
		Total	56.583	59			
	Technology	Between groups	12.149	2	6.075	6.478**	2 > 1; 3 > 1
		Within groups	53.451	57	0.938		
		Total	65.600	59			
	Engineering	Between groups	11.350	2	5.675	6.624**	2 > 1; 3 > 1; 3 > 2
		Within groups	48.833	57	0.857		
		Total	60.183	59			
	Arts	Between groups	21.749	2	10.874	15.032***	2 > 1; 3 > 1; 3 > 2
		Within groups	41.235	57	0.723		
		Total	62.983	59			
	Mathematics	Between groups	10.275	2	5.138	3.595*	3 > 1
		Within groups	81.458	57	1.429		
		Total	91.733	59			
NTUA	Science	Between groups	17.107	2	8.554	9.630***	3 > 1; 3 > 2
		Within groups	50.626	57	0.888		
		Total	67.733	59			
	Technology	Between groups	7.582	2	3.791	4.386*	3 > 1; 3 > 2
		Within groups	49.268	57	0.864		
		Total	56.850	59			
	Engineering	Between groups	14.539	2	7.269	6.430**	3 > 1; 3 > 2
		Within groups	64.444	57	1.131		
		Total	78.983	59			

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; Familiarity with the University: 1. Intuition, 2. ordinary, 3. expert.

to objectively evaluate the relationship between the five attributes and determine their weight in response to different design areas.

For design education, there are also large differences between different design fields. For example, some need to strengthen the blessing of science and technology, while others pay attention to mathematical logic, and the intervention of "art" provides a new thinking mode, connecting the four attributes in STEM to form a strategy and thought, and enhance the connotation and cultural value of design through the intervention of humanities and art. Technology is the foundation of design thinking, which pays attention to "sensual technology"; human nature is the beginning of design thinking, which focuses on "human-centered design". Finally, culture is the source of design thinking, which pursues "cultural creativity." Therefore, designers must integrate the design thinking of "sensual technology" and "human-centered design" to create a humanized organization or living environment with friendly and cultural connotations.

This study believes that the future focus should be on how to better play the characteristics of the five attributes of STEAM, which not only meets the needs of designers in different design fields to cultivate, but also should realize that only by playing the overall thinking of STEAM can we truly achieve the goal of cultivating generalist designers. Only by achieving the above purposes can design better serve society. Additionally, the STEAM model and concept need to be realized through specific courses, and the curriculum of the design department needs to be adjusted and supplemented in time according to the STEAM model under the premise of complying with policies, regulations and the actual situation of the school. Simultaneously, researchers also must grasp the effectiveness of these courses in a timely manner through periodic return visits.

Since the number of subjects is small, and all the subjects are from Taiwan, so it is impossible to determine whether the findings and conclusions apply to other countries or regions. We hope that the above findings will inspire design educators and researchers, and will encourage more people to consider how the STEAM model can be used in design education more effectively.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

RL and YS: conceptualization and writing—review and editing. RL: methodology. YS and C-CN: writing—original draft preparation.

TABLE 10 The curriculum of the college of design, NTUA.

	Science	Technology	Engineering	Arts	Mathematics	Other	Total
Department of visual communication design							
Curriculum	0	16 (20.50%)	4 (5.12%)	32 (41.02%)	0	26 (33.33%)	78
Credit	0	28 (18.66%)	8 (5.33%)	62 (41.33%)	0	52 (34.66%)	150
Arts > Other > Technology > Engineering > Science = Mathematics							
Department of crafts and design							
Curriculum	1 (1.02%)	6 (6.12%)	6 (6.12%)	53 (54.08%)	1 (1.02%)	31 (31.63%)	98
Credit	2 (0.89%)	12 (5.38%)	15 (6.72%)	131 (58.74%)	3 (1.34%)	60 (26.90%)	223
Arts > Other > Engineering > Technology > Mathematics > Sciences							
Department of multimedia and animation arts							
Curriculum	0	42 (56.75%)	1 (1.35%)	7 (9.45%)	0	24 (32.43%)	74
Credit	0	140 (61.13%)	3 (1.31%)	19 (8.29%)	0	67 (29.25%)	229
Technology > Other > Arts > Engineering > Sciences = Mathematics							
Curriculum in general education							
Curriculum	0	6 (35.29%)	0	6 (35.29%)	0	5 (29.41%)	17
Credit	0	12 (35.29%)	0	12 (35.29%)	0	10 (29.41%)	34
College of design, NTUA							
Curriculum	0	70 (26.31%)	11 (4.13%)	98 (36.84%)	1 (0.37%)	86 (32.33%)	266
Credit	0	192 (30.28%)	26 (4.10%)	224 (35.33%)	3 (0.47%)	189 (29.81%)	634
Arts > Technology > Other > Engineering > Mathematics > Sciences							

Source: The website of NTUA.

TABLE 11 The curriculum of the college of design, NTUST.

	Science	Technology	Engineering	Arts	Mathematics	Other	Total
Department of design							
Curriculum	0	23 (28.78%)	8 (10.00%)	27 (33.75%)	0	22 (27.5%)	80
Credit	0	69 (29.61%)	23 (9.87%)	71 (30.47%)	0	70 (30.04%)	233
Arts > Other > Technology > Engineering > Sciences = Mathematics							
Department of architecture							
Curriculum	0	5 (8.77%)	19 (33.33%)	14 (24.56%)	5 (8.77%)	14 (24.56%)	57
Credit	0	15 (8.47%)	73 (41.24%)	35 (19.77%)	15 (8.47%)	39 (22.03%)	177
Engineering > Other > Arts > Technology = Mathematics > Sciences							
College of design, NTUST							
Curriculum	0	28 (20.43%)	27 (19.70%)	41 (29.92%)	5 (3.64%)	36 (26.27%)	137
Credit	0	84 (20.48%)	96 (23.41%)	106 (25.85%)	15 (3.65%)	109 (26.58%)	410
Other > Arts > Engineering > Technology > Mathematics > Sciences							

Source: The website of NTUST.

All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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