MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2025, 21(10), em2722
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/17251

STEAM education: Assessment in the architecture curriculum

Wei-Ling Hsu [1*], Lin Mou [1], Zuorong Dong [1], Shan Gao [1]

[1] School of Civil Engineering, Jiaying University, Meizhou, Guangdong, CHINA

Received 09 July 2025 ▪ Accepted 21 September 2025

Abstract

This study examines the evaluation of science, technology, engineering, arts, and mathematics (STEAM) education within the architecture curriculum. By discussing the application and impact of STEAM education in the architecture curriculum, this study aims to clarify its role in improving the quality of architecture education. Taking the decision-making trial and evaluation laboratory (DEMATEL) approach, this study also assesses the degrees of association and influence between various components of STEAM education in the architecture curriculum. It is found that the engineering course group has the highest centrality, while the arts course group has the lowest. This study emphasizes the strengthening of the leading role of the arts course group and provides suggestions. This study not only reveals the mutual impact relations between different components of STEAM education in architectural education but also provides practical implications and possible research directions for educational practice, offering a scientific basis and practical guidelines for promoting innovation and development of architectural education.

Keywords: direct-influence matrix, DEMATEL, talent training plan

INTRODUCTION

In the field of education in the 21st century, the rapid development of science and technology and the continuous advancement of globalization are driving changes in educational models and methods. Among them, science, technology, engineering, arts, and mathematics (STEAM) education, as an innovative teaching philosophy, has been widely followed and popularized (Lin & Tsai, 2021). STEAM education integrates multiple disciplinary fields such as STEAM (Herro et al., 2017), with the aim of cultivating students' comprehensive quality and innovative abilities through interdisciplinary teaching. The educational modes and curriculum setting of architecture, a comprehensive discipline integrating scientificity, artistry, and technicality, are crucial for cultivating students' creativity and practical abilities (Ho et al., 2017).

However, traditional architectural education often places too much emphasis on imparting the knowledge of a single discipline while neglecting the mutual integration between disciplines, which limits the all-round development of students. In this context, introducing the philosophy of the STEAM education into the architecture curriculum is of great significance for promoting the reform and development of architectural education.

This study, by in-depth analysis of the application and influence of STEAM education in the architecture curriculum, aims to clarify its role in improving the quality of architectural education (EISayary, 2025). Specifically, the decision-making trial and evaluation laboratory (DEMATEL) approach is applied to assess the degrees of connection and influence between different components of STEAM education in the architecture curriculum, thus revealing their internal logical relations and interaction mechanisms. We expect that this study will offer a scientific basis and practical guidance for optimizing architectural education and promoting the comprehensive, diversified, and innovative development of architectural education. Additionally, this study is expected to provide useful references for the practice of STEAM education in other disciplines.

The remainder of this study is organized as follows: We first review architectural literature in science, technology, engineering, and mathematics (STEM), STEAM education, and higher education. First, an introduction to the concept of STEM education and its development towards STEAM education is provided, followed by an emphasis on the importance of

✉ quartback@hotmail.com **(*Correspondence)** ✉ 200201049@jyu.edu.cn ✉ 201701005@jyu.edu.cn ✉ 25350271@qq.com

Contribution to the literature

- This study fills a gap by quantitatively assessing STEAM integration in architecture, using DEMATEL to reveal interdependencies among disciplines, enhancing understanding of interdisciplinary teaching benefits.
- It highlights arts' significant influence within STEAM, showing how strengthening arts education indirectly improves technology and engineering, challenging traditional disciplinary boundaries.
- This study introduces DEMATEL for curriculum assessment, providing a systematic framework to identify key influence factors and optimize curriculum design, offering a valuable resource for future research.

combining the arts with STEM disciplines. Based on this, the characteristics of architectural education and the status of its curriculum planning in higher education are discussed. We then introduce the DEMATEL approach and elaborates on its definition, origin, application fields, and implementation steps, setting the methodological foundation for subsequent assessment. After that we discuss the assessment results of STEAM courses in architecture based on the DEMATEL approach, identifies the degrees of association between the criteria in the architecture talent development system through expert discussions and questionnaire surveys, and draws a cause-and-effect diagram, followed by detailed analysis and discussions. We finally summarize the main findings and conclusions of this study and highlights the important position of arts in STEAM courses in architecture, as well as the implications for educators in improving curriculum assessment.

LITERATURE REVIEW

From STEM to STEAM Education

STEM education is an educational method that combines science, technology, engineering, and mathematics (Jeong et al., 2023), with the aim of improving students' problem-solving and innovative abilities through interdisciplinary teaching (Singh et al., 2024). However, traditional STEM education often ignores the importance of arts and other non-STEM disciplines. In response, STEAM education emerged. By integrating arts and other non-STEM disciplines into STEM education, STEAM education encourages students to examine and solve real-world problems from a holistic perspective (Minces & Akshay, 2023).

Its core idea is that arts can be combined with STEM disciplines to help students recognize the value of STEM in solving complex practical problems, thus stimulating students' interest and motivation to learn (Gu et al., 2023). This is especially true for girls, as STEAM education provides a more appealing way of learning, making it easier for them to enter and participate in STEM fields. In addition, STEAM education also emphasizes interdisciplinary research, which helps students develop a variety of horizontal skills that modern society requires, such as critical thinking, innovative thinking, and teamwork ability (Affandy et al., 2024).

The STEM (along with STEAM, which is based on STEM) approach is a significant improvement over traditional teaching methods. That is, while traditional teaching methods rely too much on non-STEM approaches provided by lecture-based teaching, the STEM/STEAM approach can better connect high-quality knowledge and cognitive skills with real-life needs. In real life, students run into all kinds of problems, and interdisciplinary teaching allows them to view problems from multiple angles, so as to find more comprehensive and effective solutions.

High-quality knowledge in STEM/STEAM education transcends factual retention, integrating contextual relevance (rooted in real-world application), cognitive complexity (Kang, 2019) (interdisciplinary thinking and metacognition), and actionable impact (Boice et al., 2021) (solving societal challenges). This tripartite model, supported by global frameworks (OECD and UNESCO), ensures knowledge is actively constructed and deployed to address real-world needs.

Architecture in Higher Education

As an important discipline in higher education, architecture not only requires students to master solid theoretical knowledge but also emphasizes their practical ability and innovative spirit. The architecture curriculum covers architectural design, urban planning and design, interior design, construction, engineering management, etc., and is designed to cultivate high-quality application-oriented talents with a strong sense of social responsibility, innovative spirit, and practical ability. This is the context in which artificial intelligence (AI) and robotics have attracted much attention (Ananias & Gaspar, 2022). Driven by the increasing demand for technology, they are being applied to meet the needs of the economy and the labor market. This reflects the changes in the needs and requirements of the educational system, especially for learning spaces. These fields can serve as educational bridges for learning human assistance, AI, and robotics skills (Juškevičienė et al., 2021), having a profound impact on the training of future teachers. They ensure that students understand the significance of technology and have an awareness of maximizing the utilities of future education. This marks

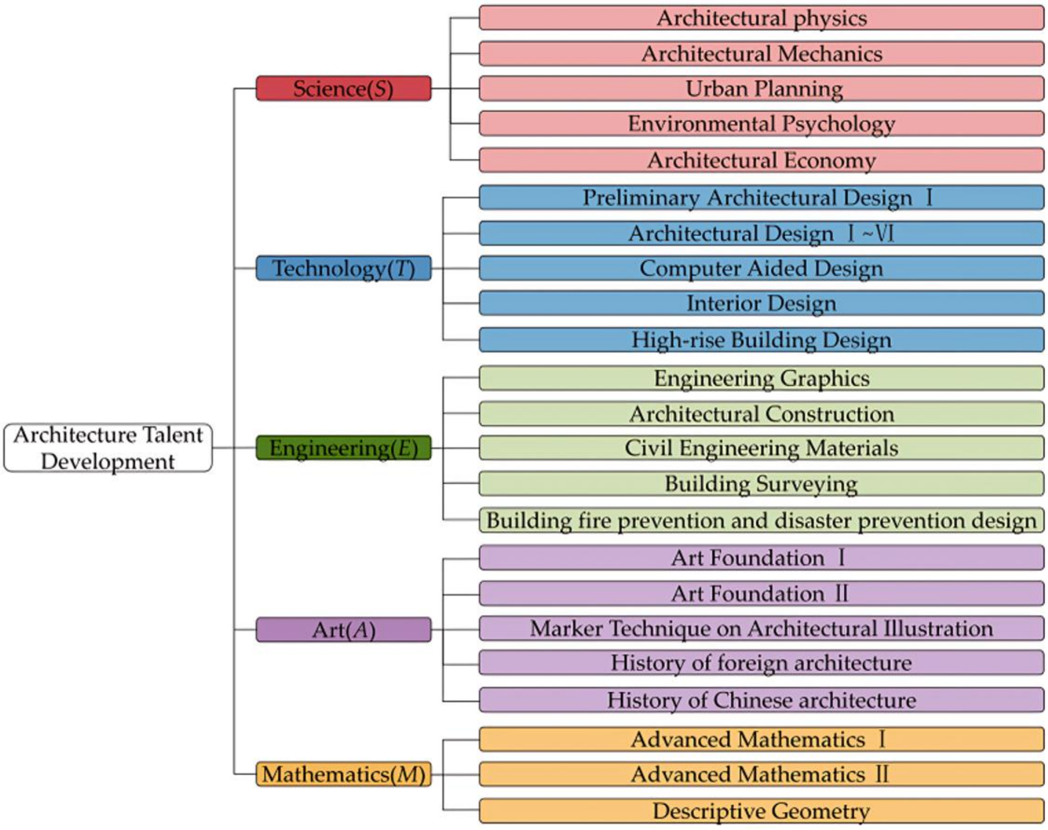

Figure 1. Distribution system of STEAM courses in architecture (Source: Authors' own elaboration)

the beginning of applied innovation and motivational teaching and draws attention to these disciplines. In this context, architectural education is also undergoing constant reform and innovation. In order to adapt to new social demand, the architecture curriculum should place greater emphasis on interdisciplinary teaching and research. By introducing the STEAM education philosophy, architectural education can cultivate students' abilities in a more comprehensive way, so that they can better cope with challenges in their future work.

Architecture is of particular importance in STEAM education, as it perfectly combines arts with engineering, science, and technology and provides rich opportunities for interdisciplinary learning (Leavy et al., 2023). It not only emphasizes aesthetics and design, but also focuses on the sustainability of structures, materials, and the environment. It acts as a bridge in the STEAM curriculum, encouraging students to think from multiple perspectives, develop practical skills, and prepare for future careers and society. The distribution system of STEAM courses in architecture is shown in **Figure 1**. Therefore, architecture, as an important component of STEAM education, promotes the development of students' comprehensive and problem-solving abilities and enhances their creativity.

Figure 1 presents the curriculum structure, which reflects the hierarchical framework and classification of various disciplines in architectural talent cultivation. It encompasses the contributions of disciplines such as STEAM to the curriculum. The distribution mechanism within the curriculum pertains to the allocation of credits, resources, or assessment weights across different disciplines. This mechanism serves to ensure educational balance and foster the development of comprehensive skills in students.

Emphasizing the integration of arts and other disciplines, this structure adheres to the STEAM principles (science, technology, engineering, arts, mathematics). Its core objective is to cultivate versatile architects capable of addressing complex challenges in the field.

Curriculum Planning and Assessment Methods

In terms of curriculum planning and assessment, DEMATEL is a very effective tool. It can be viewed as a method for multiple criteria decision making (MCDM). As a systematic analysis approach based on graph theory and matrix tools, it analyzes the inter-influence relationships between different elements of a system by constructing a direct-influence matrix. This approach can calculate the degrees to which an element influences and is influenced by other elements in order to determine the place and role of each element in the system. In MCDM, decision-makers need to weigh multiple criteria or standards before making decisions, and the DEMATEL approach helps to identify the internal relationship and mutual influences between these criteria or standards, providing important input information for decision-makers.

The DEMATEL approach is widely used to analyze complex decision-making problems, such as balanced scorecards, supply chain management, and sustainable development (Zhang et al., 2024). In the field of pedagogy, the DEMATEL approach can also identify the causality between objectives, thus providing a systematic approach for educators to construct professional development pathways (Wu et al., 2018). In the assessment of the architecture curriculum, the DEMATEL approach helps us identify the curriculum elements that have significant impact on students' growth and development, thus providing strong support for curriculum optimization.

To summarize, the STEM/STEAM educational philosophy has important application value for the architecture curriculum in higher education. By introducing advanced assessment methods such as DEMATEL, we can plan and evaluate the architecture curriculum more scientifically, offering a strong guarantee for cultivating high-quality application-oriented talents.

MATERIALS AND METHODS

DEMATEL

DEMATEL is a powerful method that can be used to identify the components of the causal chain in a complex system and assess the interdependence between factors. It is a systematic analysis method that uses graph theory and matrix tools to explain problems. Relying on expert assessment, DEMATEL creates the direct-influence matrix between factors that reflect their interactions. By analyzing the matrix and identifying the key factors, we can draw the influence relation map (IRM) to show the mutual influence relations between factors.

DEMATEL is also widely used to analyze complex decision-making problems. It can not only transform the interdependence between factors but also identify the key factors in a complex system, providing a basis for long-term strategic decision-making and improvement. Furthermore, DEMATEL has also been extended to decision analysis under uncertain conditions such as an ambiguous or grey environment to better solve complex practical problems (Altuntas & Gok, 2021). The DEMATEL methodology was introduced by the Geneva Research Center at the Battelle Memorial Institute, with the aim of illustrating the intricate framework of causality through matrices or diagraphs (Gabus & Fontela, 1973). It is a general method of systematic analysis that has been widely used in many fields, including corporate planning and decision-making, urban planning and design, geographical environment assessment, global problem analysis, marketing, online assessment, control systems, and security problems (Wu et al., 2018). Furthermore, in the development of goals, DEMATEL can be used to identify the causality between goals, thus providing a systematic logical approach for educators in developing architectural education. This method can effectively identify the causality between criteria or elements, as well as the degree of their mutual influence.

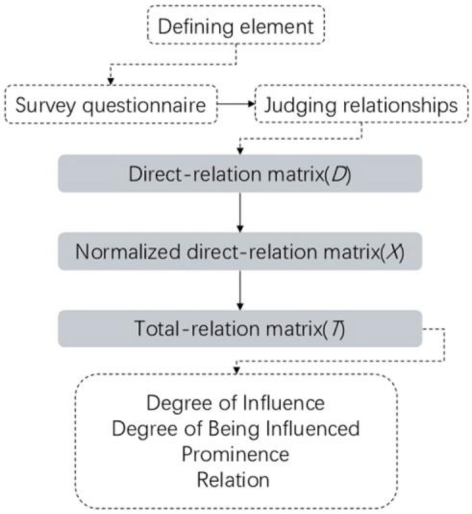

Figure 2. The general steps of DEMATEL (Source: Authors' own elaboration)

As a powerful method of systematic analysis, DEMATEL is suitable for researching the application and impact of STEAM education in the architecture curriculum. It can effectively identify and assess the interdependence between factors in the field of STEAM and discover the key factors and their roles in improving the quality of architectural education. By creating the direct-influence matrix through expert assessment, DEMATEL can visually show the causality between factors, providing a scientific basis for improving the quality of architectural education. It is applicable to goal development and decision analysis in the field of education.

Implementation Steps

DEMATEL can transform the interrelationships between factors into an understandable systematic structure model and then divide it into a cause group and an effect group. The general steps of DEMATEL are given below (**Figure 2**) (Alinezhad & Khalili, 2019).

Step 1. Defining elements and judging relationships

The elements in the system are analyzed and defined, and the relations between elements are estimated based on expert discussions, questionnaires, surveys, etc. The direct-influence matrix (also called the "relational matrix") is generated based on the relations between elements.

Step 2. Generating the direct-relation matrix

First, the relation between elements is expressed by one of the following figures based on the degree of

Table 1. Format of a questionnaire survey using DEMATEL

Causality	*T* (technology)	*E* (engineering)	*A* (arts)	*M* (mathematics)
S (science)	1	1	0	1

influence: 0 (no influence), 1 (slight influence), 2 (strong influence), and 3 (very strong influence). Second, experts compare the elements in pairs according to their mutual influence relations as well as the degrees of influence. If the number of elements is n, the obtained comparison results will form an $n \times n$ matrix, i.e., a direct-relation matrix denoted by d, where element d_n indicates the degree to which element i influences element j and its diagonal element is set to zero.

Step 3. Normalization of the direct-relation matrix

This step is presented as follows: Assuming that

$$\lambda = min(\frac{1}{\max\limits_{1 \le i \le n}(\sum_{j=1}^{n} v_{ij}), \max\limits_{1 \le j \le n}(\sum_{i=1}^{n} v_{ij})}). \quad (1)$$

The elements of the direct-relation matrix can be multiplied by λ, yielding:

$$X = \lambda \times D. \quad (2)$$

In this way, the normalized direct-relation matrix X can be obtained.

Step 4. Calculation of the total-relation matrix

After the normalized direct-relation matrix X is obtained, since $\lim\limits_{k \to \infty} X^k = 0$, the total-relation matrix T can be obtained from the following equation, where 0 denotes the zero matrix, I denotes the unit matrix, and t_{ij} denotes the degree to which element i influences element j.

Total-relation matrix is as follows:

$$T = \sum_{k=1}^{\infty} X^k = X(I - X)^{-1}. \quad (3)$$

Assuming that r and c represent the row sum and the column sum, respectively, we can acquire:

$$T = [t_{ij}]_{n \times n}, j = 1,2, \dots, n. \quad (4)$$

$$r = [r_i]_{n \times 1} = \left(\sum_{j=1}^{n} t_{ij}\right)_{n \times 1}. \quad (5)$$

$$c = [c_j]_{1 \times n} = \left(\sum_{i=1}^{n} t_{ij}\right)_{1 \times n}. \quad (6)$$

Assuming that r_i denotes the sum of the i-th row in the total-relation matrix T, r_i means the sum of the degrees of direct or indirect influences of this element on other elements. Assuming that c_j denotes the sum of the j-th row in the total-relation matrix T, c_j denotes the sum of the degrees of direct or indirect influences of other elements on the element. In the DEMATEL method, the centrality ($r + c$) is a crucial metric that represents the overall importance or prominence of an element within the system, considering both its outgoing and incoming influences. In addition, ($r + c$) is defined as the centrality (prominence). When $i = j$ is present, ($r_i + c_j$) denotes the total degree of the i-th element influencing and being influenced by other elements, i.e., the centrality of element i in the problem group; (r - c) is called the relation. That is, if (r_i - c_j) is positive, the i-th element influences other elements and is an influencing element; if (r_i - c_j) is negative, the i-th element is influenced by other elements and is an influenced element (Gabus & Fontela, 1973).

Step 5. Label the known (r + c) and (r - c) in a 2D coordinate system

The cause-and-effect diagram takes ($r_i + c_j$, $r_i - c_j$) as a paired coordinates, that is, those above the x-axis are classified as a cause group while those below it are categorized as an effect group. Each element is then displayed in the form of coordinates. This cause-and-effect diagram is drawn to simplify the complex causality into a simple structure, thus deepening the understanding of the problem and clarifying the direction of problem-solving. With the help of the cause-and-effect diagram, decision-makers can also make appropriate decisions based on the influencing or influenced elements in the criteria. In this sense, IRM can be used to visualize the relation between prominence and relationality. Nodes with high scores for both prominence and relationality are usually considered key nodes in the system.

Step 6. Analysis of specific problems

The final step involves interpreting the causal relation map generated from the total relation matrix. Key thresholds are established to filter out negligible effects, simplifying the complex network of influences. The causal diagram is a directed diagram with arrows representing significant influence relationships. This visualization allows researchers to identify critical causal factors, trace the pathways of influence throughout the system, and pinpoint the most influential drivers for targeted intervention and strategic decision-making.

RESULTS AND DISCUSSION

Calculation of the Total-Relation Matrix Based on DEMATEL

The DEMATEL approach is used to identify the degrees of connection between criteria in the talent development system in architecture, and the relations between elements are estimated based on expert discussions, questionnaire surveys (**Table 1**), and in-depth interviews with 11 experts. Regarding expert scoring, they evaluate the degree of influence between different criteria based on their professional experience

Table 2. Direct-relation matrix D

	S (science)	T (technology)	E (engineering)	A (arts)	M (mathematics)
S (science)	0.00	2.57	2.29	1.29	2.57
T (technology)	2.86	0.00	2.43	1.71	2.43
E (engineering)	2.86	2.71	0.00	2.00	2.57
A (arts)	1.43	1.29	1.57	0.00	1.43
M (mathematics)	2.14	1.71	1.86	1.29	0.00

Table 3. Normalized direct-relation matrix X

	S (science)	T (technology)	E (engineering)	A (arts)	M (mathematics)
S (science)	0.00	0.28	0.25	0.14	0.28
T (technology)	0.31	0.00	0.26	0.18	0.26
E (engineering)	0.31	0.29	0.00	0.22	0.28
A (arts)	0.15	0.14	0.17	0.00	0.15
M (mathematics)	0.23	0.18	0.20	0.14	0.00

Table 4. Total-relation matrix T

	S (science)	T (technology)	E (engineering)	A (arts)	M (mathematics)
S (science)	1.80	1.86	1.81	1.39	1.98
T (technology)	2.14	1.74	1.91	1.50	2.07
E (engineering)	2.25	2.07	1.80	1.60	2.18
A (arts)	1.37	1.25	1.25	0.87	1.34
M (mathematics)	1.68	1.52	1.50	1.18	1.46

in the architectural field, such as considering how science promotes other aspects like technology in architectural practice and then assign scores accordingly.

A four-level scale (0, 1, 2, and 3) was adopted to reflect the degree of influence between indicators. All questionnaire surveys are unified to form a matrix od the degree of influence between the criteria. Finally, the elements in the matrix of the degree of influence of each expert are summed up, and after integration, a matrix of direct relationships is obtained. The matrix is represented by D, i.e., $D = [d_{ij}]_{n\times n}$, where n denotes the number of indicators, d_{ij} denotes the degree to which indicator i influences indicator j after the integration of expert opinions, and its diagonal element is set to zero. In this way, the comparison results between criteria, i.e., the direct-relation matrix T, are obtained by means of questionnaire surveys, as shown in **Table 2**.

According to the above direct-relation matrix D, the column sum set is [9.29, 8.29, 8.14, 6.29, 9.00], and the row sum set is [8.71, 9.43, 10.14, 5.71, 7.00]. Accordingly, the column sum with the maximum value of engineering is 9.29, and, according to Eq. (1), we have $\lambda = 1/9.29 = 0.107642$. Then the normalized direct-relation matrix X can be obtained from Eq. (2), as shown in **Table 3**.

Then the total-relation matrix can be obtained from Eq. (3), as shown in **Table 4**.

Cause-and-Effect Diagram

For the total-relation matrix T, its centrality ($r + c$) and relation (r - c) are calculated, and the cause-effect diagram is drawn, as shown in **Figure 3**. The cause-and-effect diagram intuitively expresses the causality between evaluation indicators and can be used to identify those with desirable improvement effects. That is, the higher the centrality of an indicator, the greater the importance of the indicator in the entire system. W influenced indicator, or an influenced facet, without great room for improvement. Conversely, where an indicator has a positive relationality, this means that the indicator is a highly influencing indicator with high flexibility.

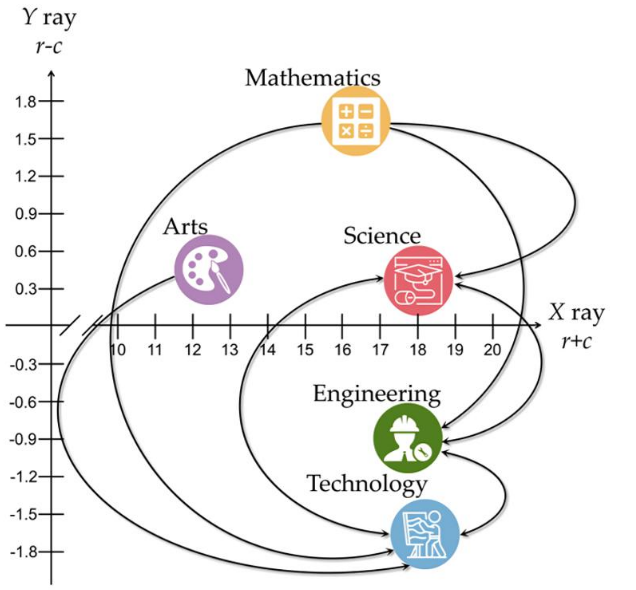

Figure 3. Cause-and-effect diagram (Source: Authors' own elaboration)

As can be seen from **Table 5**, M (mathematics), A (arts), and S (science) are all influencing facets, while T (technology) and E (engineering) are both influenced

Table 5. Centrality and relation between criteria

	S (science)	*T* (technology)	*E* (engineering)	*A* (arts)	*M* (mathematics)
$r_i + c_i$	18.08	17.81	18.16	12.62	16.37
$r_i - c_i$	0.39	-0.93	-1.62	0.47	1.69

facets. They can be ranked as follows in the descending order of centrality: *E* (engineering) > *S* (science) > *T* (technology) > *M* (mathematics) > *A* (arts). That is, *E* (engineering) has the highest degree of influencing and being influenced by other criteria, followed by *S* (science), while *A* (arts) has the smallest degree.

The cause-and-effect diagram in **Figure 3** shows the complex causality between the five facets. To be precise, the values of science, technology, and engineering are all located on the right side of $r + c$ (the degree of association) in the cause-and-effect diagram, and the calculated $r + c$ values of these three facets are all greater than the average value of 16.61. This means that these three facets have higher degrees of connection than the other facets. In addition, the $r - c$ values of science, arts, and mathematics are greater than 0, which means that they are influencing facets, or the cause in the causality. On the contrary, the $r - c$ values of technology and engineering are less than 0, which means both facets are influenced, that is, the effect in the causality.

Centrality (r + c) analysis

1. The engineering (*E*) course group has the highest centrality, which indicates that it has the highest degree of connection with other criteria in the entire architecture curriculum assessment system, and the highest degree of influencing and being influenced by other criteria.
2. The science (*S*) course group has the second highest centrality, which means that science also plays an important role in architectural education and is closely integrated with other disciplines.
3. Each technology (*T*) and mathematics (*M*) course group has a relatively high centrality, which suggests that technology and mathematics are indispensable elements in architectural education.
4. The arts (*A*) course group has the lowest centrality, but is still a component of STEAM education, whose overall influence on the architecture curriculum cannot be ignored.

Relation (r - c) analysis

1. The mathematics (*M*) course group, the science (*S*) course group, and the arts (*A*) course group each have a positive relation, indicating that these criteria tend to influence other criteria in the system and are influencing factors. It should be noted that the high relationships of the mathematics (*M*) course group and the science (*S*) course group suggest that they play prominent roles in promoting other criteria.
2. The technology (*T*) course group and the engineering (*E*) course group each have a negative relation, indicating that these two criteria are largely influenced by other criteria in the system and are "effect" factors. This means that in order to improve the quality of teaching in the technology (*T*) and engineering (*E*) course groups, we may need to start with other criteria that influence them.

Comprehensive analysis

When improving the architecture curriculum, we should put emphasis on high-centrality criteria, such as the engineering (*E*) and science (*S*) course groups, as they have the most prominent influence on the whole system. Considering the relation, we can prioritize influencing criteria with a relatively high centrality, such as the mathematics (*M*) course group and the science (*S*) course group. In particular, the science (*S*) course group not only has a high degree of connectivity, but also serves as an influencing element, the improvement of which may produce a systematic positive effect.

Although the centrality of the arts (*A*) course group is relatively low, it is an influenced facet, and the arrow directions only unidirectionally point to other facets (e.g., the technology [*T*] course group and the engineering [*E*] course group). Therefore, improving the arts (*A*) course group can also effectively promote the improvement of other facets, without being reversely influenced by them. In this sense, the arts (*A*) course group is also a point of improvement worth considering.

According to the above analysis, strengthening the teaching of science and mathematics is also an improvement strategy that can enhance their influence on other disciplines. Attention should also be paid to the teaching of arts in order to stimulate students' creativity and aesthetic appreciation in architectural design. For technology engineering, it is necessary to indirectly improve the quality of teaching by comprehensively improving other related disciplines.

Discussions

In the above analysis, the DEMATEL approach is taken to discuss in depth the interrelationships between different components of STEAM education in architectural education, and the cause-and-effect diagram is drawn to intuitively express these relations. Next, we will further discuss the implications of these findings for educational practice, as well as the possible research directions, from the perspective of academic researchers.

Implications for educational practice

1. **Strengthen the leading role of the arts (*A*) course group:** Our research shows that the arts facet plays a crucial role in architectural education. It is an influenced facet, and its arrow directions generally point to other facets, such as technology and engineering. This means that strengthening arts education can not only directly improve the teaching quality of arts, but also effectively boost the improvement of facets such as technology and engineering. Therefore, educators should give more attention and support to arts education when developing lesson plans and curriculum arrangements.
2. **Promote interdisciplinary integrated teaching:** The shift from STEM to STEAM emphasizes the importance of non-STEM disciplines such as arts. Our research has also proved the effectiveness of this interdisciplinary integrated teaching method. Architectural education should encourage interdisciplinary projects and practices. For instance, in the architectural history course, geometric knowledge from mathematics is integrated to analyze the structures of ancient architecture. Relevant in-class activities are designed to guide students to conduct on-site measurements of ancient buildings and apply geometric principles to create models. Additionally, assignments are assigned that require students to analyze the properties of ancient architectural materials based on scientific principles. Through such forms of in-class activities and assignments, students are enabled to comprehensively apply knowledge and skills from multiple fields to solve practical problems. Given that science and mathematics have been identified as components with high centrality and positive influence, it is highly beneficial to explore how the two interact in practical architectural education settings. For example, we may consider whether there are integrated curriculum designs or specific teaching strategies that can demonstrate their combined impact on students' learning processes or design thinking.
3. **Optimize curriculum design and improve teaching quality:** Based on the result of the DEMATEL analysis we can identify the key facets and influencing factors in architectural education. Educators can optimize curriculum design. For example, in the architectural technology course, the number of teaching hours dedicated to explaining scientific principles should be increased, and practice assignments related to mathematical calculations should be designed. Meanwhile, students should be guided to conduct analysis and project design by integrating real-world architectural cases. Through such case analyses and project-based design tasks, the quality of teaching and students' learning outcomes can be enhanced, thereby strengthening the connection between analytical skills and practical application.

Possible research directions

1. **Explore the specific action mechanisms of arts education:** Although we have shown the importance of arts education in architectural education, its specific action mechanisms need to be further clarified. For example, we can discuss how arts can influence the learning and development of other facets by stimulating students' creativity and imagination.
2. **Develop interdisciplinary teaching evaluation methods:** With the popularization of interdisciplinary teaching, how to effectively evaluate this teaching method is an urgent problem. In the future, a method or indicator system suitable for interdisciplinary teaching evaluation can be developed to more accurately assess the quality of teachers' teaching and the impact on students' learning.
3. **Explore the applications of STEAM education in other fields:** Besides architectural education, the STEAM education method can also be introduced into other fields, such as engineering education and art design education. In the future, interdisciplinary research can be conducted to explore the applicability, effectiveness, and specific implementation strategies of STEAM education in different fields.

To summarize, this study not only reveals the mutual influence relations between different components of STEAM education in architectural education but also provides useful implications and possible research directions for educational practice. In the future, we will continue to delve into this field to provide novel insights and strengthen the innovation and development of architectural education in China.

CONCLUSIONS

This study, by assessing the application and impact of STEAM education in the architecture curriculum through the DEMATEL approach, provides a scientific basis for optimizing architectural education. Based on a literature review, we elucidate the transition from STEM to STEAM education, emphasizing the importance of non-STEM disciplines such as arts in developing students' comprehensive abilities. On this basis, we construct a system for distributing STEAM courses in architecture, and elaborate on the steps of implementing DEMATEL, including defining elements, assessing relations, generating the direct-relation matrix, normalizing the direct-relation matrix, calculating the total-relation matrix, and drawing the cause-and-effect diagram.

The DEMATEL approach was taken to calculate the degrees of association and relations between criteria in the architecture talent development system, and the cause-and-effect diagram was drawn. The comprehensive analysis reveals that the facets of engineering, science, and technology have great significance in architectural education, and educators may be more willing to improve these facets. We also noticed that the arrow directions of the arts facet, as an influenced facet, only unidirectionally point to other facets, indicating that improvement of the arts facet can also effectively promote the improvement of other facets, without being reversely influenced by other facets. Therefore, we suggest that educators should start with the improvement of the arts facet to enhance the overall effect of the architecture curriculum.

In summary, this study reveals the complex relations of STEAM education in the architecture curriculum through the DEMATEL approach. Specifically, it was observed that art plays a pivotal and leading role, significantly influencing technology and engineering. Science and mathematics exhibit strong centrality with positive impacts, interacting with and facilitating other components. Technology serves as a bridge connecting scientific theories and engineering practices, while engineering provides a practical platform for the application of knowledge from other STEAM areas. Future research can further discuss the impact of different teaching methods and strategies on the effectiveness of STEAM education and explore how to better integrate the STEAM education into the architecture curriculum, thereby cultivating students' innovative thinking and practical ability. Finally, the DEMATEL approach can be integrated with other assessment tools to provide a more comprehensive evaluation of the quality and effectiveness of architectural education.

Author contributions: W-LH & SG: methodology; **W-LH:** conceptualization, supervision, and writing–original draft; **LM, ZD, & SG:** investigation; **LM:** data curation and software; **ZD:** formal analysis and project administration; & **SG:** writing–review & editing. All authors agreed with the results and conclusions.

Funding: This study was supported by the Scientific Research Fund, Jiaying University (grants 2022WRC12, 422A0413, PX-59243355, PX-29232015, PX-29243038, and PX-103232546).

Ethical statement: The authors stated that the study does not require any ethical approval. The study involved experts who voluntarily responded to an anonymous questionnaire, without requiring physical procedures or the collection of sensitive data. Written informed consents were obtained from the participants.

AI statement: The authors stated that generative AI tools (e.g., ChatGPT by OpenAI) were used to check the English language clarity of the manuscript only. No content generation was performed by AI.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

Affandy, H., Sunarno, W., Suryana, R., & Harjana. (2024). Integrating creative pedagogy into problem-based learning: The effects on higher order thinking skills in science education. *Thinking Skills and Creativity, 53*, Article 101575. https://doi.org/10.1016/j.tsc.2024.101575

Alinezhad, A., & Khalili, J. (2019). *New methods and applications in multiple attribute decision making (MADM)*. Springer. https://doi.org/10.1007/978-3-030-15009-9

Altuntas, F., & Gok, M. S. (2021). The effect of COVID-19 pandemic on domestic tourism: A DEMATEL method analysis on quarantine decisions. *International Journal of Hospitality Management, 92*, Article 102719. https://doi.org/10.1016/j.ijhm.2020.102719

Ananias, E., & Gaspar, P. D. (2022). A low-cost collaborative robot for science and education purposes to foster the Industry 4.0 implementation. *Applied System Innovation, 5*(4), Article 72. https://doi.org/10.3390/asi5040072

Boice, K. L., Jackson, J. R., Alemdar, M., Rao, A. E., Grossman, S., & Usselman, M. (2021). Supporting teachers on their STEAM journey: A collaborative STEAM teacher training program. *Education Sciences, 11*(3), Article 105. https://doi.org/10.3390/educsci11030105

ElSayary, A. (2025). Enhancing teachers' design thinking mindsets through reflective practice: Cultivating innovation in an upskilling STEAM training program. *Eurasia Journal of Mathematics, Science and Technology Education, 21*(3), Article em2600. https://doi.org/10.29333/ejmste/16048

Gabus, A., & Fontela, E. (1973). *Perceptions of the world problematique: Communication procedure, communicating with those bearing collective responsibility*. Battelle Geneva Research Center. https://www.scirp.org/reference/ReferencesPapers?ReferenceID=1429249

Gu, X., Tong, D., Shi, P., Zou, Y., Yuan, H., Chen, C., & Zhao, G. (2023). Incorporating STEAM activities into creativity training in higher education. *Thinking Skills and Creativity, 50*, Article 101395. https://doi.org/10.1016/j.tsc.2023.101395

Herro, D., Quigley, C., Andrews, J., & Delacruz, G. (2017). Co-measure: Developing an assessment for student collaboration in STEAM activities. *International Journal of STEM Education, 4*, Article 26. https://doi.org/10.1186/s40594-017-0094-z

Ho, S.-Y., Chen, W.-T., & Hsu, W.-L. (2017). Assessment system for junior high schools in Taiwan to select environmental education facilities and sites. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(5), 1485-1499. https://doi.org/10.12973/eurasia.2017.00681a

Jeong, H.-M., Kwon, H., & Kim, S.-H. (2023). A meta-analytic approach for examining the effects of STEAM education programs in South Korea. *Innovation and Education*, *5*(1), 81-97. https://doi.org/10.55396/ined.22.0006

Juškevičienė, A., Stupurienė, G., & Jevsikova, T. (2021). Computational thinking development through physical computing activities in STEAM education. *Computer Applications in Engineering Education*, *29*(1), 175-190. https://doi.org/10.1002/cae.22365

Kang, N.-H. (2019). A review of the effect of integrated STEM or STEAM (science, technology, engineering, arts, and mathematics) education in South Korea. *Asia-Pacific Science Education*, *5*, Article 6. https://doi.org/10.1186/s41029-019-0034-y

Leavy, A., Dick, L., Meletiou-Mavrotheris, M., Paparistodemou, E., & Stylianou, E. (2023). The prevalence and use of emerging technologies in STEAM education: A systematic review of the literature. *Journal of Computer Assisted Learning*, *39*(4), 1061-1082. https://doi.org/10.1111/jcal.12806

Lin, C.-L., & Tsai, C.-Y. (2021). The effect of a pedagogical STEAM model on students' project competence and learning motivation. *Journal of Science Education and Technology*, *30*, 112-124. https://doi.org/10.1007/s10956-020-09885-x

Minces, V. H., & Akshay, N. (2023). STEAM for all: A vision for STEM and arts integration. In R. J. Tierney, F. Rizvi, & K. Ercikan (Eds.), *International encyclopedia of education* (pp. 10-18). Elsevier. https://doi.org/10.1016/B978-0-12-818630-5.13053-2

Singh, M., Azad, I., Qayyoom, M. A., & Khan, T. (2024). A study on perceptions and practices of STEAM-based education with university students. *Social Sciences & Humanities Open*, *10*, Article 101162. https://doi.org/10.1016/j.ssaho.2024.101162

Wu, Y., Hu, Y., Lin, X., Li, L., & Ke, Y. (2018). Identifying and analyzing barriers to offshore wind power development in China using the grey decision-making trial and evaluation laboratory approach. *Journal of Cleaner Production*, *189*, 853-863. https://doi.org/10.1016/j.jclepro.2018.04.002

Zhang, H., Chen, S., Wang, C., Deng, Y., Zhang, Y., & Dai, R. (2024). Analysis of factors affecting space teleoperation safety performance based on a hybrid fuzzy DEMATEL method. *Space: Science & Technology*, *4*, Article 0140. https://doi.org/10.34133/space.0140

https://www.ejmste.com