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THE IMPACTS OF SCIENCE, TECHNOLOGY, ENGINEERING, ART, AND MATHEMATIC EDUCATION ON STUDENTS' PERFORMANCE THROUGH CREATIVE EDUCATION: A META-ANALYSIS

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Abstract. STEAM education is necessary to ensure the success of creative education. The interdisciplinary approach offered in STEAM learning considerably enables to shape student creativity. However, STEAM learning has not fully explored its various elements, particularly "Art" element. In fact, artistic and cultural values contained in "Art" are able to be the potential sources to develop creative education. Therefore, the purpose of this research is to investigate the impacts of implementing the STEAM approach in creative education. The review method was carried out using the PRISMA framework (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) by analyzing 19 scientific publications involving 2520 students. The findings of this review show that the Art element plays an important role in STEAM learning, especially in creative education (the Size Effect ranges from 0.04–1.32). In addition, artistic and cultural integration by combining STEAM learning and EDP strategy (STEAM-EDP) is a promising step in enhancing students' creative education as an effort to fulfill the demands of 21st century skills.

Keywords: creative education, impacts, meta-analysis, performance, STEAM education, students.

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1. Introduction

STEAM (Science, Technology, Engineering, Art, and Mathematics) education is derived from STEM (Science, Technology, Engineering, and Mathematics) by adding "Art" content (Aróstegui et al., 2019). STEAM is described as multidisciplinary (Conradty & Bogner, 2019; H. Kim & Chae, 2016; S.-W. Kim & Lee, 2022), interdisciplinary (Diego-Mantecon et al., 2021; M. K. Kim et al., 2019; Stenard, 2021; Tkachenko et al., 2022), and transdisciplinary (Aróstegui et al., 2019). The multidisciplinary approach is carried out by integrating and making connections across content areas. The interdisciplinary approach focuses on overlapping content areas, while the transdisciplinary approach teaches with a conceptual framework, epistemology, and application (Marshall, 2014).

The ideal STEAM Education employs an interdisciplinary or transdisciplinary approach. However, the implementation is, in fact, still multidisciplinary. As a result, the learning is convergent, and make the cognitive load more complex albeit containing the same content. The implementation of such STEAM learning is criticized by Gettings (2016) even though the learning actually still intersects with traditional way. In a broader sense, STEAM can be applied

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as a learning strategy (Talib et al., 2019), as a pedagogical model (Anito Jr. & Morales, 2019; Belbase et al., 2021; Rahmawati et al., 2022), as an educational method (Ahmad et al., 2021; Hoi, 2021; Yungkeun, 2022), and as a STEAM-based curriculum (Tran et al., 2021a), and as a learning approach (Bassachs et al., 2020; Bin Amiruddin et al., 2022; Liao, 2016). All sorts of application in the classroom are of course adjusted by taking into the consideration both instructional advantages and disadvantages and learning objectives.

Many studies, in myriad perspectives and approaches, related to STEAM learning have been done. The spread of STEAM initially evolved in the United State of America and became well-known as a center for STEAM education. In contrast, in Asian country, Malaysia, for instance, has not entirely embraced STEAM, which focuses on combining art and STEM education (Talib et al., 2019). Yet, it is worth noting that the development of STEAM is not as wide as the spectrum of STEM education. The Shifting of STEAM from STEM in terms of content and discipline is conducted to obtain more holistic education, including the artistic aspects in particular.

STEAM learning positively contributes to creative education in which students are able to think by their own ability and imagination to yield new and meaningful ideas (Gibson, 2010). It also actively involves students in learning process, implementing creative concepts in the class, providing clear instructions, and utilizing the opportunity of authentic creative learning. Creative education underlies on seven main principles, namely truth, beauty, learning, observation, reasoning, expression and production (Osborn, 1927). The characteristics of a favorable learning are basically centered on creativity, which encompasses the ability to think out of the box, find new solutions, and apply innovative ideas in relevant contexts. This notion is certainly in line with creative education through which cultivation of creative virtues enables to emerge when teachers, as determinant agents, are able to provide a creative space, train students' independence, explore new attractive themes in learning process (Robinson et al., 2018).

Evidence from studies carried out over the past 10 years have shown that the use of STEAM has played a crucial role to fulfill the demands of 21st century skills, one of which is creative education. Apart from that, STEAM education also influences students' ability on problem solving (Chang et al., 2023; Erol et al., 2023; Y.-H. Lin et al., 2023; Zhan et al., 2023), multi-sensory experiences on student learning outcomes (Huang et al., 2023). In this sense, through STEAM the space for students to develop creativity is widely open. Although various studies show that STEAM has brought about positive impact on students' performance, many studies in the opposite results also denote the inconsistency of the role of Art within STEAM in cultivating students' creative values. However, the development of evaluative research toward creative education is still limited. Critical studies recently conducted have not comprehensively elaborated the element of Art in STEAM, including the integration of cultural values that have been integral part of creative education. Thus, this meta-analysis research focuses to review the impact of STEAM on creative education.

The research questions for this meta-analysis are: (1) What student performance is developed through STEAM in creative education? (2) What is the impact of the role of art in the context of STEAM based on creative education? and, (3) What is the role of culture in STEAM education integrated with creative education?

2. Methods

The methodology in this research uses a systematic literature review and meta-analysis, which has protocols and rules for collecting and selecting articles. The use of PRISMA (Page et al., 2021) has three stages, namely identification, screening, and inclusion. The search uses PRISMA aim to determine eligible articles for analysis (Figure 1).

The article selection procedure

PRISMA stands for preferred reporting items for systematic reviews and meta-analysis, which is a guideline used as a reference in presenting eligible literature (Page et al., 2021). PRISMA can direct the determination of the method to be selected through the Scopus and Web of Science (WoS) databases as well as the research publisher Taylor & Francis Online (Tanfonline). Article review starts with article identification, followed by screening for articles that are accepted and rejected, and feasibility assessments and articles that are in accordance with the purpose of writing obtained. All articles found through keywords will go through all three stages of assessment so that the article review is much concentrated on the purpose of writing.

Identification

Identification of scientific works as the first step in searching uses keywords, namely STEAM, creative, education from sources. This stage is essential because the keywords used come from articles (Shaffril et al., 2018), guiding us to start searching for scientific works using search keywords (Table 1). Search through the Scopus and WoS databases has a high impact factor in this literature review. Apart from that, Tanfonline as a trusted research publisher is wielded in the article search as well.

Table 1. Keywords for searching scientific works (source: created by authors)

Database/Publisher	Keywords	Number of scientific works
Scopus	STEAM+creative	365
WoS	STEAM+education	310
Taylor & Francis Online	STEAM+education+creative	633

The Scopus database found (n = 365) by filtering several supporting and relevant keywords. Searches in the WoS database used more general keywords, namely STEAM+education, to avoid the meaning of STEAM as a word that is not an abbreviation for approach and specifically in the scope of education (n = 310). In addition to the database, a search was also carried out on Taylor & Francis Online (n = 633) so that a total of scientific works (n = 1308). In the identification process, duplicate and irrelevant scientific works were discarded (n = 1243).

Screening

The next step is screening to determine the limitations of scientific work to be used. Screening will filter out articles that are not criteria (Tran et al., 2021a). As the result of this screening, it was obtained articles (n = 573). This filtering process is necessary in order the focus of analysis is in accordance with the analysis objectives. Of the total 573 articles, 279 articles were considered

appropriate since their scope of studies was still in the educational realm, while the rests (n = 294) were rejected by the consideration outside educational and learning concentration. The filtering then was manually carried out related to keywords of STEAM and Creative, so that articles (n = 214) were rejected due to such studies beyond the scope of STEAM and creative education. As such, the filtered articles were obtained (n = 65), namely from the Scopus (n = 36), WoS (n = 21), and Tanfonline (n = 8) database respectively. The next filtering (n = 65) was manually conducted and grouped based on the type and research subject, in which it was gained quantitative research and mixed methods (n = 23), qualitative research, development and literature studies (n = 36), research samples other than students (n = 6). Further filtering was obtained 23 articles with the criteria of quantitative research, mixed research, and students as the samples accessed from the Scopus (n = 13), WoS (n = 8), and Tanfonline (n = 2) database. However, from 23 articles, there are evidently double published articles, so two articles from Tanfonline and WoS respectively were removed. Hence, there were 19 eligible articles (13 of Scopus and 6 of WoS), and regarded as appropriate to be further examined.

Included

At this stage, the results of the search were 19 articles that met the criteria and were analyzed using a systematic literature review. The stipulated standard criteria are scientific works in the form of articles for the 2013–2022 period published by two databases (Scopus and WoS), and one publisher (Tanfonline). The research sample consists of students and is the result of quantitative evaluative research on the application of STEAM and its impacts on student creativity. Figure 1 below is a PRISMA flow diagram adapted from (Page et al., 2021).

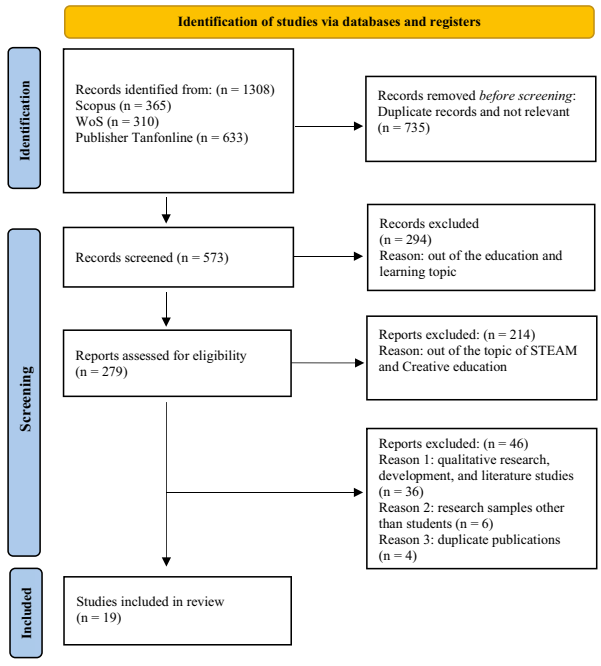


Figure 1. PRISMA 2020 flow diagram illustrating the study selection process (source: adapted from Page et al., 2021)

Data extraction procedure

The included data were descriptively analyzed, grouped, and conclusions to answer research questions. The analysis comprises of: (1) student performance developed through STEAM in creative education; (2) the impact of the role of art in the context of STEAM based on creative education; and (3) the role of culture in STEAM education integrated with creative education.

3. Result and discussion

The basis for content analysis employs meta-analysis of 19 articles published in a decade (2013–2022) with the scope of STEAM implementation and its influence on students' creative education. This analytical study is to answer research questions.

Development of student performance in creative education through STEAM

Based on the type of student performance as a part of creativity, according to Rhodes, it is divided into four categories: student creativity, product, context, and press (Firestien, 1994). Most studies tend to much creativity of person and process, but very few of them involve in evaluating the creativity of product and press. Table 2 is described to answer research questions about the type of performance developed and the instruments used.

RQ1: What student performance is developed through STEAM in creative education?

Table 2. Types of student performance developed through STEAM and instruments used to measure student performance (source: created by authors)

Study	Performance Type	Instrument
(Bati et al., 2018)	Person	Computational Thinking skills (Weintrop et al., 2014)
(Chung et al., 2018)	Person	Ad hoc Questionnaire
(Thuneberg et al., 2018)	Person	5-point Likert scale (Miller & Dumford, 2016)
(Bureekhampun & Mungmee, 2020)	Person and Press	Ad hoc Questionnaire
(Conradty & Bogner, 2020)	Product	CPAC questionnaire (Miller & Dumford, 2016)
(Conradty et al., 2020)	Person	Processes Associated with Creativity (Conradty & Bogner, 2018)
(Mierdel & Bogner, 2020)	Process	Questionnaire (Conradty & Bogner, 2019)
(Wannapiroon & Petsangsri, 2020)	Person	Ad hoc Questionnaire
(Ahmad et al., 2021)	Person	Assessment Score Instrument
(Park et al., 2021)	Person	Assessment of Scientific Reasoning (Sternberg & Sternberg, 2017)
(Salmi et al., 2021)	Process	Creativity measure (CREAT) (Miller & Dumford, 2016) and modified by (Conradty & Bogner, 2018)
(Tran et al., 2021a)	Person	Scientific Creativity Test (Hu & Adey, 2002)
(Tran et al., 2021b)	Person	Scientific Creativity Test (Hu & Adey, 2002)
(Wannapiroon & Pimdee, 2022)	Person and Process	Creativity assessment form used concepts adapted from (Guilford, 1954) and (Brookhart & Nitko, 2019) and consists of four sub-skills including originality, fluency, flexibility, and elaboration.

Study	Performance Type	Instrument
(Hsiao et al., 2022)	Person	STEAM Knowledge Examination Paper (STEAM KEP) (Hsiao et al., 2019)
(S.-W. Kim & Lee, 2022)	Process	Creative Problem-Solving Profile Inventory (CPSPI) (H. Lee et al., 2014)
(Lu et al., 2022b)	Process	Torrance Tests of Creative Thinking (TTCT) (Wallach & Torrance, 1968)
(Cheng et al., 2022)	Person	CSE a five-point Likert scale (Steele et al., 2018)
(Lu et al., 2022a)	Person	Assessment of Creativity (H. T. Lin & Wang, 1994; Williams, 1972)

The results of the study (Table 2) show the development of types of student performance as measured in evaluative research. The tendency in this study is to measure the type of performance of person that is the creative sides of students in this regard. The learning through STEAM is mindful, whether a teacher remains engaged in learning or not, this process demands students' creativity and independence, not limited to strict rules of curriculum (Craft, 2004). Creativity is the basis for students to optimalize their self-potency, think more critically, and stimulate to be innovative. This sort of ability is actually in accordance with the 21st century skills also known as the century of creativity (Camacho & Romero, 2022).

The development of personal creativity performance through STEAM forms individuals who are able to think creatively (Hlukhaniuk et al., 2020; Sakon & Petsangsri, 2021; Tsurusaki et al., 2017). Creative thinking makes students think divergently (Connor et al., 2015; Harris & De Bruin, 2018). If a person's creative performance developed well, students can be authentic and create something new in their lives. The development of this performance ultimately influences other performances such as products, processes, and press.

However, the other main aspects of creativity performance that have been rarely examined through evaluative research in the last decade are the product and press creativity. This fact certainly becomes an opportunity as well as a challenge in itself. Creativity as a product (Torrance, 1969) is the result of a process of invention or improvised products. When an existing idea is visualized in the form of a product and traced back, the product reflects the maker's idea (Rhodes, 1961). The results of student performance work in the form of products show that STEAM has made a major contribution in the world of creative education (Ahmad et al., 2021; Liu et al., 2021; Timotheou & Ioannou, 2021). Originality of thinking produces creative thinking product. Without a touch of art in STEAM, products look like "unfinished" (Liu & Wu, 2022).

Teachers basically play a pivotal role in the development of student performance. In this respect, students must have sufficient knowledge of such domain in which they require to be trained to appreciate and build their creativity in learning context. Searching and understanding, as the process of constructing meaning, are the most significant things in the development of personal pedagogy (Jackson et al., 2006). With an appropriate environment, students can create their creative products as a form of implementing their creative thinking (S.-S. Lee, 2020; Wandari et al., 2018). In addition, students also can improve their best

performance through a safe and supportive environment so that they are able to learn how to be a responsible individual and form a self-efficacy (Conradty & Bogner, 2020).

Impact of the role of art in the context of STEAM based on creative education

Creative education as the basis of STEAM requires educators to position art as an equal part of other elements (S-T-E-M). Therefore, it is necessary to explore the definition of STEAM used in creative education to answer research question 2.

RQ2: *What is the impact of the role of art in the context of STEAM based on creative education*

Table 3. Definitions of STEAM education from the meta-analysis (source: created by authors)

Study	Definition
(Chung et al., 2018)	STEAM is a teaching method that is centered on the relationships that occur between its components at any time (Lou et al., 2011)
(Thuneberg et al., 2018)	STEAM functions in increasing interest and level of understanding related to technology in solving problems (Kofac, 2017)
(Bureekhampun & Mungmee, 2020)	STEAM is a form of integrated learning between science, technology, engineering, art, and mathematics. Adding art according to needs (Orapiriyakul, 2019)
(Conradty & Bogner, 2020)	STEAM as a way of teaching or as a learning solution that is difficult, abstract, and boring (J. Bennett & Hogarth, 2009; Henriksen, 2013)
(Conradty et al., 2020)	Not specified.
(Wannapiroon & Petsangsri, 2020)	STEAM education that integrates its five components in learning
(Salmi et al., 2021)	The STEAM approach as integration between art, and creativity (Yakman & Lee, 2012)
(Tran et al., 2021a)	STEAM as an interdisciplinary or multidisciplinary approach suitable for project-based learning
(Tran et al., 2021b)	STEAM is formed from a combination of STEM and art which plays a role in student involvement in learning (Perignat & Katz-Buonincontro, 2019)
(Wannapiroon & Pimdee, 2022)	Not specified
(Hsiao et al., 2022)	The combination of S-T-E-A-M is learning science and technology based on mathematics with elements of art (Sochacka et al., 2016)
(S.-W. Kim & Lee, 2022)	Not specified
(Lu et al., 2022b)	Not specified
(Cheng et al., 2022)	Not specified
(Lu et al., 2022a)	Integration of the five components to hone students' analytical and logical thinking (Maryland, 2012)

Table 3 shows the various definitions of STEAM which have meanings and perspectives. The author's tendency to define STEAM by including elements of Science, Technology, Engineering, Arts, and Mathematics is a derivative of STEM with the addition of "art". In its application, STEAM has become an inherent part of learning process or integrated with relevant learning models (Khamhaengpol et al., 2021). However, there are elements that have not been maximally explored in STEAM, particularly in elements "E" and "A".

To certain extent, STEAM still has unclear differences with STEM; even, both are often considered the same, so that distinctions of characteristics between the two are blurred. However, the point of differences lies in the focus of content development in which STEAM provides a space for EA to be equal with other content, while STEM views EA content that has been already centered and included in the analysis of student products (Aguilera & Ortiz-Revilla, 2021). In the context of creative education, STEAM considerably deems an appropriate and supportive ecosystem environment. The position of "Art" in STEAM is as important as other contents. Art is considered capable of contributing and even providing solutions in the development of science. Cultural values within Arts can reinforce STEAM learning which is able to of course be valuable sources in creative education (Park et al., 2021; Salmi et al., 2021). In this regard, teachers are required to create not only a fun and enjoyable learning, but also formulate interdisciplinary learning approach as a solid foundation so that the overlapping between STEAM and STEM is no longer a serius problem. The addition of "Art" makes a learning more meaningful when supported by a "technique" component it will provide opportunity to persistently be developed and applied. Therefore, STEAM serves as a choice for present and future learning by striving to integrate it with EDP (Engineering Design Process). EDP is an important strategy that bolsters STEAM and creative education. The process and procedure in EDP assist STEAM implementation (Khamhaengpol et al., 2021). So the solution to reinforce the elements E and A within STEAM is STEAM-EDP for creative education (Erol et al., 2023; Khamhaengpol et al., 2021).

The role of culture in STEAM education is integrated into creative education

RQ3: *How is the role of culture in STEAM education integrated with creative education?*

The values of culture can be empowered in shaping creativity, but, in fact, no much research has revealed the role of local culture or wisdom related to creativity improvement. Such indication can be highlighted from 19 articles in Table 4 in which none of those examined and elaborated the values of local culture in learning activity. Even though all the results of the studies have positive impact on creative education, the role of culture has not been touched and still insignificant. Moreover, elements of creativity can be found in sort of cultural products such as local arts, crafts, and traditional food, these product potentially can inspire students to build creativity (A. G. Bennett, 2016; H. Kim & Chae, 2016).

Table 4 shows that STEAM has a positive influence on creative education. Although the studies have applied variety of methods and strategies, local culture or wisdom has not touched in learning. The implementation of STEAM through various activities has significant impacts on students' creativity. The magnitude of the influence using the Cohens' formula was not determined in several articles because they either did not record enough data or did not provide data to determine the magnitude of STEAM's influence in developing student creativity.

The application of STEAM with multiple strategies shows positive impacts on creative education. Such strategies are integrated with STEAM. Nevertheless, not all articles present complete data to calculate the effect size using Cohen's d, and some articles do not even provide it. STEAM is used in the classroom using strategies and integrated models or methods. The trend of the model used is Project-Based Learning (PBL) which is a learning model most often combined with STEAM. In each step of PBL, teachers can design and incorporate

Table 4. Effect of STEAM on creative education and reasons (source: created by authors)

Study	N	AS*(d)	Effect	Reasons
(Bati et al., 2018)	104	–	Positive	Based program on computational thinking in science education
(Chung et al., 2018)	46	–	Positive	- STEAM-6E course based on the theme of creative design of IoT (Internet of Things) assistant devices for the elderly - Mobile learning platform as a context for students to engage in cooperative learning
(Thuneberg et al., 2018)	392	–	Positive	STEAM hands-on inquiry-based math module
(Bureekhampun & Mungmee, 2020)	15	–	Positive	Design a STEAM Learning Activity
(Conradty & Bogner, 2020)	550	a	Positive	Teacher training.
(Conradty et al., 2020)	92	a	Positive	Employ inquiry-based learning Promote cooperative work
(Mierdel & Bogner, 2020)	114	–	Positive	Model of Modelling (Justi & Gilbert, 2002)
(Wannapiroon & Petsangsri, 2020)	90	1.32	Positive	STEAMification model in flipped classroom learning environment
(Ahmad et al., 2021)	27	–	Positive	STEAM method in learning
(Cheng et al., 2022)	68	a	Positive	Employ project-based STEAM
(Park et al., 2021)	169	–	Positive	STEAM Related Creative Problem Solving
(Salmi et al., 2021)	392	–	Positive	4Dframe' Math and STEAM learning toolkits
(Tran et al., 2021a)	62	a	Positive	Lock Science Courses stage and STEAM-based courses stage
(Tran et al., 2021b)	66	–	Positive	STEAM-based courses
(Lu et al., 2022a)	3	–	Positive	Employ Project-Based Learning Oriented STEAM Curriculum with Micro:bit
(Wannapiroon & Pimdee, 2022)	60	1.09	Positive	Digitally based virtual classroom learning environment (VCLE) STEAM-ification model
(Hsiao et al., 2022)	199	0.65	Positive	Employ project-based learning (PBL) strategy and the cognitive–affective interaction model (CAIM)
(S.-W. Kim & Lee, 2022)	50	0.71	Positive	Employ Science, Mathematics, and Informatics Convergence Education (SMICE) Promote computational thinking
(Lu et al., 2022b)	21	0.65	Positive	Project-based learning-oriented STEAM
	2520			

Note: * Effect sizes (Cohen's d); [a] insufficient statistical data available; "–" not applicable.

S-T-E-A-M elements. These five STEAM elements have their own characteristics but can be combined to build knowledge and creativity. Students must firstly understand knowledge base built before creating a product using PBL. The foundation of knowledge is the basis for students to solve problems, find proper solutions, and end by creating innovative products. The S-T-E-A-M elements do not have to appear all the time, but identifying the important emphasis in the PBL step determines what STEAM elements emerge.

The efforts to hone student creativity actually have been carried out in many ways through STEAM. It is paralel with the demands of 21st-century skills in which creativity becomes one of main concerns. The magnitude of STEAM's impacts varies in distribution, most of the effect sizes are in the medium and high categories, while some of them cannot be determined due to not enough available data. Although it is found inconsistency between the tests of the STEAM implementation impact and the terms of the size, the studies show that the use of STEAM in learning brings about a positive result on student creativity. Yet, it is possible that the art factor has not yet been prominent, so there are exceptions in the form of a large number of samples that do not necessarily have a large effect size.

In fact, the current development of STEAM learning provides challenges and opportunities in the world of education. Armed with the distribution of evaluative research in STEAM education, strengthening elements of art integrated with culture can be a new force in creative education. So, teachers can develop it in learning to answer the learning challenges of this century. As such, teachers can develop it in learning activity to answer learning challenges in this century. Apart from reinforcing STEAM through STEAM-EDP, which hones "E" and A", STEAM becomes more characterized when integrated with culture.

EDP, according to the Accreditation Board for Engineering and Technology (ABET), is the process of designing a system, component, or process to fulfill a desired need. Such process makes use of basic sciences, mathematics, and applied engineering to transform resources optimally in order to achieve goals. The engineering design component of curriculum in EDP is the development of students' creativity to solve problems in engineering issues (Haik & Shahin, 2011). Selecting EDP to collaborate with STEAM is very appropriate to overcome the weaknesses in the implementation of STEAM, particularly in the component of engineering and art. The use of EDP in strengthening STEAM is able to fill students' creative space (Abdurrahman et al., 2023). EDP has a process stage developed by (Abdurrahman et al., 2023; Carberry et al., 2010; Crotty et al., 2017; Haik & Shahin, 2011; Johnston et al., 2019; Lie et al., 2021; Massachusetts Department of Education, 2001), namely determining goals and problems, synthesizing solutions, constructing prototypes, testing and evaluating, and redesigning. However, from the research results in Table 4, none of research focuses on culture-integrated STEAM education. It is a fundamental part of this study because there is a close relationship between art, culture, and education. As sources of learning, culture had been a primordial identity of the local community, so STEAM-EDP can more have living characters. If there is an empty space in STEAM (de Vries, 2021), it can be filled with culture. Local culture can increase creativity and inspire artistic elements within STEAM (H. Kim & Chae, 2016). Art and culture through STEAM eventually can be a means to know and understand the wealth culture of a nation in globalization era (Taylor, 2016).

Research opportunities and implications of using STEAM for creative education

This study provides an overview of opportunities and challenges that can be explored for future research. STEAM education has high and advanced prospects for pedagogical purposes (Belbase et al., 2021). STEAM has many benefits, one of which bridges a real-life connection through interdisciplinary elements such as science, technology and engineering, art (culture) and maths. This will be the basis of innovative thinking for future of students (Gettings, 2016).

STEAM education through its approach can respond to social and technological changes needed by students as skills in the 21st century (Tkachenko et al., 2022). Nevertheless, the implementation of STEAM has not spread evenly in developing countries, including Indonesia. Understanding and awareness about the urgency of knowledge for life can stimulate students to be more creative and innovative. This objective condition certainly can be an opportunity for researchers to develop STEAM in learning activity with approach, method and perspective that are relevant to the spirit of the times. Considering that STEAM can be implemented at every level of education starting from early childhood education to higher education (Torrance, 1969) it definitely opens up broad chances for researchers who are interested in the STEAM discourse.

STEAM education is a solution to deal with complex educational problems nowadays (Anisimova et al., 2022). The development of STEAM in the realm of creative education has pointed out good achievements so far. However, the artistic elements in it have not been the main focus, instead often ignored (Khamhaengpol et al., 2021). The weakness of research related to STEAM is the lack of attention to elements "A" and "E". Apart from that, putting culture as the basis of learning strategy, if seen from the 19 articles analyzed previously, has not been a priority or an important part in developing STEAM education. There are many ways to strengthen elements of art and culture in STEAM learning, one of which can be implemented by integrating it with EDP. The application of culture-based STEAM-EDP learning is an alternative toward the lack attention on art and culture as shown by previous studies. This is also a great occasion to develop creative education through art and culture to answer the challenges of the 21st century.

Viewed from the basis of need and opportunity, STEAM education should be able to act as an alternative offer to shape students' creative spirits, and overcome problems they face independently. Therefore, through a culture-based STEAM-EDP strategy it is believed to increase positive implications of STEAM education on student performance in creative education. This effort calls for the need to integrate culture and art more deeply into STEAM education. Again, although research shows that STEAM education is effective in increasing students' creativity and innovative thinking, the use of local culture and artistic elements is still not optimally conducted. This integration is necessary since it can provide a more relevant and meaningful context for students, helping them to connect STEAM learning to real life and their cultural heritage as well. This way can stimulate student engagement and motivation to learn, as well as foster appreciation for art and culture.

It is hard to deny that there is currently a gap in the literature regarding the best way to integrate aspects of culture and arts in STEAM education. Further research is, therefore, required to more explore pricise strategy, approach and practice in combining such elements. This endeavor includes developing more inclusive and diverse curricula, training teachers to provide a deep understanding on strategies effectively in learning activity, and assessing the long-term impact of culture and arts in STEAM education on student learning outcomes. These implications emphasize on the importance of a holistic approach in STEAM education, by which technical knowledge and skills are balanced with the development of creativity, critical thinking, and cultural awareness.

4. Conclusions and recommendations

STEAM in creative education plays an important role in developing students' performance in multiple aspects. STEAM education significantly advances student creativity in the 'person'. This can be observed from the myriad performances which are much dominated by students' individual creativity. It further allows students to think creatively and divergently, generate new ideas and innovative solutions. STEAM education focuses not only on developing 'person' creativity, but also on process, product, and press (an environment that supports creativity). While research has mostly evaluated person and process creativity, there are other opportunities and challenges in measuring product and press creativity. Creativity in products shows that STEAM contributes greatly to the world of creative education, in which students can produce creative products due to innovative learning processes. The "Art" factor in STEAM contributes to the creation of more 'finished' and creative products.

This is reinforced by considering cultural aspects in STEAM as a source for creative education, which enables teachers to more develop divergent and integrated learning. The integration of Art within STEAM not only adds an aesthetic dimension, but also strengthens meaningful learning process by supporting "Engineering" component. In this regard, STEAM approach, reinforced with EDP, is considered an appropriate option for current and future learning. The process and procedure in EDP sustain the implementation of STEAM and creative education, demonstrating solutions to reinforce "E" (Engineering) and "A" (Art) elements in STEAM. Thus, STEAM with EDP integration is important in supporting creative education.

The role of culture in EDP-integrated STEAM education has great potential for creative education, but it has not been fully explored. Although the studies show that STEAM education has a positive influence on creative education, none of studies specifically utilize values of local culture in STEAM learning. Moreover, elements of creativity actually can be found in various cultural products, such as local arts, crafts, and even traditional foods, which contain rich artistic elements and can inspire students to stimulate creativity. It indicates that local culture has not become the sources of inspiration and creativity development in STEAM education. Instead, by incorporating such cultural elements, the STEAM approach can be diverse and more relevant to students, helping them understand and appreciate the diversity of national and global culture. The integration of culture into this approach obviously offers new opportunity to make learning process more meaningful.

Furthermore, trends in the implementation of STEAM education show that the use of various integrated strategies and models, with Project Based Learning (PBL) is a frequently used model. In each step of PBL, teachers can design and incorporate STEAM elements, each of which has its own characteristics, but can be combined to build knowledge and creativity. The utilization of cultural elements in STEAM education provides new opportunities for the development of creative education. The integration of arts and cultural elements in STEAM education can reinforce creative education, allowing teachers to develop more diverse and fun learning in order to meet the challenges of 21st century learning.

The integration of local arts and culture in STEAM education by integrating it with EDP should be improved. Although it has been proven that the STEAM approach has a positive influence on creative education, the utilization of local cultural aspects is still not optimal.

To address this, educational institutions can start by identifying and integrating local cultural elements into the STEAM-EDP curriculum and learning activities. This could include the use of traditional arts, folklore, and local historical contexts as part of learning projects. This application will not only enrich students' learning experiences, but also help them appreciate their own culture.

STEAM-EDP education should focus on developing creativity and innovative thinking. It emphasizes project-based learning and practical problem solving that can help students develop these important skills. Teachers should be encouraged to create learning environments that support exploration and experimentation where they are able to apply their STEAM knowledge in real and relevant contexts. This will prepare them to face academic challenges and to be critical and creative students who contribute to in everyday social life. In this context, teachers should be trained to create innovative and enjoyable learning that is in accordance with STEAM principles. The use of PBL also facilitates collaboration between students to increase interpersonal skills and teamwork.

Further research is needed to comprehend more deeply how the integration of culture and arts in STEAM-EDP can be implemented more effectively. Due to the lack of research specifically examining the role of culture in STEAM education, educational institutions and researchers should collaborate to carry out further empirical studies in this area. This research can help in developing more innovative teaching strategies and methods, which not only improve learning outcomes but also promote cultural understanding and appreciation among students. Further research in this issue is urgently required to improve innovative teaching methods and to understand the long-term impact of cultural integration in STEAM education. This research will provide valuable insights for educational practitioners and policy makers to develop strategies that are able to enhance the effectiveness of STEAM education through culture-based STEAM-EDP. These present and future programmes will help prepare students to become informed and empathetic global citizens in an increasingly connected global society nowadays.

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