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A study on perceptions and practices of STEAM-based education with university students

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ABSTRACT

The present survey-based study was conducted with (n = 317) university students in Lucknow city of India to examine their perceptions and practices about Science, Technology, Engineering, Arts, and Mathematics (STEAM) education. The data was collected from students belonging to different academic streams including Science, Economics, Arts, Engineering, Architecture, Computer Sciences, and Business and Management etc. from different higher educational institutions of the city. The snowball sampling method was adopted for the study. A tool in the form of a 5-point rating scale with three categories viz. Awareness, Perception and Implementation along with two dimensions in the Awareness category, four dimensions in the Perception category and one dimension in the Implementation category was constructed to collect data with a total of 23 items which were related to majorly three mentioned categories and demographic information. Frequency data analysis and the Kruskal-Wallis H test were used for analysis. The findings showed that most students hold a positive perspective towards the advantages of STEAM in their learning process. Still, despite the positive perspective, significant differences in the perception and implementation category of STEAM-based education was seen. The teaching-learning process is not planned as per STEAM education and classroom teaching lacks in in-cooperating STEAM. A significant difference was observed in the perception and implementation of STEAM-based education. The study showed that more than 70 per cent of the students believed that STEAM-based Education may enhance deeper understanding, constructivist approach, professional efficiency and critical thinking. The findings also highlighted the positive role of STEAM Education in infusing aesthetic elements and holistic approach in students.

1. Introduction

Globally, interdisciplinary and trans-disciplinary learning is becoming increasingly popular and a growing area of interest for educational reform. This prompts implementation and adaptation of Science, Technology, Engineering, Arts and Mathematics (STEAM) based education, which is shifting educational paradigms toward art integration in science, technology, engineering and mathematics (STEM) subjects. Learning opportunities for students should include “authentic tasks” set in a real-world context (Reeves et al., 2020), providing ample opportunities to learn. Authentic tasks consist of ill-defined problems, complex or multi-step questions, multiple ways to approach a problem and sub-tasks that integrate across disciplines (Amory, 2014). The integration of STEAM is one such effort towards the

encouragement of interdisciplinary approach to teaching-learning. In 1990, STEM (Science, Technology, Engineering and Math) was underscored as a fundamental area of learning in the 21st century (English, 2016; Ata Aktürk et al., 2017; John, 2018). Later, this set of fields was supplemented by including arts as a basis for creativity development, and STEM was modified into STEAM (Kim & Park, 2012; Land, 2013); (Sochacka et al., 2016); (DeJarnette, 2018). The concept includes pedagogical and andragogical activities across all developmental levels in formal and informal settings. When planning an integrative curriculum, one field may be the dominant base discipline or all may be planned to be more equally represented (Wells, 2016). Therefore, STEAM can be defined as holistic education, as a model of interdisciplinary creative education (Bati et al., 2018); (Wang et al., 2018); (Aktürk et al., 2017). The five disciplines infused in STEAM have their different nature yet

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they complement each other in a way that their integration leads to an effective system. A study showed the development of creative thinking and innovation skills among undergraduate students in Thailand through STEAM education (Wannapiroon&Pimdee, 2020). The findings suggested that the STEAM program played a positive role in enhancing students' creative thinking skills and influenced their attitudes toward innovation and creativity as students reported improvements in their abilities to generate novel ideas, think critically, and approach problems from multiple perspectives. The study also highlighted a greater appreciation for the role of arts and design in enhancing scientific and technological advancements by students. In another study, a variety of key research topics and themes related to STEAM were identified such as curriculum development, pedagogical approaches, assessment methods, and the integration of arts and design thinking in environmental and scientific education (Santi et al., 2021). Another study explored how STEAM education can be implemented in early childhood education to enhance teachers' knowledge, skills, and instructional practices (Monkeviciene et al., 2020). The findings suggested that innovative STEAM education practices positively impact both teacher professional development and the learning experiences of 3-6-year-old children. Improved knowledge and skills in integrating STEAM disciplines were reported, as well as increased confidence in delivering STEAM lessons. The children demonstrated higher levels of engagement, curiosity, and problem-solving abilities. A study done with elementary school teachers revealed a strong positive correlation between their awareness and attitude towards STEM education (Kratika, 2022). A previous study found that STEAM-based courses might help students maintain their scientific creativity ability (Tran et al., 2021). Another study showed that Science teachers had a higher level of awareness than mathematics, followed by those teaching in technology and humanities respectively (Kratika, 2022). Another study concluded that STEAM education emphasizes the development of transferable skills that leads to fostering a holistic learning experience that goes beyond subject-specific knowledge (Bertrand & Namukasa, 2020). These skills include creativity, collaboration, communication, and critical thinking, which are highly vital for bright career prospects. Despite the proven advantages of STEAM-based education, it is still far from being thoroughly implemented at all educational levels. A bibliometric analysis of STEAM studies showed that there has not been an established and robust line of research over time, although the trends in this aspect are focused on the scientific branch of education (Marín-Marín et al., 2021). Its implementation is particularly required in developing countries like India, where still the concept of traditional education is being practiced and nurtured. As per the general conception, it is witnessed that out of five discipline, four disciplines (science, technology, engineering and mathematics) are seen as interrelated by their very nature but "Arts" as a discipline is perceived at a distance from other discipline but STEAM had given an important place to Arts in its concept. Fig. 1 shows the inter-related nature of all five disciplines. In the light of the above discussion, the present study was conducted to assess the perceptions and practices of STEAM education at university level, along with it to spread awareness of the concept.

1.1. Main elements of involved disciplines Leading to STEAM

Each discipline involved in STEAM has its epistemology and nature. Epistemology talks about the origin, acquisition and above all construction of knowledge in general and scientific knowledge in particular. These all disciplines with their unique elements contribute to the concept of STEAM. The nature of the scientific enterprise includes.

- Science is a complex social activity, science is organized into content disciplines and is conducted in various institutions.
- There are generally accepted ethical principles in the conduct of science.

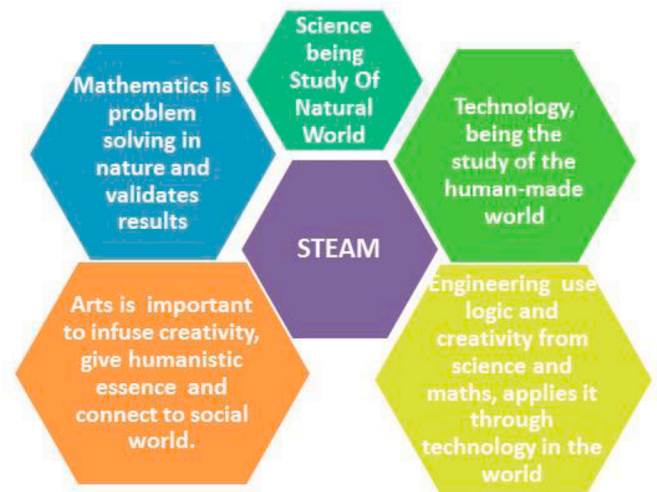


Fig. 1. Inter-related nature of all five disciplines included in STEAM education.

- Scientists participate in public affairs both as specialists and as citizens.

The Technology for All Americans Project (TfAAP) developed the standards which naturally include the necessary elements of the other fields associated with STEM that are intrinsic to the advancement of the study of technology.

The main elements of Technology Education.

- Require knowledge from a variety of fields, especially Science, Mathematics, and Engineering.
- Involves a variety of mental strategies developed through experiences in designing, modelling, testing, observations, etc.
- Determines quality and cost, risk-taking, etc.
- Evolving as per the need of society, individuals, or groups.

According to the Engineering Accreditation Commission (EAC), The Accreditation Board for Engineering and Technology (ABET) standards ramped up this movement of producing a more universally aware engineer, by promoting the following abilities as being of primary importance for instilling in development engineers. These include abilities (Yakman, 2006) mentioned below.

- To design and conduct experiments as well as to analyze and interpret data
- To design a system, component or process
- To function on multi-disciplinary teams
- To identify, formulate, and solve engineering problems
- To understand professional and ethical responsibility.
- To communicate effectively and engage in life-long learning

Art Education has always been an integral part of the human experience. For ages, art education has played role in the transformation of individuals & societies. Art, Society, and Culture are closely intertwined. Art Education is one of the main foundational bases of creativity in students. Along with creativity, it allows students to investigate, express, perceive, appreciate and interpret. The nature around them and also realizes their passions and strengths. Art Education introduces them to new realities and widens their perspective. Art Education is responsible to give an aesthetic view of science and mathematics education and make its learning more interesting. Subjects and their characteristics are rediscovered and their scope is widened (Hersh, 1994). highlighted five related ideas accepted in mathematics today:

- Mathematics is part of and fits into human culture.

- > Mathematical knowledge isn't by nature infallible.
- > There are different versions of proof and rigour, depending on time, place, and other things. The use of computers in proofs is a non-traditional version of rigour.
- > Empirical evidence, numerical experimentation, and probabilistic proof all help us decide what to believe in mathematics. Aristotelian logic is not necessarily always the best way of deciding.
- > Mathematical objects are a certain variety of social-cultural-historical objects.

This infusion of one discipline in another is present in their very nature as Mathematics is always needed to prove the concepts, theorems of physics and chemistry; similarly, Arts is very essential to add aesthetic elements to science, we need social sciences to understand the practical applications of the concepts we learn theoretical in class. The combat relationship between technology, engineering and science is a good witness and results in discoveries and inventions.

2. Purpose statement and research questions

The study was undertaken to assess the perspectives and practices of university-level students about STEAM education. The concept of STEAM education is complex and has multiple facets. The current study has examined the various aspects including awareness, perception and implementation. The purpose of analyzing these variables was to know the perception and implementation of STEAM-based Education particularly in the Indian context. The study was aimed to address the following research questions.

1. How do university-level students perceive STEAM Education?
2. Is there a difference in the perception of students and implementation of STEAM-based education in teaching-learning practices at the university level?

Furthermore, the following objectives were designed to achieve the targeted results:

To assess the perception of university-level students towards STEAM-based education.

To know the difference between the perception of students and the implementation of STEAM-based education in teaching-learning practices at the university level.

3. Methods

This section outlines the study's design and the methodology used to collect data and also elucidates the reasoning for the study design and the methodology employed for data collection. Furthermore, it provides a succinct analysis of the individuals involved and a concise overview of the instruments employed for collecting quantitative data in the following sub-sections.

3.1. Study design

The study followed a descriptive research design, which employed a quantitative data collection approach. Descriptive designs have a main focus on providing a detailed description of a social phenomenon or reality, either at a specific moment or over a prolonged period. They do not make an effort to analyze or establish a cause-and-effect relationship (Jann & Hinz, 2016). This study was an attempt to present a clear picture of how university-level students perceive STEAM education and its implementation in teaching teaching-learning process. In terms of its temporal dimension, the study is limited to examining this reality in current times and utilizes quantitative methodologies to objectively depict and analyze existing situations (Best & Kahn, 2006). For data collection, a quantitative approach was used and the data was collected in the form of a questionnaire survey. The data was collected through an

online Google form which was developed following Helsinki's declaration. Informed consent was taken from the participants and voluntary answering was sought. It was made clear that the personal details of the respondents will be kept confidential and the information will be used for research purposes only.

3.2. Participants

The survey included a total of 317 university students in Lucknow city of India. The sample included a diversified group of students in terms of their qualification diversity, stream diversity and institutions viz. from graduation, post-graduation and doctoral students belonging to different streams such as Science, Economics, Arts, Engineering, Architecture, Computer Sciences, Business and Management etc. from different higher educational institutions of the city. Table 1 depicts a breakdown of the participants in terms of gender, qualification diversity and stream diversity.

3.3. Sampling technique

The snowball sampling method was adopted for the study. The sampling method comes under the non-probability purposive sampling technique. According to Creswell (2012), snowball sampling is "a form of purposeful sampling that typically proceeds after a study begins and occurs when the researcher asks to recommend other individuals to be sampled. Sampling through the snowball method may reach to more diverse population. This process is based on the assumption that a 'bond' or 'link' exists between the initial sample and others in the same target population, allowing a series of referrals to be made within a circle of acquaintances (Berg, 1988).

3.4. Instrument

The study was conducted between 1st May and August 1, 2023 through an online questionnaire consisting of a total 23 questions in which six questions addressed the demographic details of the participants and the rest of the questions were included to know awareness, perception and implementation regarding STEAM-based education. The questionnaire was compiled under the guidance and consultation of experts from the field of Teacher education and science education at Integral University, Lucknow. The questionnaire was selected as the tool of data collection because of the easy interpretability of the results and to target a large sampling group. The questionnaire, developed in

Table 1
Demographic details of survey participants.

Demographic Variable	Frequency (n)	Percentage (%)
Gender		
Female	233	73.5
Male	84	26.5
Qualification		
Ph.D.	2	0.6
Post Graduation	57	18.0
Graduation	172	54.3
Intermediate	86	27.1
Board Stream		
Agriculture	01	0.3
Arts	40	12.6
B. Ed.	01	0.3
Commerce	65	20.5
Education	02	0.6
Engineering	43	13.6
M. Ed.	02	0.6
Medical Science	02	0.6
Pharmacy	01	0.3
Science	149	47.0
Technology	09	2.8
Others	01	0.3

English was converted into a 5-pointer rating scale and was posted on different social media platforms and shared through snowball sampling. The personal details were kept confidential. The questions were either on a 5-pointer rating scale based on a Likert scale (1 = Strongly disagree, 2 = Disagree, 3 = Can't Say, 4 = Agree, 5 = Strongly agree) or with multiple choices. The percentage was calculated according to the number of responses obtained for each question. The questionnaire is self-constructed by understanding and insight gained by the researchers after thoroughly going through the review of the related literature. The sections covered in the questionnaire were broadly divided into three categories, the first category is Awareness, the second category includes Perception-based items and the third category includes Implementation-based items. The first category Awareness includes 1 dimension viz. Knowledge, the Perception category includes 4 dimensions viz. Advantages of STEAM, Competitive skills and STEAM, Gender and STEAM, Aesthetic and STEAM whereas the Implementation category includes 1 dimension of teaching-learning practices. Each dimension has items within it (Table 2). The complete tool is mentioned after this section (Table 2). The validity of the questionnaire was achieved through face validity by 5 experts each of teacher education and science education. The statistical analysis was performed through SPSS version 2023. The

Table 2
Questionnaire (tool).

S. No.	Category	Dimension	Items
1.	Awareness	Knowledge of STEAM	Are you aware of STEAM as a concept? The concept of STEAM should be introduced from which educational level.
2.	Perception	Advantages of STEAM	STEAM has made the learning process more interesting and interactive. STEAM lead us to see the world around us with a wholesome approach. STEAM has enhanced the teaching-learning process in a blended approach. STEAM can help to develop a more holistic personality
		Competitive Skills and STEAM Education	STEAM is the centre of the basic skills needed for the 21st century. Learning through STEAM prepares me better for competitive exam Knowledge gained through STEAM is helpful towards professional efficiency STEAM can help in enhancing the soft skills of the students
		Gender and STEAM Education	Through STEAM the enrollment of girls students has increased
		Aesthetics and STEAM Education	STEAM can infuse aesthetic sense in its learners
3.	Implementation	Teaching and learning practices	The Teachers in our class are efficient in applying STEAM in the teaching-learning process. The students in my class are open to accepting STEAM for learning. STEAM-based teaching-learning practices in my class include constructivism and a critical approach The use of STEAM has increased post-pandemic in teaching-learning. In our class teaching-learning process takes place through STEAM
		Suggestions	How do you think STEAM can be promoted in your institution?

reliability was calculated using Cronbach's alpha and overall reliability was 0.957 and for the other items Cronbach's alpha reliability was high (Above 0.9).

4. Analysis and findings

The statistical operations used in the study were the frequency data analysis and Kruskal-Wallis H test. The frequency data analysis was used to answer first research question viz. How do university-level students perceive STEAM Education?, there is a need to know the number of students having positive or negative perception related to STEAM-based education and frequency data analysis along with percentage analysis serves the purpose.

The Kruskal-Wallis H test was used to answer the second research question viz. Is there a difference in the perception of students and implementation of STEAM-based education in teaching-learning practices at the university level?, according to the Kolmogorov-Smirnov normality test, the data is not normally distributed and hence a non-parametric test viz. Kruskal- Wallis test was used to determine if there is significant differences between two or more groups of independent variables on a continuous dependent variable. In the present study the independent variable is group of items included in the dimension Teaching-learning practices of implementation category and the dependent variable is other four dimensions viz. Advantages, competitive skills, gender and Aesthetic of Perception category.

4.1. Demographic details

Three demographic details viz. gender, educational qualification diversity and stream diversity of the participants were considered. The data depicted in Table 1, F ig. S1, and F ig. S2 provide details of gender, educational qualification and broad stream of the participants respectively. As evident, the majority of the students who took part in the study were of graduation level followed by intermediate, post-graduation and doctorate level respectively. On the parameter of broad stream, it was seen that 47 per cent (n = 149) of Science students participated in the study followed by Commerce viz. 20.5 per cent (n = 65), Engineering 13.6 per cent (n = 43), Arts 12.6 per cent (n = 40) and others respectively. From the findings, it could be concluded that one of the probable reasons for the involvement of more science students as compared to other streams is that science students do connect with the concept of STEAM more.

4.1.1. Category-awareness

As in the questionnaire for Awareness of STEAM-based education, there was one dimension viz. Knowledge and it has 2 corresponding items. The findings and analysis is shown in the sections below.

4.1.1.1. Dimension- knowledge of STEAM. As per the analysis, 71.7 per cent (n = 227) participants were aware of the concept of STEAM (Fig. 2, Table 3) and 38.5 per cent (n = 122) felt that the concept of STEAM should be introduced, at the secondary level followed by primary viz. 32.8 per cent (n = 104), and by graduation level 28.4 per cent (n = 90) respectively (Fig. 3) whereas only 0.3 per cent (n = 1) stood within all the levels of education.

In India, the Education system is divided majorly into three levels viz. Primary, secondary and higher education. The primary level includes (Class I-V), secondary level includes junior secondary (class VI-VIII) and senior secondary (class IX-XII), and the higher level includes graduation and above. Previous studies have also suggested that STEAM-based education has a positive impact on all three levels of education (Bae et al., 2013). Positive impact of STEAM on elementary (primary) school students has also been studied. The study highlighted the positive effect of tales on elementary (primary) students' problem-solving and creativity skills. Another study highlighted the

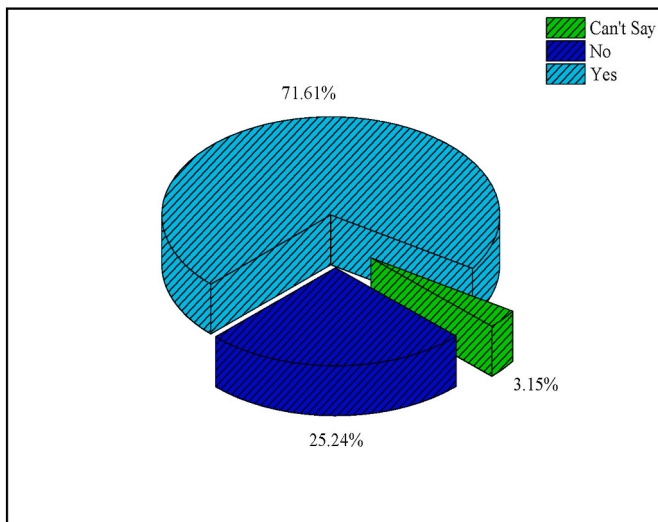


Fig. 2. Awareness regarding the concept of STEAM-based education.

Table 3
Analysis of awareness level regarding STEAM-based education.

Are you aware of STEAM?	Frequency	Percentage
Can't Say	10	3.2
No	80	25.2
Yes	227	71.6

At what level concept of STEAM be include	Frequency	Percentage
Graduation level	90	28.4
Primary level	104	32.8
Secondary level	122	38.5
All	1	0.3

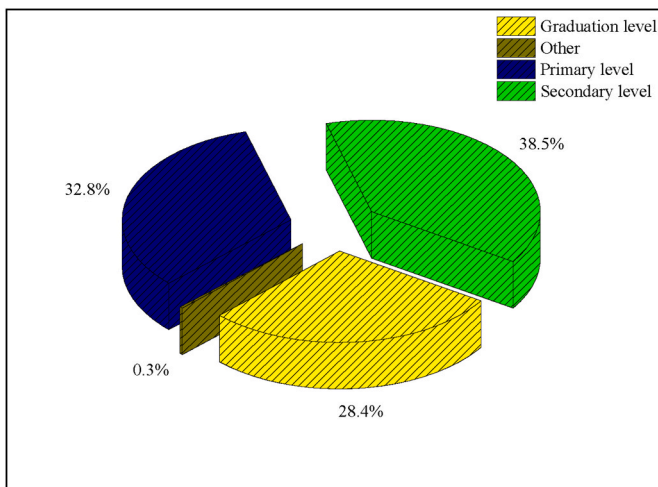


Fig. 3. Introductory level of STEAM-based education.

positive impact of STEAM on junior high school (secondary) students (Tran et al., 2021), whereas the positive impact of STEAM on learning performances of college (higher level) students has also been evaluated previously (Nong et al., 2022). STEAM education should be infused in the teaching-learning process from the very beginning and should be used in continuation in the higher classes as well. Therefore, it might be concluded that students know about STEAM as a concept but when it comes to the knowledge regarding its infusion in which level of education the responses were mixed highlighting confusion in their belief and lack of knowledge regarding it.

4.1.2. Category- perception

As in the questionnaire for the perception of STEAM-based education, there were four dimensions and further each dimension had its items. The findings and analysis of each dimension is shown in the sections below.

4.1.2.1. Dimensions-advantages of STEAM. The findings are shown in Table 4 of the first dimension viz. Advantages of STEAM-based education. The analysis of each item viz. (i) STEAM has made the learning process more interesting and interactive, (ii) STEAM led us to a constructivist and critical approach in life (iii) STEAM has enhanced the teaching-learning process in blended approach and (iv) STEAM can help to develop a more holistic personality were included to know whether the students understand the advantages of STEAM or not. As per the analysis 71.3 per cent (n = 227), participating students also expressed that the learning process can be more interesting and interactive with STEAM (Fig. S3.), 70.3 per cent (n = 223) participants agreed on the notion that STEAM led us to constructivist and critical approach in life, observing it with different perspectives, 70 per cent (n = 221) participants agreed upon the fact that STEAM imbibing may enhance teaching-learning process in blended approach (Fig. S4.) and 71.9 per cent (n = 158) participants agreed on development of a more holistic personality through studying STEAM (Fig. S5.)

As per the literature reviewed in context to the advantages of STEAM, a previous study showed that the whole STEAM-based curriculum could improve student's scientific creativity (Tran et al., 2021). In the same study, it was also found that STEAM-based courses could enhance students' scientific creativity and verbal and numerical domain-relevant creativity. A study related to STEAM found that curriculum integrating STEAM can promote pupils' learning motivation, self-efficacy, and interdisciplinary knowledge acquisition (Jia et al., 2021). A study showed positive effects of science lessons applying STEAM education on science learning motivation and science academic achievement of elementary school students (Bae et al., 2013). Another study investigated the positive impact of STEAM education on sustainable development courses and its effects on student motivation and

Table 4
Analysis of different aspects related to the advantages of STEAM-based education.

Items	Frequency	Percentage
STEAM has made learning process more interesting and interactive	Frequency	Percentage
Strongly Disagree	20	6.3
Disagree	13	4.1
Can't Say	57	18.0
Agree	94	29.7
Strongly Agree	133	42.0
STEAM led us to constructivist and critical approach in life	Frequency	Percent
Strongly Disagree	15	4.7
Disagree	18	5.7
Can't Say	61	19.2
Agree	87	27.4
Strongly Agree	136	42.9
STEAM has enhanced teaching-learning process in a blended approach	Frequency	Percentage
Strongly Disagree	12	3.8
Disagree	16	5.0
Can't Say	68	21.5
Agree	110	34.7
Strongly Agree	111	35.0
STEAM can help to develop a more holistic personality	Frequency	Percentage
Strongly Disagree	17	5.4
Disagree	13	4.1
Can't Say	59	18.6
Agree	102	32.2
Strongly Agree	126	39.7

learning (Hsiao & Su 2021). It was also found that the blend of STEAM education with VR-aided experience courses could enhance learning satisfaction and outcomes, as well as improve students' attitudes towards learning (Hsiao & Su 2021). The blend between the two was found to positively affect students' learning motivation, satisfaction, and outcomes. A study showed a positive impact on the mental motivation of STEAM-based activities framed on Experiential Learning (Mater & Mahamid, 2023). Therefore, from the literature reviewed and from the present study as well it is evident that there are many different advantages of STEAM and university students hold positive perceptions regarding the advantages of STEAM-based education.

4.1.3. Competitive skills and STEAM

The findings are shown in Table 5 for the dimension, "Competitive Skills and STEAM Education". The analysis of each item viz. (i) STEAM is centre of the basic skills needed for the 21st century, (ii) Learning through STEAM prepares me better for competitive exam, (iii) Knowledge gained through STEAM is helpful towards professional efficiency and (iv) STEAM can help in enhancing the soft-skills of the students were included to know students' perspective on the impact of STEAM education on their competitive skill. As per the analysis 76.3 per cent (n = 242), 72.2 per cent (n = 229), 72.2 per cent (n = 229) and 72.5 per cent (n = 230) participants agreed that STEAM education could enhance the skills and is necessary for professional efficiency in 21st century (Figs. 4 and 5, S6, S7). The results were supported by the role of STEAM in cultivating skills which may help them beyond their educational institutions (Singh, 2021). STEAM education may also add to developing hard skills, increasing literacy and math skills, and cultivating curious mindsets. STEAM education is essential to equip students with the skills that will make them successful innovators in the 21st century (Singh, 2021). A study showed that the inclusion of STEAM education enhances the ability to manage projects and processes, build system thinking, the

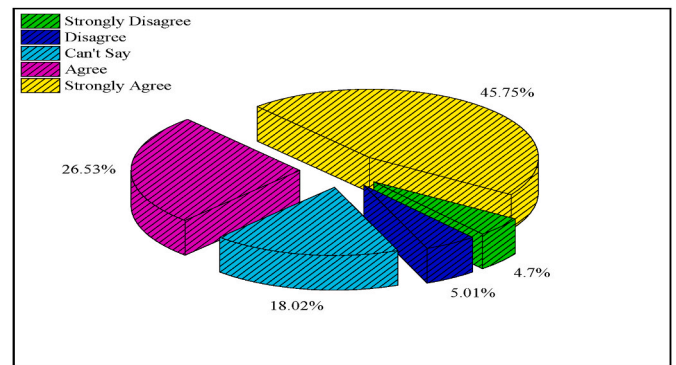


Fig. 4. Knowledge gained through STEAM and professional efficiency.

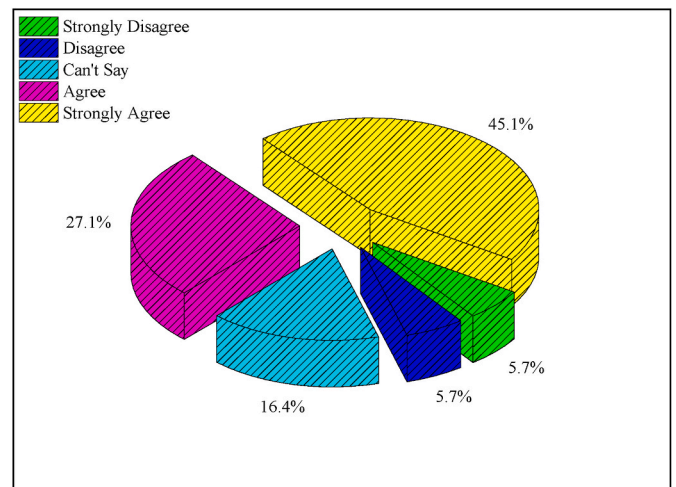


Fig. 5. Learning through STEAM-based education and preparedness for competitive exam.

Table 5 Competitive skills and STEAM.

Item	Frequency	Percentage
STEAM is the centre of the basic skills needed for the 21st century		
Strongly Disagree	13	4.1
Disagree	15	4.7
Can't Say	47	14.8
Agree	86	27.1
Strongly Agree	156	49.2
Learning through STEAM prepares me better for competitive exam		
Strongly Disagree	18	5.7
Disagree	18	5.7
Can't Say	52	16.4
Agree	86	27.1
Strongly Agree	143	45.1
Knowledge gained through STEAM is helpful towards professional efficiency		
Strongly Disagree	15	4.7
Disagree	16	5.0
Can't Say	57	18.0
Agree	84	26.5
Strongly Agree	145	45.7
STEAM can help in enhancing the soft-skills of the students		
Strongly Disagree	18	5.7
Disagree	13	4.1
Can't Say	56	17.7
Agree	85	26.8
Strongly Agree	145	45.7
STEAM is centre of the basic skills needed for the 21st century		
Strongly Disagree	13	4.1
Disagree	15	4.7
Can't Say	47	14.8
Agree	86	27.1
Strongly Agree	156	49.2

ability to art creativity, the ability to work within teams, groups and individuals, the ability to work in a regime of high uncertainty and sharpen skills needed for the industry 4.0 (Shatunova et al., 2019). Therefore, from the literature reviewed and from the present study as well it is evident that Steam-based education is a must for proficiency in today's time and university students are well aware of, and hold a positive perceptions regarding it.

4.2. Gender and STEAM education

The findings are shown in Table 6 of the dimension, "Gender and STEAM". As per the analysis, 55.2 per cent (n = 175) depicted by (Fig. 6) of participants thought that STEAM education may encourage enrollment of female students.

A previous study suggested that gender differences are essential factors influencing collaborative learning at both individual and group

Table 6 Gender and STEAM-based education.

Item	Frequency	Percentage
Through STEAM the enrolment of female students has increased		
Strongly Disagree	20	6.3
Disagree	25	7.9
Can't Say	97	30.6
Agree	90	28.4
Strongly Agree	85	26.8

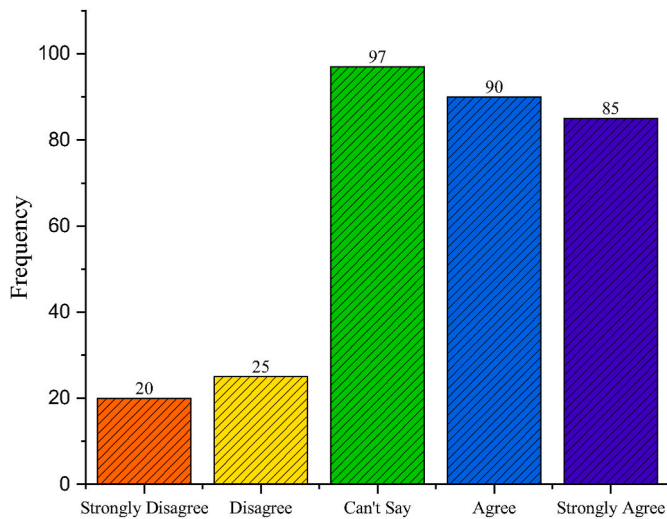


Fig. 6. STEAM-based education and enrolment of female students.

levels and that mixed-gender groups can provide the most benefits for STEAM education (Ma et al., 2022).

The most probable reason behind the result could be the prevailing conception that Arts in STEAM will gather more interest of female students and, hence, will increase girls' enrollment. Gender difference holds a significant place in the impact of STEAM Education and it can be concluded that students hold positive perceptions regarding the increase in female enrollment through infusion of STEAM-based education.

4.3. Aesthetics and STEAM education

The findings are shown in Table 7 of the dimension, "Aesthetics and STEAM Education". In the questionnaire one item viz. STEAM can infuse aesthetic sense in its learners, and highlights participants' perspectives on aesthetics and STEAM education. As per the analysis, 64 per cent (n = 203) as depicted by Fig. S8, Table 7 felt that aesthetic sense can be improved through the implementation of STEAM in education. As 64 per cent (n = 203) participants agreed on it, the most probable reason could be its multidisciplinary nature. The disciplines such as arts, engineering, technology that are included in STEAM are in themselves creative and innovative by nature. A previous study highlighted that through aesthetics and STEAM, students were able to recognize the limitations of their thoughts and transform their ideas through the application of new scientific knowledge and skills (Mun, 2022). Aesthetics and scientific thinking are closely related to each other. Many prominent scientists have claimed this relationship as cited in the book entitled "Truth and Beauty: Aesthetics and Motivations in Science" (Chandrashekar, 1987). Hence, it could be concluded that university students hold a positive perception regarding the infusion of aesthetics through STEAM-based education.

4.4. Category-implementation

As in the questionnaire for implementation of STEAM-based

Table 7
Aesthetics and STEAM-based education.

Item	Frequency	Percentage
STEAM can infuse aesthetic sense in its learners		
Strongly Disagree	18	5.7
Disagree	12	3.8
Can't Say	84	26.5
Agree	106	33.4
Strongly Agree	97	30.6

education, there was one dimension viz. teaching and learning practices and further this dimension have 5 items. For this dimension two analyses were used, frequency analysis and the Kruskal-Wallis H test. The findings by frequency analysis and Kruskal-Wallis H test are shown in Tables 8 and 9 respectively. The analysis is discussed below in detail.

4.4.1. Frequency analysis

In the questionnaire five items viz (i) The Teachers in our class are efficient in applying STEAM in the teaching-learning process (ii) The students in my class are open to accepting STEAM for learning, (iii) STEAM has led to a constructivism approach in teaching-learning practices (iv) The use of STEAM has increased post-pandemic in teaching-learning and (v) In our class teaching-learning process takes place through STEAM are included to understand the present situation of STEAM in the teaching-learning process. As per the analysis, 57.4 per cent (n = 182), 61.8 per cent (n = 196), 70.7 per cent (n = 224), 61.8 per cent (n = 196) and 22 per cent (n = 70) respectively hold positive notions in context to the above-mentioned items (Table 8). According to the present study, in a previous item viz. STEAM has made the learning process more interesting and interactive a total of 71.3 per cent (n = 227) (Table 4, Fig. S3.) of participants agreed, but for the applicability-based item under the implementation category viz. "The Teachers in our class are efficient in applying STEAM in the teaching-learning process" and "The students in my class are open to accepting STEAM for learning" only 57.4 per cent (n = 182) as depicted by (Table 9, Fig. S9) and 61.8 per cent (n = 196) as depicted by (Table 9, Fig. 7) agreed on it respectively. This shows that though participants hold a positive perception that STEAM education is interesting and interactive but when it comes to implementation the education given to them and their attitude to accept STEAM approach in their learning process showed a difference and it need to be worked upon. The other item that addresses

Table 8
Implementation of STEAM.

Items	Frequency	Percentage
The Teachers in our class are efficient to apply STEAM in teaching-learning process		
Strongly Disagree	25	7.9
Disagree	34	10.7
Can't Say	76	24.0
Agree	92	29.0
Strongly Agree	90	28.4
The students in my class are open to accept STEAM for learning		
Strongly Disagree	19	6.0
Disagree	22	6.9
Can't Say	93	29.3
Agree	84	26.5
Strongly Agree	99	31.2
STEAM based teaching- learning practices in my class includes constructivism and critical approach		
Strongly Disagree	95	30.0
Disagree	129	40.7
Can't Say	65	20.5
Agree	14	4.4
Strongly Agree	14	4.4
The use of STEAM has increased post-pandemic in teaching-learning		
Strongly Disagree	19	6.0
Disagree	24	7.6
Can't Say	78	24.6
Agree	90	28.4
Strongly Agree	106	33.4
In our class teaching learning process takes place through STEAM		
Strongly Disagree	94	29.7
Disagree	64	20.2
Can't Say	89	28.1
Agree	42	13.2
Strongly Agree	28	8.8

Table 9

Kruskal- Wallis H test Analysis.

Implementation of STEAM Education	Dimensions of STEAM Education Mean (Std. Deviation)			
	Advantages	Competitive skills	Gender	Aesthetics
Teachers in class are efficient in applying STEAM in teaching-learning process				
Strongly Disagree	3.05 (1.72)	2.91 (1.72)	2.48 (1.56)	2.76 (1.56)
Disagree	3.20 (1.01)	3.36 (1.20)	3.06 (1.30)	3.32 (1.41)
Can't say	3.64 (0.71)	3.77 (0.81)	3.25 (0.82)	3.47 (0.79)
Agree	4.01 (0.64)	4.12 (0.63)	3.65 (0.80)	3.78 (0.85)
Strongly Agree	4.71 (0.53)	4.78 (0.39)	4.41 (0.96)	4.54 (0.74)
Kruskal-Wallis H	119.445*	103.161*	84.569*	80.895*
test statistic (p-value)	(0.000)	(0.000)	(0.000)	(0.000)
Students in class are open to accept STEAM for learning				
Strongly Disagree	2.18 (1.41)	2.04 (1.33)	2.11 (1.63)	2.21 (1.62)
Disagree	3.09 (1.08)	3.10 (1.05)	2.55 (0.80)	2.73 (1.03)
Can't say	3.68 (0.72)	3.81 (0.84)	3.18 (0.79)	3.47 (0.77)
Agree	4.04 (0.69)	4.19 (0.62)	3.82 (0.92)	3.83 (0.80)
Strongly Agree	4.69 (0.45)	4.74 (0.43)	4.37 (0.90)	4.61 (0.73)
Kruskal-Wallis H	131.085*	125.022*	109.287*	123.261*
test statistic (p-value)	(0.000)	(0.000)	(0.000)	(0.000)
STEAM based teaching- learning practices in my class includes constructivism and critical approach				
Strongly Disagree	1.57 (0.87)	1.68 (1.11)	2.00 (1.57)	1.79 (1.31)
Disagree	2.41 (1.09)	2.54 (1.20)	2.43 (1.22)	2.57 (1.28)
Can't say	3.25 (0.53)	3.27 (0.63)	3.09 (0.84)	3.05 (0.74)
Agree	4.04 (0.43)	4.23 (0.51)	3.65 (0.73)	3.86 (0.65)
Strongly Agree	4.68 (0.48)	4.73 (0.44)	4.16 (1.11)	4.47 (0.82)
Kruskal-Wallis H	202.408*	185.897*	78.502*	139.152*
test statistic (p-value)	(0.000)	(0.000)	(0.000)	(0.000)
The use STEAM has increased post-pandemic in teaching-learning				
Strongly Disagree	2.36 (1.48)	2.51 (1.57)	2.32 (1.57)	2.53 (1.71)
Disagree	3.07 (1.07)	3.33 (1.25)	2.54 (1.06)	2.79 (1.18)
Can't say	3.63 (0.72)	3.66 (0.83)	3.08 (0.75)	3.37 (0.74)
Agree	3.94 (0.65)	4.10 (0.74)	3.64 (0.83)	3.76 (0.84)
Strongly Agree	4.71 (0.48)	4.73 (0.46)	4.46 (0.89)	4.59 (0.70)
Kruskal-Wallis H	145.537*	115.721*	127.819*	120.221*
test statistic (p-value)	(0.000)	(0.000)	(0.000)	(0.000)
The teaching learning process takes place through STEAM in classes				
Strongly Disagree	3.24 (1.47)	3.22 (1.55)	3.00 (1.59)	3.14 (1.60)
Disagree	3.46 (1.15)	3.57 (1.21)	2.96 (0.96)	3.32 (1.16)
Can't say	3.70 (0.66)	3.83 (0.74)	3.31 (0.76)	3.57 (0.80)
Agree	4.07 (0.62)	4.20 (0.57)	3.70 (0.89)	3.77 (0.83)
Strongly Agree	4.60 (0.67)	4.67 (0.63)	4.31 (1.06)	4.46 (0.85)
Kruskal-Wallis H	90.989*	81.864*	70.816*	64.291*
test statistic (p-value)	(0.000)	(0.000)	(0.000)	(0.000)

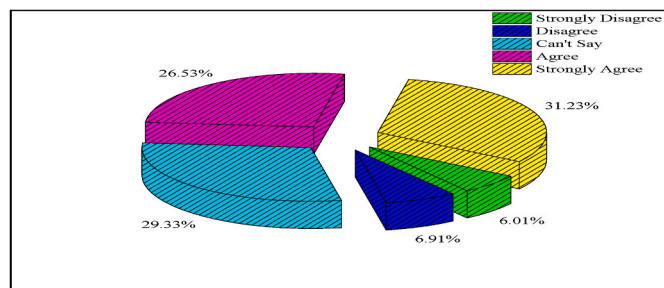


Fig. 7. Student acceptance towards STEAM-based education.

constructivism approach implementation through STEAM got 70.7 per cent (n = 224) (Table 9) views towards disagreement. This showed differences in the perception and implementation of students for STEAM-based teaching-learning practices and constructivism and critical approach. Constructivism is an approach that aims to develop students thinking in a way that they learn to construct knowledge on their

own. Different studies highlight the effectiveness of STEAM towards the enhancement of thinking abilities of students. Few of those studies highlight the development of critical thinking, problem-solving approach, constructivism, collaborative and creative thinking are key benefits of STEAM education on the cognitive skills of students (Henriksen, 2017); (Jantakun et al., 2021); (Malele & Ramaboka, 2020); (Bertrand & Namukasa, 2022).

The fourth item that addresses the use of STEAM has increased post-pandemic in teaching-learning got 61.8 per cent (n = 196) (Table 9, Fig. S10) positive views of participants. The pandemic forced us to adjust to a new world of COVID-19 and technology has proved to be one of the strongest pillars at that time and the use of technology was accelerated. The concept of STEAM has developed the art of resilience in students and acted as a boon in every field in general and the field of education in particular. There are a few previous studies that highlight the positive impact of STEAM in the pandemic time (Dúo-Terrón et al., 2022); (Singh, 2021); (Pasani & Amelia, 2021); (Ahmad, 2023). The fifth item that addresses teaching-learning process in class takes place through STEAM got lowest 22 per cent (n = 70) positive views of participants which highlights the difference between the perception of students and its implementation in teaching-learning practices at the university level.

4.4.2. Kruskal-Wallis H test analysis

The perception dimensions of STEAM Education viz. Advantages (p < 0.05), Competitive Skills (p < 0.05), Gender (p < 0.05) and Aesthetics (p < 0.05) were significantly different across the different items of the implementation category (Table 9) showing significant differences in perception and implementation category of STEAM-based education. Therefore, it can be concluded that university-level students have differences in perceptions and implementation of STEAM-based education in teaching-learning practices.

3399993.

5. Discussion and conclusion

The comprehensive online survey-based study was conducted with graduate and post-graduate students of the city to know the perceptions and practices of STEAM-based education in the curriculum. A total number of 317 students from prominent institutions in the city participated in the study. The students were from different streams such as science, commerce, economics, engineering, architecture, computer science, arts, teacher education courses etc. For the collection of data, a 5-pointer rating scale was constructed. The sampling was done by snowball sampling method. The findings of the study suggested that although students are aware of the concept of STEAM, yet the implementation is far from reality. The study concluded that STEAM-based pedagogies and learning strategies are yet to be realized at the university level, despite of the revolutionary changes in curricula owing to the implementation of National Education Policy 2020 (NEP-2020) in India. Students also felt that STEAM-based Education may enhance deeper understanding, creativity, constructivism and critical thinking. A positive role of STEAM Education in infusing Aesthetic elements and holistic approach in students was also revealed from the present study but significant differences in perception and implementation category of STEAM-based education were seen. The study can play an important role in spreading awareness regarding concept of STEAM. The study has several implications that can inform academicians, policymakers, curriculum developers, teacher training programs and educators regarding the perception and practices regarding STEAM. As “Art” is one of the main component of STEAM education the finding highlights the infusion of aesthetic elements through Arts holds a positive impact and STEAM will serve to bring creativity, imagination and a humanistic approach. Another implication of the study is spreading awareness of STEAM education with its multi-facet dimensions which are discussed. The findings of the present study make it different from other previous studies in

a number of ways. Firstly, a study on STEAM to know university student perspectives had not been conducted in an Indian context. Further, the combination of the three categories the present study has shed light on, viz., awareness, perception, and implementation, along with their dimensions, adds to the uniqueness of this study. In addition to it, the element of 'aesthetics' through the arts, which shows a positive impact on the teaching-learning process and the effect of STEAM education on Gender that highlighted students positive perceptions regarding the increase in female enrollment through infusion of STEAM-based education has been missed out on in other previous studies.

STEAM Education with blend of all the disciplines is a prime entity to play an important role in not just building our personality but also structuring the thought process of the students which will in a later phase affect the prosperity of the entire world and mankind. There exist multiple realities and now the subjects such as Science and Mathematics are not confined to objectivity, they have a space for subjectivity as well. We have seen a paradigm shift in the characteristics of nature of subjects right from the Kuhnian revolution till today. The focus is not on the knowledge which is already mentioned in the text or claimed by any authority, today there is an importance of the construction of knowledge. The students must know how to construct knowledge and it is only possible when the horizon of thinking is wide and there are several sources through which knowledge can be enhanced, multiplied, and transformed. In the present study Constructivist dimension of STEAM is also considered.

The STEAM concept is interdisciplinary in its approach and hence, it must be applied in classroom learning and teaching process. Further, the study opens up the possibilities of initially providing teacher educators with the workshops, refresher or other in-service programs to the educators on how the concept of STEAM could be used to make the teaching-learning process more effective and interesting. The present study also opens up the door towards few new perspectives such as aesthetics which could be used while imparting education through the infusion of different disciplines with the concept of STEAM.

5.1. Limitation

A limitation of the study is the possibility of selection bias owing to the snowball sampling as participants may be more likely to refer to individuals who share similar views on STEAM Education. The sample in the present study was university students studying in institutes at urban areas, the same study must be conducted in future on students studying in institutes at rural areas which may have affected the statistical representation of the results. Another constraint is the non-experimental character of the study design and the population of the sample is restricted only to Lucknow city of India, and may not capture the full range of perspectives on STEAM education across different educational levels or regions. This restricts the ability to generalize and portray the findings to other populations or contexts. In addition, the study is dependent on data from the students, which introduces the possibility of response bias.

5.2. Future scope

In future studies, it would be beneficial to use another type of sampling such as Random sampling and a bigger sample size from other cities of the country can be considered for generalization of the result. Furthermore, it can further explore the perception of teachers with the help of narrative data collected through open-ended interviews giving a mixed-method approach to the study. As the present study is restricted to student's perceptions and in future a study on teacher's perceptions must be done. There is a scope for conducting the same study using other research methods such as experimental research. Significant knowledge might be acquired by comparing the perceptions of teachers and students regarding STEAM education at the university.

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CRedit authorship contribution statement

Manisha Singh: Writing – review & editing, Formal analysis, Data curation, **Iqbal Azad:** Software, Methodology, Formal analysis, **Mohammad Aamir Qayyoom:** Validation, Investigation, **Tahmeena Khan:** Writing – original draft, Supervision, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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