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Evolving Minds: A Literature-Driven and Empirical Exploration of STEAM Skill Development and Learning Approaches

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Abstract

This article delves into the evolving landscape of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education, a dynamic pedagogical paradigm that amalgamates 'Arts' into the realms of STEM (Science, Technology, Engineering, and Mathematics). Focusing on the critical dimensions of skill development and learning approach, this study undertook a systematic literature review spanning 2018 to 2022. The examination of contemporary literature sheds light on students' evolving attitudes and perceptions toward integrating Arts within STEM subjects. To augment this exploration, an empirical survey was conducted, gathering insights from students from diverse European countries and spanning various levels of pedagogy. This combined study unveils intricate correlations between specific forms of Arts and the skill sets essential for fostering innovation and entrepreneurship. Additionally, it delves into the learning approaches that resonate with students as they navigate the complexities of this transformative pedagogy. As education evolves, this article encourages readers to delve into how students view STEAM education. It provides insights into how STEAM education can help shape versatile innovators and entrepreneurs ready to tackle future challenges.

Keywords: STEAM; Skills; Learning approaches; Entrepreneurship; Pedagogy.

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1 Introduction

In the 21st century, pedagogy is continuously changing its form and methodology. Teaching in classrooms has modernized over the years, particularly in the field of Innovation and entrepreneurship. Creativity has emerged as one of the quintessential skills in learning Innovation. In addition, the literature suggests that it's challenging to identify and establish a relationship between learning innovation and developing creativity as a skill.(Nakano & Wechsler, 2018) Universities can play a significant role in shaping the modern 21st-century skills of students. According to a study by (Zeng et al., 2023) based on semi-structured interviews, art, and design students in higher vocational colleges must acquire knowledge and skills such as entrepreneurial courses, professional knowledge, and entrepreneurial skills to achieve the goal of entrepreneurship. Implementing this learning technique to construct an entrepreneurial education training program (Durão et al., 2023) proposes applying a redesigned experiential learning model for fostering entrepreneurship and innovation. Based on various forms of practical teaching, the research looked at several kinds of

practical teaching to improve the quality and applicability of future business skills while encouraging their inventive potential and societal effect. However, these studies didn't consider the competency development approaches or involvement of arts education from a student's perspective.

Such investigations set the background for further research of the new skill requirements in Innovation and entrepreneurship. Understanding the regional needs is inevitable to address innovation and entrepreneurship, and skill development challenges. In Europe, the long-term impact of human capital on Innovation and entrepreneurship development is still considered a black box. As per European Commission communication, the European countries should focus on bridging the gap in the skill matrix between graduate students and job requirements. The higher education institutions are not doing enough to contribute better to innovation. Higher academic institutions need to upgrade themselves with the changing facets of academia. (European Commission, 2017).

However, the fundamental question remains, what is the proper educational model that could develop an innovative and entrepreneurial mindset through formal academic courses? Or Are the common STEM (Science, Technology, Engineering, and Mathematics) pedagogy models doing enough for such skill development? Research studies have demonstrated how arts education may improve students' communication, teamwork, creativity, and innovative abilities (Liao, 2016) (Haseman & Österlind, 2014). Entrepreneurial talents include the ability to think spatially, abstractly, divergently, with self-efficacy, curiosity, and creativity (Root-Bernstein, 2015). This strategy suggested STEAM (Science, Technology, Engineering, Arts, and Mathematics) pedagogy approaches to deal with this difficulty.

STEAM and the "Arts" are defined in various ways (Perignat & Katz-Buonincontro, 2019). However, for STEAM pedagogy to advance to the point where it can be used in classrooms and researched, fundamental STEAM educational principles must be created together with efficient procedures for fostering creativity through the arts. A few studies have been performed to understand the student's perspective on STEAM pedagogy. However, these studies were limited to primary school students. Future pedagogy in innovation and entrepreneurship requires more insights into student's perspectives toward the STEAM approach. The mindset of the receiving end, i.e., students, is crucial for future learning. Even after the post-pandemic situation, classroom learning has transformed in many ways. (Deák et al., 2021) Novel models are suggested to enhance the learning outcomes in STEAM modules such as Project-based learning, mostly in science subjects.(Suryaningsih et al., 2022) Thus, a survey addressing the student's point of view is inevitable for enhancing the learning space in innovation management and entrepreneurship with novel STEAM models at various levels of academia.

Recent developments in STEAM education models suggest a shift from interdisciplinary to transdisciplinary skills. (Liao, 2016) Art educators can play a vital role in this transformation. Modeling the paradigm shift in innovation learning is a time endeavor and will require a broader transformative outlook. Henceforth the student's participation and their perspective on this integration are crucial.

Further findings can help further research to understand cognitive thinking from the student's perspective on STEAM learning for Innovation and entrepreneurship. The quantitative analysis through various participants provides a regional picture for the further development of education models.

This study holds significant importance for readers, industry professionals in entrepreneurship, and policymakers/academicians alike. By gaining insights into the students' mindset at the receiving end of this pedagogy, we can identify potential areas for improvement and better align educational practices with students' needs and aspirations. It offers a deeper understanding of

how students perceive "skills development" and the " learning approach" within this innovative pedagogy, shedding light on its strengths and weaknesses. In addition, it attempts to highlight the acceptance and student's perspective on integrating “Arts” in traditional STEM pedagogy.

Industry professionals in entrepreneurship can benefit from this research as it offers insights into the skill sets and learning experiences that student's value in the context of innovation and entrepreneurship. Understanding student's perspectives can help bridge the gap between academic preparation and industry expectations, enabling a more targeted and effective talent development pipeline.

Policymakers and academicians will find this study instrumental in shaping future pedagogical approaches in entrepreneurship education. Incorporating student's opinions and perceptions into curriculum design and policy-making can fine-tune the pedagogy to enhance student engagement, motivation, and overall learning outcomes.

This manuscript presents a comprehensive literature study and survey-based assessment of student's viewpoints on two critical aspects of the STEAM pedagogy: skill development and learning approach. **Section 2** outlines the research methodology, including the chosen method, data collection procedures, and data analysis techniques. In **Section 3**, the background of the topic is thoroughly examined through a comprehensive systematic literature study. We delve into the literature to explore the outcomes suggested regarding skill development through STEAM and the various approaches practiced in STEAM pedagogy. Subsections **(3.1.)** and **(3.2.)** present insights into students' perceptions of skill development and the distinct learning approach, respectively. **Section 4** offers detailed findings from the survey on students' perspectives. **Section 5** provides a brief discussion, highlighting this research's theoretical and managerial contributions. Finally, **Section 6** offers concluding remarks, including study limitations, and identifies potential areas for future research. By analyzing the knowledge gap from students' viewpoints, this manuscript contributes valuable insights to inform the design and implementation of innovative and impactful future pedagogical approaches in entrepreneurship education.

2 Methodology

2.1 Topic Review and Research Questions

The systematic literature survey focuses on understanding the two basic questions:

- What outcomes does the literature suggest on skill development through STEAM in Europe?
- What different approaches are being practiced at European Universities in STEAM pedagogy and its associated contrivances?

The research questions that are addressed in the survey analysis are as follows:

- How do students perceive the development of entrepreneurial skills through the STEAM approach?
- What are the student's attitudes towards the different learning approaches employed in STEAM-based entrepreneurship education?
- How do students view the integration of science, technology, engineering, arts, and mathematics in fostering innovation and entrepreneurship capabilities?
- How do students' perspectives on the STEAM approach differ across various educational levels and backgrounds?

By addressing these research questions, this study aims to provide a literature-based assessment along with evidence-based insights that will contribute to advancing future pedagogy in innovation

and entrepreneurship, ultimately fostering a more skilled and entrepreneurial workforce prepared for the challenges of the ever-evolving global landscape.

2.2 Literature Search

This study employs a systematic literature review approach combined with a emipirical validation survey to gain insightful results on the impact of the STEAM approach on skill development and classroom learning in entrepreneurship education. The systematic literature review follows a structured process outlined in the flowchart as shown in Figure 1, starting with defining research questions, conducting a comprehensive search in the Scopus database, applying inclusion and exclusion criteria, screening and selecting relevant studies, and finally analyzing the literature for key themes and patterns.

The systematic literature review and the validation survey combined allowed for a comprehensive exploration of the impact of the STEAM approach on skill development and distinct learning methods in entrepreneurship education within the European context. By considering students' perspectives from diverse EU (European Union) countries and academic backgrounds, this study aimed to provide a holistic understanding of the effectiveness and relevance of STEAM pedagogy for future innovation and entrepreneurship education practices.

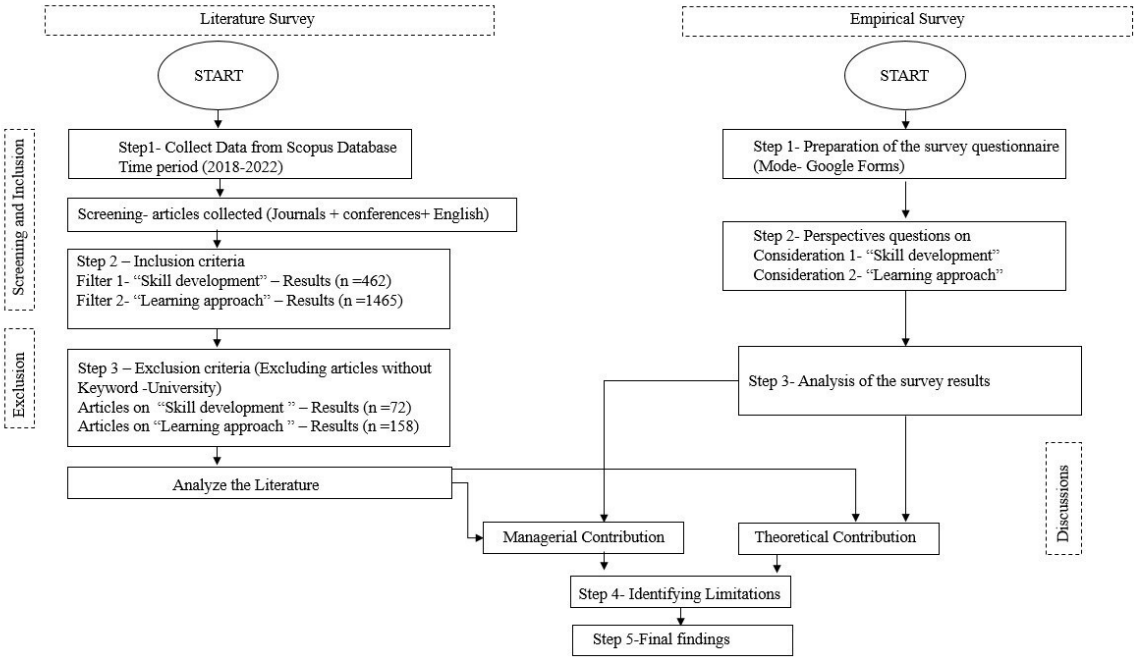

Figure 1. Pictorial representation of the flowchart and methodology adopted for the present study.

2.3 Initial Selection Criteria: Keywords and Terms

To support the overarching research aim and objectives, the establishment of initial selection criteria was pivotal in guiding the broad exploration of articles. The primary intention was to comprehensively evaluate the spectrum of paradigms surrounding "skill development" and "learning approaches" within the context of STEAM education, taking into account theoretical and methodological commonalities, as well as disparities.

As Hughes (2017) aptly pointed out, students are increasingly required to cultivate character-building or transferable skills, essential for successful learning, living, and working in today's

complex world. These skills transcend traditional disciplinary boundaries and are indispensable for personal and professional development.Within the framework of STEAM pedagogy, the emphasis on "learning approaches" takes on a distinctive character. It endeavors to promote a transdisciplinary, inquiry-based approach to education, designed to nurture the future innovators and entrepreneurs of tomorrow. This approach prioritizes skills over a rigid content-focused learning paradigm, challenging the conventional boundaries of learning within STEM disciplines.

Hence, the choice to initiate this study with a focus on "Skill development" and "Learning approaches" emerged as highly relevant. This context of STEAM pedagogy needed to be thoroughly examined through a comprehensive literature analysis, considering the interplay of these critical elements. However, it is important to note that a complete understanding cannot be achieved solely through literature review; it requires validation with the invaluable perspective of the students who directly engage with these aspects. Therefore, the subsequent phase of this study involves a survey that addresses students' viewpoints on "Skill development" and "Learning approaches," adding depth and dimension to the insights gleaned from the literature.

2.4 Inclusion and Exclusion criteria

Eligibility criteria for inclusion of articles:

- Data source: Scopus database
- Type of article: Journal articles and conference papers
- Papers published only in english language
- Time period consideration: (2018-2022)
- Keywords used for inclusion: "STEAM," "skill development," and "learning approach."
- Second round of keyword filter: "STEAM and SKILLS" and "STEAM and LEARNING."

Exlusion criteria of articles:

- The articles which were not having the “university” keyword or context in their title or abstract.
- Articles without full text availability.
- Articles referring to social media posts, short letters, summaries etc.

2.5 Analysis and findings

Combining the systematic literature review with survey data analysis represents a mixed methods research design. The purpose is to triangulate findings from both qualitative (literature review) and quantitative (survey data) sources to provide a more comprehensive and robust understanding of the research topic. This approach helps ensure that the research conclusions are well-supported and less prone to bias or misinterpretation.To validate the findings of the literature review and gather student's perspectives, a survey was administered using Google Forms. The participants were approached through a Google questionnaire link shared via university mailing lists and academic forums. This approach allowed the researchers to reach students from diverse backgrounds and at different levels of study within various European countries. The survey questionnaire was designed to elicit student's opinions and perceptions regarding the STEAM approach in entrepreneurship education. It included questions about skill development experiences and classroom learning preferences within the STEAM pedagogy. The responses from the survey participants provided valuable insights into their firsthand experiences and perspectives, complementing the findings from the literature review. The extracted data were synthesized to identify common themes, trends, and patterns related to STEAM pedagogy, skills development, and learning approaches. The aim was to provide a comprehensive overview of the current state of research in these areas. The synthesized findings were discussed in the context of the research objectives, and comparisons

were made between different studies to draw insights and conclusions about STEAM pedagogy, skills, and learning approaches briefly discussed in section 5 and section 6.

3 Systematic Literature review

In this systematic literature review, the authors focused on understanding the impact of the STEAM approach on skill development and different learning approaches at different pedagogical levels of education within the European subcontinent. Keyword searches were conducted in the Scopus database for the last five years (2018-2022) to identify relevant publications. In the first subsection, the keyword "skills" in the context of STEAM yielded a total of 462 publications. Similarly, in the second subsection, the keyword "learning" with STEAM resulted in the identification of 1465 articles, as shown in Figure 2. After applying a filter for "university," the search results were narrowed down to 72 articles for skill development and 158 articles for classroom learning.

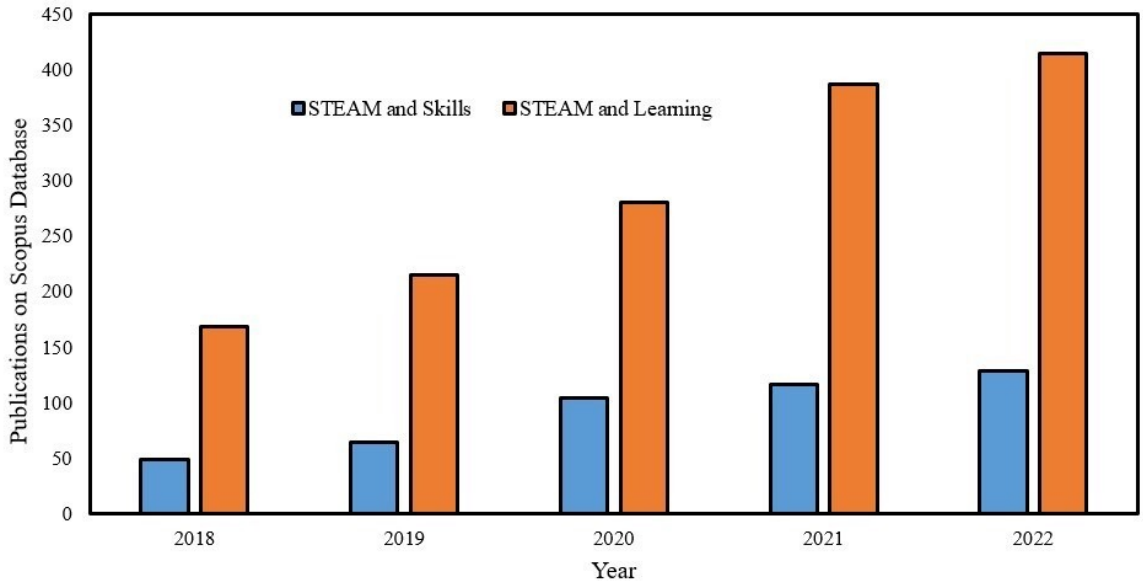

Figure 2. Publications per year on the topic of STEAM in the context of "Skills" and "Learning" for the period of the Year (2018-2022).

Among these filtered articles, only those with a contextual background related to STEAM education in the European subcontinent were carefully examined. For the skill development section, a few studies are also from outside Europe. This contextual background ensured that the studies were directly relevant to the topic at hand and provided valuable insights into the impact of STEAM on skill development and the adopted learning approach.

The results of the literature review are presented in the respective subsections, where the findings related to skill development and learning approaches are discussed separately in the discussion section. Through this rigorous review process, the authors aimed to present a comprehensive understanding of how the STEAM approach has influenced skill development and classroom learning in entrepreneurship education within the European subcontinent.

3.1 Review on Skill development through STEAM

The year 2023 has been designated as the "Year of Skills" by the European Commission, which will revitalize lifelong learning, empower individuals and organizations to support green and digital transitions and foster innovation and competitiveness through several EU initiatives (Commission,

2023). The PISA (Programme for International Student Assessment) report of 2018 (Schleicher, 2018) suggests a stagnant advancement of STEM Education and the lack of progress in students' performance in Mathematics and Science could have implications for the future entrepreneurial ecosystem in the EU region. To address this concern, a new model of pedagogy, such as STEAM education, which combines creativity, arts, and interdisciplinary learning with the core STEM disciplines, is recommended to better prepare students for entrepreneurship. Also, European Schoolnet (EUN), a network of more than thirty ministries of education whose mission is to support Ministries of education, schools, teachers, and any stakeholders in Europe in the transformation of education processes, presented a report in 2019 (Schoolnet, 2019)suggesting similar suggested raising awareness and interest in STEAM Employment. By incorporating STEAM into the educational system, the region can foster a new generation of entrepreneurs with the skills, mindset, and innovative thinking necessary to drive economic growth and societal development. Through the use of "creative spaces" for the execution of student's project activities and the inclusion of the category "art" in its content, experimental work by (Shatunova et al., 2019)has demonstrated how students may develop the skills and competencies required for Industry 4.0.

Across various educational levels from primary schools to university settings across different countries, a captivating narrative unfolds, highlighting the potent efficacy of STEAM pedagogy in nurturing a spectrum of vital skills among students. The review highlights insights into the journey of learning innovations that transcend borders and age groups. Engineering and architecture students experience an accelerated transformation of spatial abilities through immersive virtual and augmented reality, unveiling the immense potential of such experiential approaches. Meanwhile, STEAM educators navigate uncharted territories, recognizing the imperative to encompass Responsible Research and Innovation (RRI) skills within STEAM education. Pioneering the way, the community-based participatory research method emerges as an avenue to cultivate skills deemed arduous to foster using conventional methods. Another study explores the world of K-12 students, where a novel rubric method, "Co-Measure," is devised to gauge collaborative problem-solving (CPS) skills through STEAM activities. This innovation stands poised to transcend its primary boundaries, promising post-secondary and elementary education applications. The scene shifts to the undergraduate realm, where the Virtual Classroom Learning Experience (VCLE)-based STEAM-ification cultivates enriched innovative thinking and creativity, eclipsing traditional pedagogical approaches. As the narrative ascends to the high school level, a pedagogical STEAM model takes center stage, elevating project competency and learning motivation, equipping students with tangible skills for real-world challenges. Traverse the tapestry of secondary and primary school education, where STEAM integration enhances critical thought, creativity, and problem-solving prowess, albeit with encountered challenges of resource management and subject integration. Ascending to the university level, the spotlight is on pursuing scientific efficacy and creativity, underscoring STEAM's role in fortifying scientific and entrepreneurial competitiveness.

The compilation of Table 1. aims to illuminate the outcomes of diverse case studies conducted across a spectrum of pedagogy levels, showcasing the results of these studies in developing distinct skills through the lens of STEAM pedagogy. Carefully curated from primary schools to university settings, these case studies provide a holistic view of how STEAM principles are harnessed to enhance skills across different educational stages.

Each row in the table represents a distinct pedagogy level, ranging from primary school to university, and offers a snapshot of the skills developed through STEAM approaches. The "Skills Developed" column encapsulates the key abilities each case study sought to foster among learners. From spatial skills to critical thinking, creativity, collaborative problem-solving, and beyond, this column distills the essence of the skills-centric goals of each study.

The "Outcomes" column offers a window into each case study's findings, providing insights into how effective these STEAM approaches were in achieving their intended goals. The succinct descriptions in this column encapsulate the essence of the research outcomes, shedding light on the impact of each study on the targeted skills. The progression of the table, from primary school to university, mirrors students' educational journey. It presents a narrative arc of how STEAM strategies evolve and adapt to cater to students' unique developmental stages and learning needs. This compilation is a presentation of varied experiences, methodologies, and countries, underscoring the versatility of STEAM pedagogy.

By juxtaposing the skills developed and outcomes achieved across different educational levels, the table accentuates the interconnectedness of these skills, demonstrating how they scaffold and contribute to the holistic growth of students. It showcases the multifaceted nature of STEAM education and its potential to shape skill development from the early years of education to advanced academia.

Table 1. Outcomes of diverse case studies conducted across a spectrum of pedagogy levels for skill development through STEAM pedagogy.

Pedagogy Level	Skills Developed	Outcomes	References
Engineering and Architecture Students	Spatial skills	According to the study's findings, immersive virtual reality and augmented reality are particularly useful for teaching students of engineering and architecture spatial abilities quickly.	(Gomez-Tone et al., 2023)
STEAM Educators	Responsible Research and Innovation Skills	According to the research, STEAM education must innovate to cover the RRI skills, and the community-based participatory research method makes it easier to build the majority of the skills that were thought to be challenging to put into practice using the other techniques.	(Malagrida et al., 2022)
K 12 Students	Collaborative problem solving (CPS)	This article describes the creation of a rubric called Co-Measure that researchers and teachers may use to evaluate student collaboration while engaging in K–12 STEAM activities. The "Co-Measure" technique being developed may be altered and substantially expanded to evaluate CPS in post-secondary and elementary classes that use STEAM educational strategies.	(Herro et al., 2017)
Undergraduate level	Creative thinking and innovation skill	Students proved to attain better levels of innovative thinking and creativity when they studied using the Virtual Classroom Learning Experience based STEAM-ification format than those who studied using the conventional lesson plan.	(Wannapiroon & Pimdee, 2022)

Pedagogy Level	Skills Developed	Outcomes	References
High School Students	Project Competence and Learning Motivation	The outcomes showed that implementing the pedagogical STEAM model might improve the experimental group of students' project competency and learning motivation.	(Lin & Tsai, 2021)
Secondary School Students	Critical and creative thinking skills	According to study findings, students improved their creativity and critical thought capacity. The research encountered difficulties with STEAM integration with chemical principles, teacher empowerment, student engagement, and time and resource management.	(Rahmawati et al., 2019)
Primary school students	Creativity and problem-solving skills	The results show that teaching STEAM via the engineering design process (EDP) has a favorable impact on students' creativity and problem-solving abilities.	(Erol et al., 2023)
University Level	Scientific efficacy and creativity	Aiming to boost interest and enthusiasm in science as well as scientific efficacy and creativity, STEAM education was developed to boost scientific competitiveness. The author counters that minimal data is confirming the benefits of the STEAM program and that there is no special STEAM framework that focuses on cultivating convergent talent.	(Jazbec, 2023)

However, lurking within the tale are gaps in data and a vacuum of specialized frameworks tailored for convergent talent cultivation. As this section of the narrative draws to a close, it emphasizes the pivotal role of student perspectives in shaping the trajectory of STEAM education for future skills. A call to action resonates: a survey capturing student opinions holds the potential to illuminate untrodden paths, guide the evolution of STEAM pedagogy toward holistic effectiveness, and align with the aspirations and needs of the learners themselves.

3.2 Review of Learning approaches through STEAM

Crucially, new learning approaches and curricula shift the focus from a standardized, one-size-fits-all approach to an inclusive, personalized, and creative learning experience, which equips students with the skills and mindset needed to thrive in an ever-evolving world and contribute to future societal and economic advancements. By embracing innovative instructional learning models and allowing flexibility in the curriculum, educators empower students to develop these essential skills and be prepared for the challenges of the future (Litz, 2011). EU nations must set up mechanisms that enable people to recognize, record, evaluate, and certify all types of learning so they may utilize it to further their careers and pursue additional education and training (CEDEFOP, 2023). Amidst the educational landscape of various European countries, a tapestry of innovative learning approaches within the STEAM framework has been woven, each thread contributing to the augmentation of student skills. It is essential to review these narratives through a holistic

understanding of how diverse pedagogical Learning approaches can sculpt the talents of tomorrow's innovators and entrepreneurs. Table 2. presents a collection of case studies focusing on the implementation of the STEAM learning models in various European countries. Each case study is associated with a specific learning approach and highlights the outcomes of the implemented approach in the context of augmenting student skills through STEAM pedagogy.

In one corner of Europe, a visionary approach blends Arts and creativity to empower students for the cities of tomorrow (Jesionkowska et al., 2020). Across borders, an Augmented Reality journey engages learners actively, catalyzing skill development that resonates with real-world applications. Meanwhile, a Creative pedagogy course, woven through a divergent creativity test, unveils a struggle to break free from conventional teaching methodologies but underscores the significance of nurturing inventive thinking through pioneering assessment techniques. Zooming in, a Chemistry-centered approach, nestled in non-formal contexts, breathes life into the subject matter, rendering it relevant and approachable (Domenici, 2022). Simultaneously, a Multidisciplinary STEAM module intricately entwines inquiry-based learning, igniting curiosity and driving motivation. Connected learning theories orchestrate a symphony of instruction, harmonizing STEAM principles with collaborative teamwork and contextualized exploration. Project-based learning emerges as a beacon of success, with a "Sustainability" project drawing students into an immersive experience, yielding exceptional results (Vicente et al., 2021). In another instance, the integration of STEAM with physics projects illuminates pathways to practical understanding, albeit accompanied by challenges of resource allocation and coordination.

Table 2. Learning approaches and their outcomes from case studies in various European countries.

STEAM Model	Learning approach	Outcomes	References
Empowering Arts and creativity for the Cities of tomorrow	Forward Variant and Backward Variant	All curricula are quite similar in terms of their contents and degree of application, making it simple to transfer STEAM projects created in one nation to another.	(Montés et al., 2023)
Augmented Reality for STEAM Education	Active Learning Augmented Reality	With the case study demonstrating evidence of learning to code, working with a physics simulation engine, ray-tracing, and geometry, learning how to manage teams and interact with other students and instructors, and engineering a functional prototype of a game, the Active Learning approach served as a catalyst for students' skill development.	(Jesionkowska et al., 2020)
CreaCube task (a creative problem-solving task involving modular robotics)	Creative pedagogy course, through a divergent creativity test	According to the study, instructors' propensity for emphasizing speed and applying already-existing solutions remains a deterrent to engaging in more creative behaviors that call for putting a stop to tried-and-true tactics and considering novel ones.	(Leroy & Romero, 2021)

STEAM Model	Learning approach	Outcomes	References
The STEAM project-based learning methodology	Chemistry-centered approach with future chemistry teachers in non-formal contexts, such as science museums	The effectiveness of creating educational activities relevant to current and real-life chemistry-centered subjects as well as the function of the non-formal environment in teaching and learning chemistry, appeared as extremely favorable components of the suggested strategy from the students' comments and final evaluation.	(Domenici, 2022)
Multidisciplinary STEAM module integrating inquiry-based learning	Pre-/Post-/Retention-Test design monitored knowledge	The results show that encouraging creativity is a potential starting point for research into boosting motivation and creativity in educational settings. Examples of such environments include STEAM environments.	(Conradty & Bogner, 2019)
STEAM instructional practices	Connected learning theory	The study discovered substantial agreement between the concepts of STEAM and linked learning, including a common focus on design, teamwork, and contextualized learning.	(Quigley et al., 2020)
The STEAM project-based learning methodology	"Sustainability" as STEAM project	The classroom experiment was conducted with 30 students, who were extremely engaged in the assignment and produced work that was more than excellent.	(Vicente et al., 2021)
The STEAM project-based learning methodology	Integrate STEAM learning with projects for the improvement in the learning of physics	Students observed how fundamental concepts are applied to issues pertaining to their line of work, which produces pleasant feelings, supports the learning process, and increases students' drive to study more. On the negative side, this integral learning process necessitates extra work from the teaching staff because they must be familiar with the other subjects in order to achieve perfect integration. We also encounter issues at the organizational level because the schedules are flexible and affected by the learning sequence.	(Montés et al., 2022)

In contemplating this development of educational innovations, the authors perceive both bright spots and challenges. Yet, one unifying thread runs through these case studies—the paramount importance of student perspectives. Amidst this diverse tapestry, student's voices emerge as pathways, illuminating the role of effective STEAM pedagogy. Furthermore, the potential of a survey to capture these STEAM models seems inevitable for the proper development of future methodologies and learning practices. Thus, the next section covers the empirical survey on student's opinions.

4 Empirical Survey - Student's perspective

As the pendulum of educational paradigms swings across time, STEM models have etched their journey under the watchful gaze of educators and researchers. Decades of scrutiny have illuminated the landscape, revealing the attitudes and perspectives of those involved. However, as the new era explores STEAM, a fresh narrative begins to unfurl—an exploration into the heart of student perspective.Further, STEAM steps onto the stage, carving its niche by weaving "Arts" into this tapestry. A question emerges, floating like a whisper in the wind: What do students feel about this new dimension, this blend of creativity and logic? The two prime parameters are "Skill development" and "Learning approach." The stage is set for a duel of insights—will the addition of "Arts" invigorate students' skill sets, fashioning them into well-rounded innovators? And how will this infusion influence their approach to learning, igniting a journey of exploration and understanding that reaches beyond the walls of the classroom? As these students hail from diverse European lands, their backgrounds are as varied as the cultures that shape them. From the eager eyes of elementary students to the inquisitive minds of university scholars, their perspectives become fragments of a larger viewpoint.

At the heart of this narrative, the authors propose the empirical survey for perspective exploration. A survey designed to capture the essence of student sentiment towards "Arts" interwoven with the fabric of STEM. It beckons students from different levels of education, beckons those from lands where diverse languages and customs unite under the umbrella of Europe. It beckons as if whispering, "What do you think of this fusion? How does it mold your skills, and alter your approach to learning? How does it shape the classroom of tomorrow?"

And so, the tale remains open-ended—a journey yet to be traversed. As the survey unfolds and the voices of students emerge, the story takes a turn, revealing insights that illuminate the unexplored corners of STEAM education. What patterns will emerge? How will students' voices shape the STEAM path forward?

4.1 Background of students

In several parts of the world, academic surveys are being used to understand student's perceptions of certain pedagogy model developments. Questionnaires could help understand students' satisfaction levels in adapting to the changes. (Bennett & Kane, 2014) Integrating "arts" cannot become the immediate panacea in modernizing skill development among students. It requires a holistic viewpoint and understanding of student's mindsets, How they feel about the integration of Arts in the STEM model. Some studies investigated the teacher's perception of STE(A)M, and they revealed that many respondents were not even familiar with the STE(A)M model.(Ishartono et al., 2021) In our study, we conducted a conjoint survey among students from diverse backgrounds in STEM. The respondents belong to all categories of higher education, For example, bachelor's, master's, and doctoral levels as well with a combined number of 60 students. The students belonged to various backgrounds of studies, but the most dominant of them are from the engineering side. We tried to include respondents from several European region countries, namely, France, Italy, Austria, Hungary, Slovakia, Slovenia, Finland, the UK, and Lithuania. The representation of the belongingness of students in various countries and backgrounds is represented in Figure 3. In the further section, we discuss the responses of the students in terms of Skill, Approach, and Learning.

4.2 Skills Assessment

In recent years academia has been considering the aspect of student's perception in enhancing the competencies at the university level in innovation pedagogy.(Keinänen et al., 2018) In our questionnaire, we asked the students for their opinions by setting up a step-by-step background of

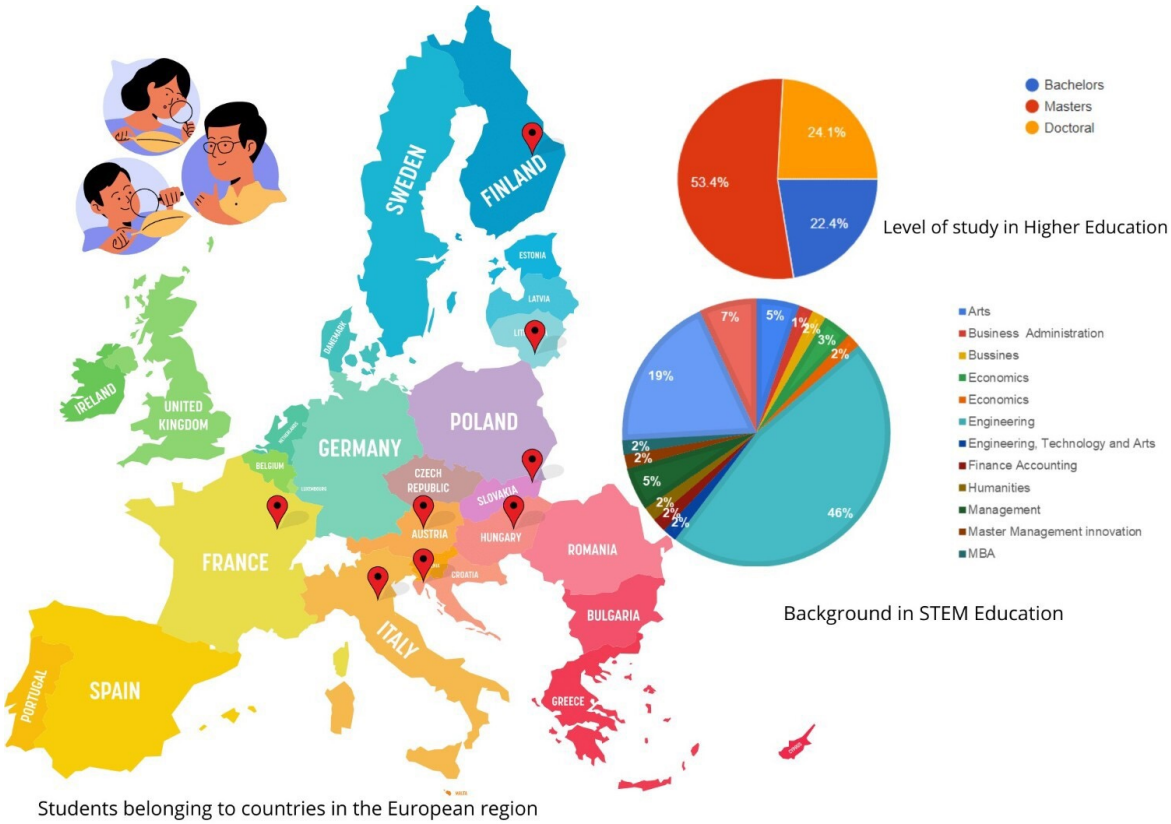

Figure 3. Categorization of students based on region, level of study, and study background.

arts. Today, various forms of arts are integrated with technology in different industrial applications. The extensive use of blogging and social media platforms are perfect example of such an approach. This argument is supported by the fact that (37%) of the respondents feel most connected with the form of the visual arts, followed by literature (25%) and music (23%). Architecture as an art form has the least appeal among students, with a (13%) response rate. These numbers reflect visual arts' acceptability as the most dominant form of art students feel could be a stepping-stone towards integration with STEM subjects.

Studies suggest many factors aid in the debilitated status of Innovation and entrepreneurship education for university students. Ying Ying Ding (Ding, 2017) investigated the constraints in Innovation and entrepreneurship education through the Grey-DEMATEL method, which suggests improving students' awareness of the subject. The scarcity of educators is another challenge In broadening the dimensions of Innovation. Entrepreneurship still needs more promotion as a futuristic subject of study, and societal support for students taking up such topics needs encouragement. We asked students to share their perceptions about which skills they believe are most important as a competency to become an innovator or an entrepreneur. Around half of the respondents feel that creative problem-solving is the most critical skill which needs to be developed, with 46% share as shown in Figure 4. Communication skills are the second most preferred choice, with a share of 25%. Strategic thinking has a decent place with 18% of the votes. Surprisingly, students believe that leadership skills are the least required skill in Innovation. These numbers could be interesting for educators while realizing the curriculum of Innovation and entrepreneurship subjects while teaching. Furthering the analysis, students were asked to match the skills with the art forms that they felt would enhance skill development while learning. The

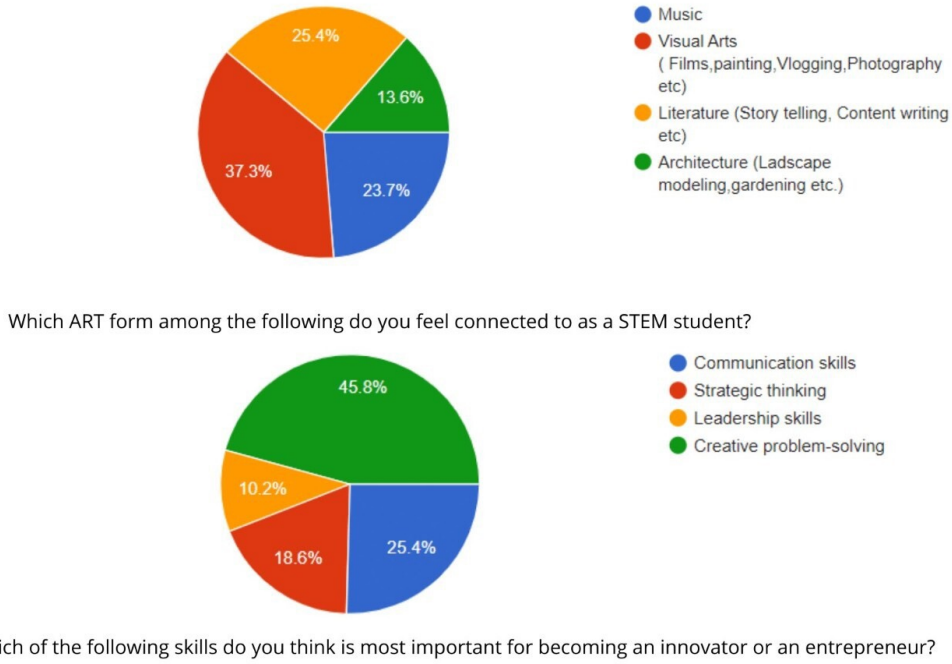

Figure 4. Student's perception of different forms of arts and the skills required in Innovation and entrepreneurial ecosystem.

logic behind this approach is to establish a correlation between the skills and arts in Innovation and entrepreneurship learning. The results are displayed in Figure 5. Showing students believe music and literature can significantly help develop communication skills.

Similarly, visual arts can help in the development of creative thinking. In addition, Architecture as an art form can aid in strategic thinking and creative problem-solving skills. The student's perception of the long-lasting effect of integrating arts with STEM was recorded on a scale of 1-10. The majority of the students voted with a value higher than five, reflecting the firm opinion of students supporting the transformation from STEM to STEAM in learning Innovation and entrepreneurship. As the students are from diverse backgrounds in STEM, such opinions give educators wisdom to consider the inclusion of arts as a subject in improving students' learning experience.

4.3 Learning approach assessment

The integration of various STEM branches is a complex problem. Several researchers have been trying to develop models for integrating STEM subjects. (Kelley & Knowles, 2016)The new-age problems require modern solutions and skills. Many reforms are needed at several levels to upgrade STEM education in academia. Modern educators must not confine themselves to one discipline and should be more cohesive in integrating subjects. Different educators and researchers have tried different approaches to bettering STEM education. Multidisciplinary is commonly applied to benefit STEM integration. (Rogers et al., 2015) In our study, we proposed various interlinkage approaches as mentioned below and asked the opinion of students on the transformation of STEM to STE(A)M.

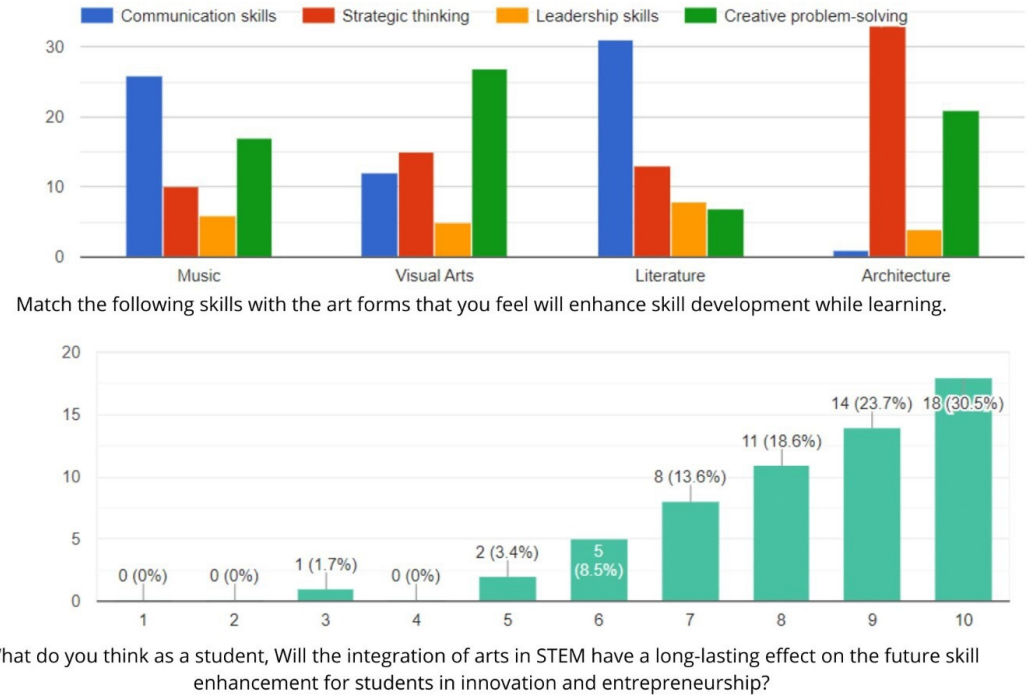

Figure 5. Student's perception of interlinkage between various forms of skills and integrating arts with STEM

Several words are perceived with the same meaning but have different approaches while implemented in reality. Considering this reason, all approaches were described briefly in the options available to the students. The multidisciplinary and Interdisciplinary approach was the most favorable method for transforming STEM into STEAM. Innovation and entrepreneurship, in general, by nature, are themselves multidisciplinary. The high favorability is a sign that students prefer such multidisciplinary projects or learning experiences.

In Figure 7. We present students' recommendations on integrating arts at the policy level and enhancing the classroom learning experience. Inclusion at the policy level is still dicey for a few students. However, most students firmly believe that the inclusion of arts as a subject will boost their classroom learning experience.

The learning environment is a significant factor affecting students' interest in STEM pedagogy. Assessing behavioral changes with different models and experiences could help enhance the classroom learning experience. Summer schools and informal learning experiences are being used as an assessment tool for measuring qualitative learning outcomes among the students. (Roberts et al., 2018) Our assessment focused on four skills: creativity, curiosity, risk-taking, and collaboration. The students reflected their opinions in four categories of requirements and scope. The four categories were defined as (High requirement-High scope), (High requirement-Low scope), (Low requirement-High scope), and (Low requirement-Low scope). Students selected curiosity and collaboration as the highly required with high scope categories. Figure 8. Reflects the student's opinion on matchmaking between the categories and skills.

In the end, students reflected on their say on the inclusion of arts as a subject. This assessment focuses on skill development in an innovation ecosystem and entrepreneurial mindset. It is observed

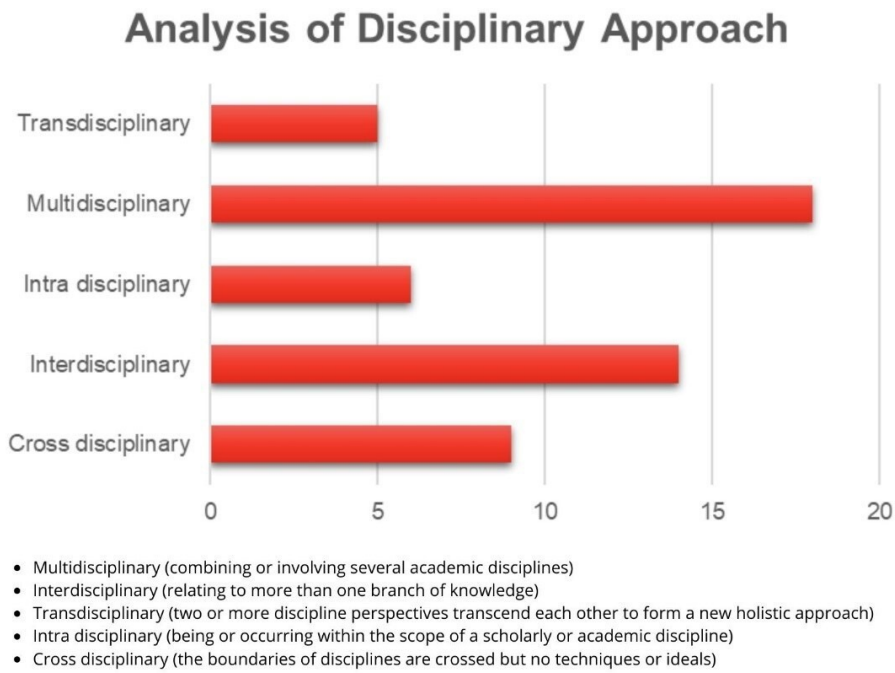

Figure 6. Student's preferences in disciplinary approach for transformation of STEM to STEAM.

that more than 60% of the students support this integration of arts in the curriculum of innovative learning. The student's feedback is a firm demonstration of their inclusiveness towards the subject. The paradigm shift in learning experience expectations of students is summarized in the graph in Figure 9. Challenges in transforming STEM to STE(A)M should be considered an opportunity to look for more creative learning beyond a specific subject.

5 Discussion and limitations

In recent years, the field of STEAM education has garnered increasing attention from researchers and educators alike. Previous studies have delved into the multifaceted aspects of STEAM pedagogy, often employing a combination of literature reviews and surveys to gain a deeper understanding of this interdisciplinary approach. Table 3. provides a synthesis of the key findings from several of these earlier investigations. Perignat and Katz-Buonincontro (2019) underscored the need for a more comprehensive discussion of learning outcomes beyond STEM subjects and associated skills within STEAM education. Kang's study in South Korea (2019) emphasized the positive impact of STEAM education on both cognitive and emotional learning. Alghamdi (2023) exploration of Saudi teachers' beliefs shed light on the challenges surrounding the integration process and the essential methods and skills required for successful STEAM implementation. Rodrigues-Silva and Alsina (2023) highlighted the importance of improving children's ideas of engineering through a thoughtful STEAM approach. Meanwhile, Anisimova et al. (2020) discussed the readiness of future teachers to adopt STEAM practices. Building upon the insights gained from these earlier studies, the present study conducts a systematic literature review coupled with a survey to investigate students' perceptions of skill development and learning approaches within STEAM pedagogy. Our study also delves into the incorporation of "arts" in STEAM education,

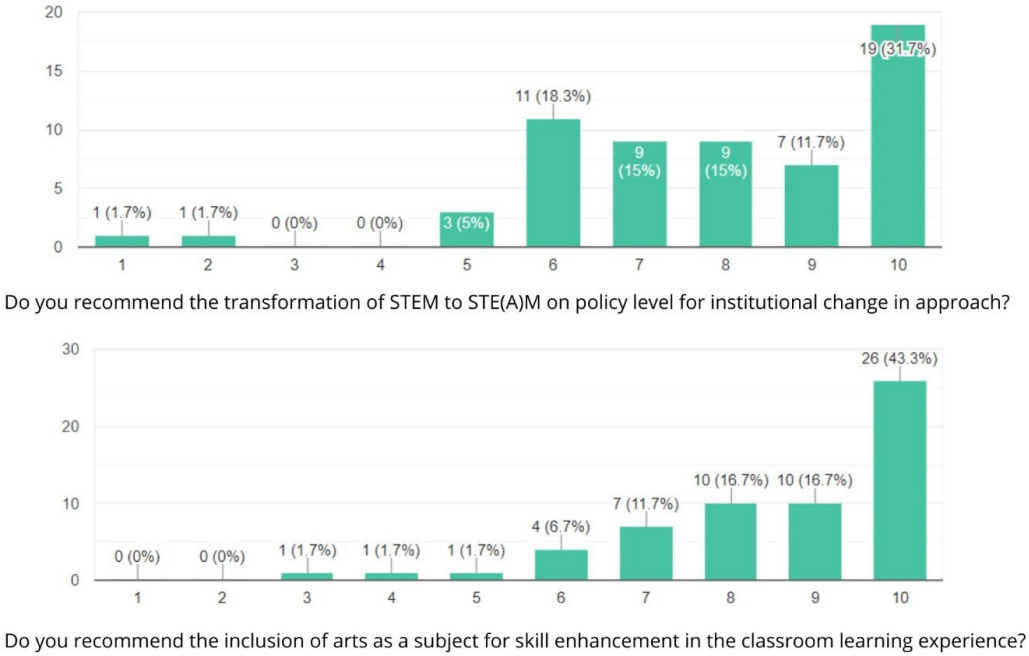

Figure 7. Student's recommendations on approaches on policy level and classroom learning.

highlighting both the enthusiasm of students toward this subject and the challenges faced in the STEAM pedagogy. By situating our study within this broader context of previous inquiries, we aim to contribute to the ongoing dialogue on STEAM education and provide fresh insights into the perceptions and experiences of its key stakeholders.

Table 3. Recent studies with similar methodology and their respective findings on STEAM implementation.

Title	Approach	Findings	Reference
STEAM in practice and research: An integrative literature review	This integrative review examines 44 published articles (empirical, descriptive, and pedagogical frameworks) on the topic of STEAM education from 2007 to 2018.	The study emphasizes how learning outcomes in STEAM education that go beyond STEM subjects or associated skills are not discussed or given enough attention.	(Perignat & Katz-Buonincontro, 2019)
A review of the effect of integrated STEM or STEAM education in South Korea	Literature review along with meta-analysis through survey	The study revealed that STEAM education for pupils was helpful for both cognitive and emotional learning.	(Kang, 2019)
Exploring Early Childhood Teachers' Beliefs About STEAM Education in Saudi Arabia	Study explores Saudi teachers' beliefs with survey and meta-analysis	According to the survey, there is little understanding of the integration process and the fundamental methods and skills required to implement STEAM.	(Alghamdi, 2023)

Title	Approach	Findings	Reference
Systematic Review About Students' Conceptions of Engineering Accessed Through Drawings: Implications to STEAM Education	Systematic Review and Meta-Analysis with survey investigation of children's conceptions of engineering.	The study highlights the need for more research, teacher preparation, and a thoughtful STEAM approach to improve kids' ideas of engineering.	(Rodrigues-Silva & Alsina, 2023)
Formation of Design and Research Competencies in Future Teachers in the Framework of STEAM Education	Narrative review along with a survey of future teacher's perceptions related to the readiness for the formation of project-research competencies.	Highlights issues with both educating current teachers to apply STEAM pedagogy's practice-oriented teaching activities as well as with teachers' readiness to adopt new educational programs.	(Anisimova et al., 2020)
Present Study	Systematic literature review with a survey of student's perception of skill development and learning approaches through STEAM pedagogy	Student feedback clearly indicates their openness to the subject of "arts" in STEAM pedagogy for skill development, and the literature research also highlights the obstacles in STEAM.	

The amalgamation of insights from previous studies and the findings of the present study forms a crucial foundation for delineating future research areas in the domain of STEAM education and skill development. Prior research, as elucidated, underscored several significant aspects. It emphasized the relative absence of attention to learning outcomes that extend beyond STEM subjects and associated skills within STEAM education, signifying a substantial gap in the current discourse. Furthermore, it revealed the positive impact of STEAM education on pupils, encompassing both cognitive and emotional dimensions of learning. These findings, in conjunction with the revelation of a dearth of understanding regarding the integration process and the requisite methods and skills for effective STEAM implementation, spotlight the pressing need for further research and teacher preparation.The present study extends this narrative by elucidating students' receptiveness to the incorporation of "arts" in STEAM pedagogy for skill development. Additionally, it acknowledges the presence of obstacles within the STEAM educational landscape. These collective insights, amalgamated with the previous research, delineate the contours for prospective research endeavors in STEAM education.

In the future, research in this field can delve into exploring innovative pedagogical approaches that holistically integrate "arts" within STEAM, with a focus on skill development and cognitive growth. Investigating the impact of such an integration on students' holistic development could be a promising avenue. Moreover, future studies might seek to bridge the knowledge gap identified in the integration process and the fundamental methods and skills required for effective STEAM education.Teacher perspectives in STEAM pedagogy are equally vital. Future research can draw on the propositions furnished in this review to investigate teachers' readiness to adopt new educational programs and their preparedness to implement practice-oriented teaching activities within the STEAM framework. This can aid in refining teacher training and professional development programs to enhance the efficacy of STEAM education.

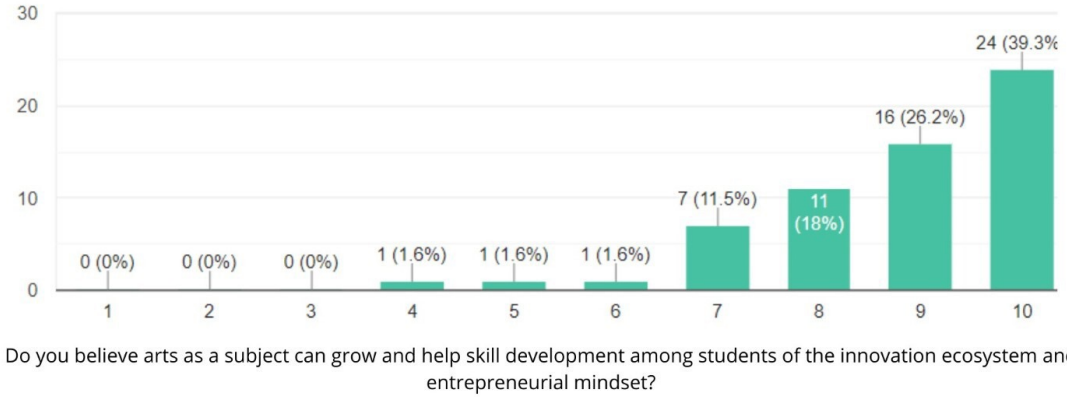

Figure 8. Student's recommendations on learning approaches in Innovation and entrepreneurship.

Overall, the present review findings, in concert with previous research, serve as a benchmark for future studies in the dynamic realm of STEAM education. They offer a roadmap for future inquiries to explore uncharted territories of STEAM pedagogy, address existing challenges on classroom experiences, and ultimately contribute to the continued evolution of STEAM pedagogy.

5.1 Theoretical contributions

The insights gleaned from the survey's skills assessment offer significant theoretical contributions to the field of STEAM education:

Skill-Form Correlation: By mapping students' perceptions of art forms to specific skills required in innovation and entrepreneurship, this study enhances the theoretical understanding of how different forms of arts align with skill development.This correlation can inform curriculum designers and educators in crafting more targeted learning experiences.

Skill Prioritization: The survey's revelation of creative problem-solving as the most critical skill for innovation, followed by communication and strategic thinking, contributes to the ongoing discourse about the essential competencies for fostering innovation and entrepreneurship. These findings align with existing theories while adding nuance to their practical application.

Transformation Advocacy: The students' firm belief in the transformative potential of integrating arts with STEM, as reflected in their votes higher than five, underscores a theoretical standpoint that advocates for the shift from STEM to STEAM. This aligns with evolving discussions about the educational paradigm and echoes a need for multidisciplinary approaches.

5.2 Managerial Contributions

The learning approach assessment from the survey yields valuable managerial implications for educational institutions aiming to enhance skill development through STEAM:

Curricular Transformation: The survey results suggest a strong alignment between students' preferences and the multidisciplinary and interdisciplinary approaches. These findings provide educational institutions with a clear direction for curricular transformation, focusing on cross-

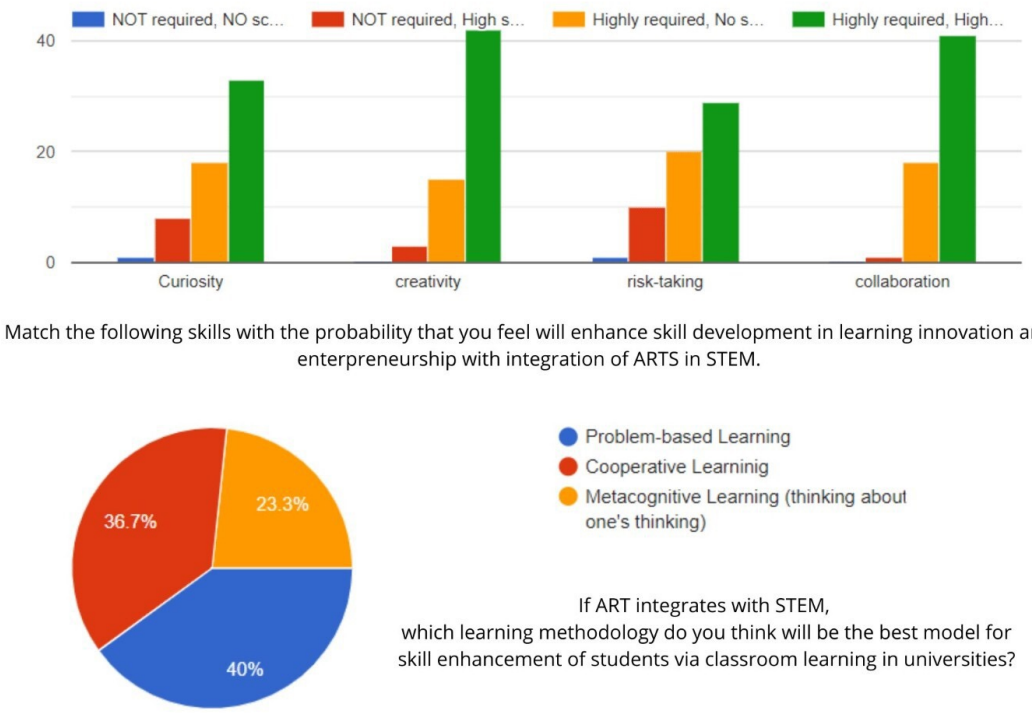

Figure 9. Student's opinion on skill development with arts as a subject in the innovation ecosystem and entrepreneurial mindset.

disciplinary projects that stimulate curiosity, collaboration, and creativity.

Policy-Level Integration: While some uncertainty exists about policy-level integration, the majority of students expressing confidence in the inclusion of arts as a subject highlights the managerial significance of aligning curricular decisions with student aspirations. Institutions can consider this feedback when designing policies that foster a STEAM environment.

Enhancing Learning Experience: The student's perception that the inclusion of arts as a subject will boost their classroom learning experience points to practical managerial steps that institutions can take. This insight encourages educators to explore innovative teaching methods and interdisciplinary collaborations to enhance student engagement.

Behavioral Assessment for Learning Enhancement: The survey's focus on assessing behavioral changes using summer schools and informal learning experiences as measurement tools reflects a managerial approach to improving the classroom learning experience. These insights guide institutions in designing effective learning environments that nurture creativity, curiosity, risk-taking, and collaboration.

Inclusivity and Paradigm Shift: The strong student support (over 60%) for integrating arts in the innovation curriculum showcases the importance of student inclusivity in pedagogical

decision-making. These findings recommend a managerial shift towards involving students in shaping the learning journey, aligning with modern educational paradigms.

As the theoretical and managerial insights from this survey unfold, they not only contribute to the scholarly discourse but also offer pragmatic guidance for institutions seeking to optimize skill development through STEAM. The nuanced understanding of skill-form relationships, the prioritization of competencies, and the managerial implications of learning approaches underscore the importance of holistic educational transformation that transcends traditional disciplinary boundaries. As educators and institutions grapple with the challenge of transforming STEM to STEAM, these contributions offer compass points for navigating this evolving educational landscape.

5.3 Limitations

The paper offers a comprehensive summary of the review findings and their implications for STEAM education. However, it's important to mention its limitations. Here are some potential limitations and study dimensions that might have been missed:

Limited Timeframe: The study's focus on literature and survey data from 2018-2022 may have missed valuable insights from older research or emerging trends beyond that period. The dynamic nature of education could mean that relevant developments occurred before or after the specified timeframe.

Regional and Cultural Variations: The study may not have delved deeply into regional or cultural variations in students' perspectives on STEAM education. Differences in educational systems, cultural values, and curriculum approaches could influence students' perceptions.

Sample Size and Diversity: While the study included survey data from 60 students, the sample size may not fully represent the diversity of students across different educational contexts, age groups, or backgrounds. A larger and more diverse sample could provide a broader perspective.

Self-Report Bias: The survey data relied on self-reports from students, which can introduce bias. Students may respond in ways they believe are socially desirable or may not accurately reflect their true perceptions.

Methodological Constraints: The choice of research methods, including the literature review and survey, may have limitations. Different research methods or data sources, such as interviews or observations, could provide a more comprehensive understanding.

Educator and Stakeholder Perspectives: The study primarily focused on students' perspectives. Exploring educators' and stakeholders' views on STEAM education could provide a more holistic understanding of its implementation and impact.

Technology Integration: Given the evolving role of technology in education, the study did not extensively explore the impact of technology on STEAM practices and learning outcomes.

6 Conclusion and future research

In summation, this comprehensive literature review embarked with a thorough exploration of student perspectives within the dynamic and ever-evolving landscape of STEAM education, bridging the integration of Arts with STEM disciplines. Our dedicated investigation delved meticulously into two pivotal dimensions - "skill development" and "learning approach" - to intricately illuminate and decipher students' perceptions of this innovative and interdisciplinary pedagogical paradigm. The insightful empirical survey results unveiled a significant and notable alignment between specific forms of Arts and the precise skills required for fostering innovation and entrepreneurship in the modern educational landscape. Most notably, the competency of creative problem-solving emerged resoundingly as a paramount and pivotal factor, bearing profound implications for holistic student development.

Furthermore, the surveyed students demonstrated a strong resonance and affinity for both multidisciplinary and interdisciplinary learning approaches, indicating a burgeoning appetite for immersive and cross-disciplinary learning experiences that transcend traditional silos. This resounding endorsement and resonance underscore the transformative potential of STEAM education, as it promises to cultivate dynamic and adaptive skill sets while nurturing a learning environment that celebrates curiosity, collaboration, and creativity. Armed with these profound and strategic insights, educators, curriculum designers, and policymakers stand uniquely poised to harness the transformative capabilities of Arts-infused education, effectively equipping students with versatile and agile competencies that are indispensable for navigating the complex and rapidly evolving challenges of the future. As the educational landscape continues its dynamic evolution, this pioneering study serves as an invaluable cornerstone for future research endeavors, ranging from exploring cultural and regional variances in students' perceptions to the probing investigation of the pivotal role of technology in shaping modern pedagogical practices. Thus, the study paves the way for a deeper, more nuanced understanding of STEAM's transformative power with future research precisely on the educator's perspective and its enduring relevance in shaping the educational landscape of tomorrow.

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