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CONNECTIONS AND APPLICATIONS OF MATHEMATICS IN A STEAM EDUCATION CURRICULAR UNIT

CONEXÕES E APLICAÇÕES DA MATEMÁTICA NUMA UNIDADE CURRICULAR DO ENSINO SUPERIOR

CONEXIONES Y APLICACIONES DE LAS MATEMÁTICAS EN UNA UNIDAD CURRICULAR DE EDUCACIÓN STEAM

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Abstract

Mathematics is a fundamental component of STEAM education, providing a foundation for many scientific and technological fields. It provides a foundation for scientific inquiry, technological development, engineering, and the arts. By emphasizing the connections between mathematics and other STEAM areas, we can help students develop a deeper understanding of the world and the necessary skills for success in the 21st century. With this in mind, this paper presents a study in which the main objective is to understand the difficulties experienced by higher education students of this curricular unit when they need to establish connections between mathematics and other STEAM areas. The study involved thirteen students aged between 18 and 21 taking a degree course in technologies for STEAM education. The study was a qualitative investigation, and findings suggest that visualizing the connections can be challenging for students. Different languages and terminologies, different ways of thinking, and the lack of previous interdisciplinary teaching are some of the reasons for students to report having difficulties establishing connections with the STEAM areas.

Keywords: mathematics, STEAM, education, interdisciplinarity, technology.

Resumo

A matemática é uma disciplina fundamental para a educação STEAM, fornecendo uma base para muitas áreas científicas e tecnológicas. A matemática fornece uma base para a investigação científica e para o desenvolvimento tecnológico, da engenharia e das artes. Ao enfatizar as conexões entre a matemática e outras áreas STEAM, podemos ajudar os alunos a desenvolver uma compreensão mais profunda do mundo

e as habilidades necessárias para o sucesso no século XXI. Com base nestas premissas, este trabalho apresenta um estudo cujo objetivo principal é compreender as dificuldades sentidas pelos alunos de uma unidade curricular do ensino superior quando precisam estabelecer conexões entre a matemática e outras áreas STEAM. O estudo envolveu treze alunos com idades compreendidas entre os 18 e os 21 anos que frequentam um curso de licenciatura em tecnologias para educação STEAM. Procedemos a uma investigação qualitativa e os resultados sugerem que a visualização das conexões pode ser um desafio para os alunos. Diferentes linguagens e terminologias, diferentes formas de pensar e a falta de um ensino interdisciplinar prévio são alguns dos motivos pelos quais os alunos relatam ter dificuldades em estabelecer ligações entre a matemática e as áreas STEAM.

Palavras-chave: matemática, STEAM, educação, interdisciplinaridade, tecnologia.

Resumen

Las matemáticas son un componente fundamental de la educación STEAM, proporcionando una base para muchos campos científicos y tecnológicos. Proporciona una base para la investigación científica, el desarrollo tecnológico, la ingeniería y las artes. Al enfatizar las conexiones entre las matemáticas y otras áreas STEAM, podemos ayudar a los estudiantes a desarrollar una comprensión más profunda del mundo y las habilidades necesarias para tener éxito en el siglo XXI. Con esto en mente, este artículo presenta un estudio en el que el objetivo principal es comprender las dificultades que experimentan los estudiantes de educación superior de esta unidad curricular cuando necesitan establecer conexiones entre las matemáticas y otras áreas STEAM. El estudio involucró a trece estudiantes de entre 18 y 21 años que cursaban un curso de grado en tecnologías para la educación STEAM. El estudio fue una investigación cualitativa y los hallazgos sugieren que visualizar las conexiones puede ser un desafío para los estudiantes. Los diferentes lenguajes y terminologías, las diferentes formas de pensar y la falta de una enseñanza interdisciplinaria previa son algunas de las razones por las que los estudiantes reportan tener dificultades para establecer conexiones con las áreas STEAM.

Palabras-clave: matemáticas, STEAM, educación, interdisciplinariedad, tecnología.

INTRODUCTION

STEAM stands for Science, Technology, Engineering, Arts, and Mathematics. It is an interdisciplinary approach to education that combines these five subjects into a cohesive learning framework. STEAM education promotes critical thinking, creativity, innovation, and problem-solving skills among students. STEAM education significantly benefits education by promoting holistic learning, real-world relevance, 21st-century skills, career readiness, inclusion, and innovation (Duderstadt, 2010; Afolabi et al, 2023). By embracing STEAM education, educational systems can better equip students with the knowledge, skills, and mindset needed to thrive in an increasingly interconnected and rapidly evolving world (Pandey, 2023). In this work, we report on a study in progress prepared within the scope of curricular unit connections and applications of mathematics in STEAM education; the main objective is to understand the difficulties experienced by higher education students of this curricular unit when they need to establish connections between mathematics and other STEAM areas. The article introduces STEAM education and briefly introduces the advantages for the students to learn to establish connections between STEAM areas. Then we present the methodology adopted and its description. Finally, we offer a discussion on the results, the main conclusions and proposals for future investigations.

1 RELATED WORK

The world is now experiencing constant evolution, transformation and technological advancement that fundamentally reorients human existence (Pandey, 2023). STEAM education is significant for the new generation of students (Hin, 2020; Afolabi et al, 2023). It prepares them for the future workforce, fosters innovation and entrepreneurship, develops technological literacy, nurtures global citizenship and sustainability, and cultivates a mindset of lifelong learning and adaptability (Lettmann et al, 2023). By embracing STEAM education, we empower the new generation to navigate and shape a complex and rapidly changing world (Pandey, 2023).

The new generation of students will face complex challenges that demand innovative solutions. STEAM education nurtures a mindset of innovation and entrepreneurship by encouraging students to think creatively, take risks, and develop solutions to real-world problems (Lettmann et al, 2023). Integrating arts in STEAM recognizes the importance of creativity and thinking in problem-solving. It acknowledges that artistic expression and design principles can enhance technological and scientific advancements and contribute to innovation and human-centred solutions (Pandey, 2023). Overall, STEAM education aims to prepare students for the challenges of the 21st century by equipping them with a broad range of skills and knowledge across multiple disciplines (Afolabi et al, 2023). It encourages a holistic approach to learning and supports the development of well-rounded individuals who can thrive in a rapidly changing world (Duderstadt, 2010). In today's digital world, technological literacy is crucial for the new generation of students (Pandey, 2023). Also, in this area, STEAM education represents an essential value for integrating technology across disciplines, enabling students to develop a strong foundation in digital literacy and computational thinking (Duderstadt, 2010). They learn to harness technology as a tool for problem-solving, communication, and collaboration (Kivunja, 2014). This empowers them to navigate the digital landscape, adapt to new technologies, and become responsible digital citizens (Lettmann et al, 2023).

By integrating science, engineering, and arts, students understand sustainability principles and develop the skills to address environmental, social, and economic issues. This fosters a sense of global citizenship and empowers students to contribute to a more sustainable future. The new generation of students will experience a rapidly changing world where continuous learning and adaptability are essential. STEAM education emphasizes inquiry-based learning, problem-solving, and critical thinking skills. It nurtures a growth mindset, encouraging students to embrace challenges, learn from failures, and continuously seek new knowledge. This teaches them to adapt to evolving technologies, industries, and societal needs.

2 METHOD

In this paper, we present part of a work still under development with which we intend to understand the difficulties experienced by higher education students of this curricular unit when they need to establish connections between mathematics and other STEAM areas. We started by proposing to all students of a curricular unit called “Connections and Applications of Mathematics in STEAM Education I” at the School of Education at the Polytechnic University of Porto the implementation of a didactic proposal that interconnects at least three of the STEAM areas. The class consists of fourteen students. Thirteen students aged between 18 and 21, enrolled in the same curricular unit and from different countries (Finland, Holland, Spain and Portugal), participated in this study. Data were collected through direct observation, direct observation notes and semi-structured interviews with students to understand their perceptions of the difficulties they experienced. The data were later transcribed, organized and confronted. Data were also subjected to a second content analysis to better understand the phenomenon (Bogdan and Biklen, 1994). The analysis of the student's answers was carried out based on the following analysis categories that emerged from the data analysis: (i) ways of thinking, (ii) terminologies and concepts, (iii) lack of previous

interdisciplinary experience. We use the designation *Si* for student *i* to code the students' responses, *with i = 1,...13.*

3 RESULTS

Organized into groups, students created didactic proposals for students in the first cycle of primary education, encompassing at least three STEAM areas. At the end of this process, students reflected on the process of linking mathematics with the other STEAM areas and on the difficulties, they felt, and we present the students' responses in the semi-structured interviews below (Table 1):

Categories of analysis from student responses in semi-structured interviews

Dimension	Student
Ways of thinking	"*It is difficult to visualize the connections, to be able to establish the connection between the STEAM areas, to find an activity that makes the connection between STEAM areas*" (S1). "*For me, the main difficulty was finding an experimental learning* activity *that encompassed all these disciplines and connected them*" (S2). "*Sometimes establishing a connection can be confusing and (not well related to figuring out how to integrate everything to do an interesting project*" (S3). "*Thinking about ways to establish relationships between STEAM areas and justifying all the connections was very difficult*" (S5). "*Matching all the subjects to create an activity was the hardest for me*" (S8). "*For me the most difficult part was to think critically (to the research for the ideas), so that the kids would find out about the different materials and then experiment on their own and try it out*" (S9). " *It led us to reflect and think*" (S10). "*Thinking about how to add specific tasks from an area in order to use all the disciplines requested by the teacher*" (S11). "*The hardest thing was thinking about how to show kids that everything in this world is connected and that the different disciplines complement each other, I think so, because it ends up helping students to understand a little bit of all the subjects*" (S12).
Terminologies and concepts	"*It was an important challenge, because with this technique, children will understand that mathematics are present everywhere and this will probably get them more interested*" (S2). "Matching *all the subjects to create an activity for children in primary school*" (S3). "*Finding a task for young children, which would include science was the hardest part for me*" (S5). "*It was a little bit difficult to think about the terminologies of each area to achieve the requested activity*" (S6). "*Relating mathematics to the arts, at first. It was difficult to understand how they could come together, but after some research, it was easier to understand*" (S7). "*I think it is important to link mathematics to other areas such as science, technology, engineering and the arts because in many real-life projects and jobs they encompass different disciplines, such as building architecture design*" (S9). "*Thinking about the science area part was a little bit more difficult*" (S10).
Lack of interdisciplinary experience previously	"*If we had already been given examples of the application of STEAM in previous years, it would have helped us to solve the problems*" (S4). "*There are many different apps and programs, but I had never worked with the idea of STEAM, I had never thought about the connection between these areas*" (S7). "*I didn't know what STEAM was, it should have been present in previous research work and projects* " (S9). "*For me, it was the first time I heard about STEAM, and that's why it was so hard to find something*" (S10). "*If they had shown me more practical examples earlier at school, it could have helped me in carrying out this work and in connecting the STEAM areas, for example showing videos or (lesson preparation of a teacher) in a primary school*" (S12).

4 DISCUSSION

The focus of this paper is to describe a part of a study conducted in the context of a curriculum module that explores the connections and practical applications of mathematics in STEAM education. We seek to gain insights into the challenges higher education students in this module face as they navigate linking mathematics with other areas within the STEAM framework.

The proposal led them to think "*about establishing relationships between STEAM areas and justifying all the connections was very difficult*" (S5), which was sometimes a challenge because it led students to think differently than usual and find difficulties in "*visualizing the connections*" (S1). The fact that they had to "*think about how to add specific tasks from an area*" (S11), "*about the different materials*" (S9) to be used in proposed activities and led students to think about how "*in this world is related and that the different disciplines complement each other's*" (S12).

The terminology and the need for "*articulation between concepts from STEAM areas are also a limitation for the students involved*" (S7). Despite the difficulties encountered, students recognise the importance of the work proposed to them and the importance of young students working in the STEAM areas, as it is a "*way children understand that mathematics are present everywhere and this will probably get them more interested*" (S2). The lack of previous interdisciplinary experience is another aspect pointed out by the students as a limitation for the proposed work. All refer that they had never done an activity in which they "*thought about the connection between these areas*" (S7) and would have been essential for their training "*to have this technique implemented previous research work and projects*" (S9).

The STEAM education emphasizes hands-on learning, collaboration, and inquiry-based exploration. It encourages students to think critically, analyse data, design solutions, and communicate their findings effectively (Pandey, 2023; Afolabi et al, 2023). According to our students, they were led to "*think critically in the research for the ideas, so that the kids would find out about the different materials and then experiment on their own and try it out*" (S9) and to "establish relationships between STEAM areas and justifying all the connections" (S5).

STEAM education promotes a global perspective and encourages students to explore solutions to these challenges. According to the view of our students, establishing the connection of mathematics with other areas of knowledge so that it (has to mean learning the curriculum) "*is an important challenge because, this way, children understand that mathematics are present everywhere and this will probably get them more interested*" (S2), "*it led them to reflect and think*" (S10). According to our students, the proposed work led them through "an experimental learning activity that encompasses all these disciplines and connects them" (S2). Moreover, by engaging students in experiential learning, STEAM education fosters innovation, creativity, and a deeper understanding of the world around us (Lettmann et al, 2023). Also, López et al. (2021), in their study with which they analysed Brazilian and Spanish mathematics teachers' opinions about the predispositions to use toward gamified activities in STEAM education, realised that most of the participants in their research think this kind of activity has positive effects on students' development, improving their engage toward mathematics and required skills for mathematical competence.

5 CONCLUSIONS

This paper describes a study prepared within the scope of curricular unit "Connections and applications of mathematics in STEAM education I". The main objective is to understand the difficulties experienced by higher education students of this curricular unit when they need to establish connections between mathematics and other STEAM areas. In this study, we involved 13 students aged between eighteen and twenty-one, attending, (at the moment of reflection), a degree course in technologies for STEAM education at the School of Education of the Polytechnic University of Porto.

Results suggest that students are receptive to activities that establish the relationship between mathematics and other areas such as arts, engineering, sciences and technology. This is important to foster curiosity around the content of mathematics and its connections with other regions of knowledge. However, findings suggest that visualising the connections can be challenging for students. Different languages and terminologies, different ways of thinking, and the lack of previous interdisciplinary teaching are some of the reasons students report for needing help establishing connections with the STEAM areas.

Lettmann et al. (2023) propose a planet-centred and community-focused fashion and textile curriculum, equipping students with the required competencies for cultural change that enables a prosperous future for all. This curriculum proposal explores how an environment at Birmingham City University to observe nature and explore materials can be where artistic, scientific and technical perspectives thrive through collaborative and reflective practice. Like these authors, we seek to design a STEAM approach capable of embedding mathematics within the other STEAM areas through a pedagogical structure that allows for several entry points and lifelong learning. In future investigations, it is suggested that we understand which areas (science, technology, engineering or arts) students experience more difficulties establishing a connection to mathematics.

In future developments of this work, with the participation of a larger number of students, we intend to design a questionnaire suitable for students to understand their Mathematics difficulties and how they feel this can translate to their future students.

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