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WELCOME

In recent years, the manufacturing processes have undergone a profound transformation, driven by the rapid evolution of additive manufacturing (AM) technologies. What began as a tool primarily for prototyping through stereolithography has now expanded into a versatile and innovative field capable of producing functional, end-use components across a wide range of industries. From fused deposition modeling (FDM) to selective laser melting (SLM) and beyond, AM has unlocked new possibilities in design, material utilization, and production efficiency. Today, additive manufacturing encompasses an extensive array of materials, including metals, polymers, paper, and even biological tissues, enabling applications that span from the mechanical industry to the biomedical sector.

One of the most compelling aspects of additive manufacturing is its potential to drive sustainability in modern production processes. Unlike traditional subtractive methods, which often generate significant material waste, AM builds components layer by layer, minimizing excess material and promoting resource efficiency. Furthermore, the ability to use eco-friendly and recyclable materials aligns with global efforts to reduce environmental impact. AM also supports the production of complex, customized parts on demand, reducing the need for large inventories and long-distance transportation, thereby lowering carbon emissions. By optimizing resource use and enabling more efficient production cycles, additive manufacturing is emerging as a cornerstone of sustainable manufacturing practices.

This proceeding book arrests the latest advancements, challenges, and opportunities in the field of additive manufacturing, with a particular focus on its transformative potential and contributions to sustainability. The works presented here reflect the interdisciplinary nature of AM, showcasing innovative techniques, materials, and applications that are shaping the future of manufacturing. From cutting-edge research to real-world case studies, this collection aims to inspire further exploration and collaboration, driving the adoption of additive manufacturing as a key enabler of sustainable industrial progress. We invite readers to probe into these pages and discover how AM is not only redefining manufacturing but also paving the way for a more sustainable and efficient future.

The IWAM 2024 Organizing Committee,

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Learning linear algebra with the MathE platform: an experience in a Mechanical Engineering course

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ABSTRACT

Linear algebra is part of the curriculum of most engineering courses. However, many students' difficulties in this area and the heterogeneity of their mathematical knowledge pose significant challenges for teachers. In this context, more personalized and interactive learning is needed to help overcome individual difficulties and promote autonomy in constructing knowledge. Technological platforms such as MathE are important tools in this process, as they facilitate the development of skills in searching, selecting, and analyzing the information provided. Therefore, as part of the Linear Algebra and Analytical Geometry course unit of a Mechanical Engineering degree course, we proposed that students use the Self Need Assessment component of the MathE platform to take two tests: one at a basic level and the other at an advanced level on the topics of Vector Spaces (VS) and Linear Transformations (LT). After submitting each test consisting of seven multiple-choice questions, the students were asked how they had performed. We also asked them to present their solutions to get them to identify and correct their own mistakes based on the feedback provided by the platform and the teacher. When complemented with other approaches, the MathE platform can be a valuable tool to increase students' autonomy in overcoming their difficulties, thus promoting the learning of linear algebra.

Keywords: Linear algebra, MathE platform, higher education

INTRODUCTION

The massification of higher education in Portugal, and more recently, the increase in students from other countries, has led to a significant heterogeneity in their mathematics education. On the other hand, the assumptions of Bologna imply that student autonomy should be promoted, with students assuming the role of protagonists in the teaching-learning process (Caballero & Bolívar, 2015; Lima, Menezes & Carregã, 2016). All of this poses a challenge for higher education teachers to propose tasks that promote self-regulation of learning, lead students to work autonomously and develop the ability to identify and correct their mistakes to overcome difficulties (Barros, 2018). The MathE platform (https://mathe.pixel-online.org), designed to enrich the mathematics learning experience in higher education, can help achieve these goals. It provides students free access to various resources, such as video collections, teaching materials, and self-assessment questions on specific areas of mathematics (Pereira et al., 2020).

Given the learning difficulties of engineering students in linear algebra, frequently identified by the authors in the classroom context and referred to by various authors (Barros, 2018; Karrer, 2006; Andreoli, 2005; Dorier & Sierpinska, 2001; Hillel, 2000), we proposed to explore the potential of the Self Need Assessment feature of the MathE platform, to serve as self-regulation of study for the summative assessment test and promote assessment for learning. The experiment was conducted with mechanical engineering students enrolled in the Linear Algebra and Analytical Geometry course unit and evaluated using a questionnaire.

RESULTS

In the Self Need Assessment component of the MathE platform, it is possible to select the subtopic for which you want to carry out the assessment within each mathematics domain. Particularly, in the case of linear algebra, one can choose between the subtopics: Matrices and determinants, Linear systems, Eigenvalues and eigenvectors, Linear transformations and Vector Spaces. In the case of the present study, it was proposed that students take a basic-level test and another at an advanced level on the last two topics. The basic level test was carried out outside class and individually. The advanced-level test was carried out in groups and in the classroom. In the case of multiple-choice tests, the aim was for students to reformulate their solutions according to the feedback provided by the platform. In this sense, students were asked to submit their latest resolutions after consulting material or watching videos suggested by the platform to correct incorrect answers. This allowed them to reflect on their reasoning, grasp new concepts, identify their mistakes and overcome difficulties. Therefore, in addition to assessing learning, it was intended that solving tests would also have a formative role.

Figure 1 presents an example of a question about Vector Spaces, which appeared in the advanced level test of a group of students.

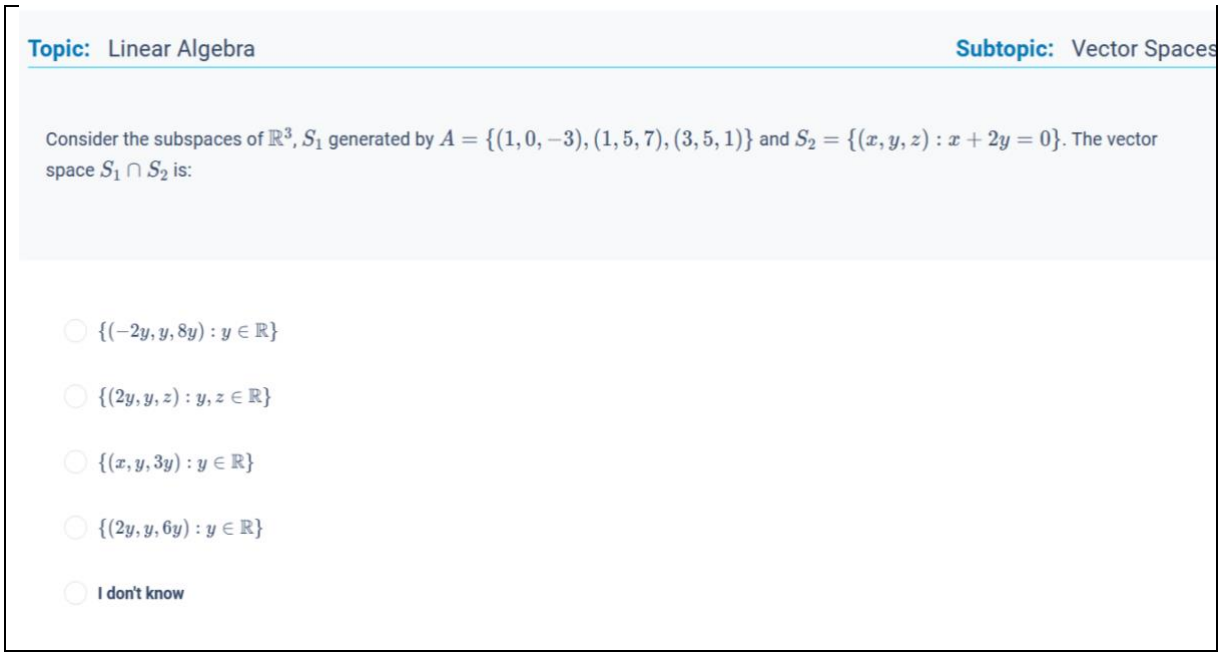

Figure 1 – Advanced level test question about Vector Spaces.

Figure 2 presents an extract of the final resolution that the group of students submitted. Although they did not formally write the expression, it seems that they started by trying to identify the subspace S_1 generated by the set A,

$$S_1 = \{(x, y, z) \in \mathbb{R}^3 : (x, y, z) = k_1(1,0,-3) + k_2(1,5,7) + k_3(3,5,1)\},$$

having concluded that $S_1 = \{(x, y, z) \in \mathbb{R}^3 : 3x - 2y + z = 0\}$.

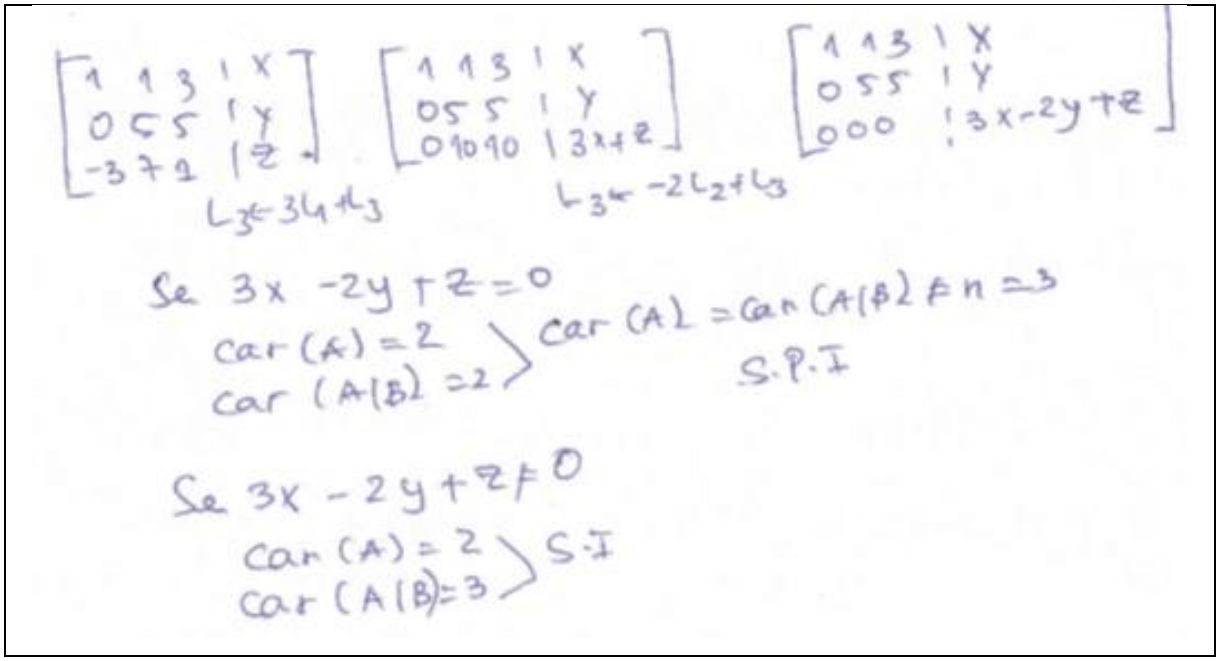

Figure 2 – Extract from the resolution of the question in Figure 2 by a group of students.

Following this resolution, the students solved the system of linear equations

$$\begin{cases} 3x - 2y + z = 0 \\ x + 2y = 0 \end{cases}$$

to find its solution set, which would correspond to the space vector resulting from the intersection of S_1 e S_2. They appropriately concluded that the correct answer was the first option in the statement, that is, $\{(-2y, y, 8y) : y \in \mathbb{R}\}$ (see Figure 2).

The students' opinions about the experience were obtained from their answers to the questionnaire. According to the results obtained, the majority of the students said that they discussed the solution of the questions with their classmates, even the basic level questions that were solved outside of class (69.2% - VS and 76.9% - LT, in the basic level tests; 76.9% - VS and 69.2% - TL, in the advanced level tests). We also found that more than 70% of the students agreed or strongly agreed that solving the questions was very difficult (76.9% - EV and 80.8% - TL in the basic level tests; 73.1% - EV and 76.9% - TL in the advanced level tests), which was also observed by the teacher when monitoring the students.

It should be noted that this experiment was carried out when the platform did not have some of the resources (Video Collection or Teaching Material) that are currently proposed for solving questions where the chosen answer is incorrect. Although the platform's resources were

insufficient to clarify mathematical concepts or procedures, the students had the teacher's help for the tests carried out in class.

Despite the challenges, the students' feedback on the MathE platform as a support tool for the Linear Algebra and Analytical Geometry course unit is favorable. More than 85% of the students agree or strongly agree that the platform is an invaluable asset for learning (96.2%), a crucial tool for individual study (100%), and a means to identify and learn from mistakes (92.3%). The platform also motivates them to persist in solving questions they got wrong, as they can see the correct options.

CONCLUSIONS

The MathE platform, when integrated with teaching strategies that engage students in their learning, as seen in this study, can be an important tool in combating the failure of linear algebra in higher education.

REFERENCES

Andreoli D. I. (2005). Construcción de los conceptos de dependencia e independencia lineal de vectores en alumnos de primer año de la universidad (Tercera fase). *In Comunicações Científicas y Tecnológicas*. Universidade Nacional del Nordeste. http://host140.200-45-54.telecom.net.ar/unnevieja/Web/cyt/com2005/9-Educacion/D-004.pdf

Barros, P. M. (2018). *O ensino e a aprendizagem de conceitos de álgebra linear no ensino superior politécnico* [Tese de doutoramento, Universidade do Minho]. Repositório Institucional da Universidade do Minho. https://hdl.handle.net/1822/56688

Caballero, K., & Bolívar, A. (2015). El professorado universitário como docente: hacia una identidade profesional que integre docência e investigacion. *Revista de Docencia Universitaria*, *13*(1), 57-77. https://doi.org/10.4995/redu.2015.6446

Dorier, J-L., & Sierpinska, A. (2001). Research into the teaching and learning of linear algebra. In D. Holton (Ed.), *The teaching and learning of mathematics at university level* (pp.255-273). Springer.

Hillel, J. (2000). Modes of description and the problem of representation in linear algebra. In J-L. Dorier (Ed.), *On the teaching of linear algebra* (pp. 191-207). Springer.

Karrer, M. (2006). Articulação entre Álgebra Linear e Geometria: um estudo sobre as transformações lineares na perspectiva dos registros de representação semiótica [Tese de doutoramento, Pontifícia Universidade Católica de São Paulo]. https://repositorio.pucsp.br/jspui/handle/handle/11068

Pereira, A. I., Fernandes, F. P., Pacheco, M. F., Barros, P. M., Cordeiro, E., Silva, F., Geraldes, Vaz, C. B., Barros, E., Barbedo, I., Almeida, J. P., Martins, C., & Pires, M. V. (2020). Developing tools for the e-learning platform mathE. In *10th International Conference The Future of Education*. Libreriauniversitaria. it. http://hdl.handle.net/10198/27032

Lima, M. L., Menezes, I & Carregã L. (2016). O ensino superior como um espaço de formação multifacetado. In M.V. Garrido and M. Prada (Coord.), *Manual de competências académicas: Da adaptação à universidade à excelência académica* (pp. 69-84). Sílabo.