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Research Article

# Gastronomic Calculus: Integrating STEAM and Flipped Learning in Higher Education Mathematics

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**Abstract:** This research explores the implementation of a flipped learning approach with first-year Electrical and Computer Engineering students through an activity called "Gastronomic Calculation: Portuguese Cream Cheese, Pumpkin, and Inverted Learning." The proposal integrates concepts of Mathematical Analysis with the gastronomic tradition of Serra da Estrela, challenging students to calculate maximum functions applied to ingredient proportions. This study highlights the relevance of cultural context as a mediator of mathematical learning, fostering communication skills, collaborative work, critical thinking, and creativity. The primary research question is: How does the integration of cultural context and a flipped learning approach within a Science, Technology, Engineering, Mathematics and Arts (STEAM) activity influence the motivation, development of transversal skills, and perceived applicability of mathematical analysis in engineering students? The evidence for this, exploratory case study is predominantly descriptive, based on self-report data (questionnaire) and qualitative records from observation and analysis of students' work products. The results suggest that interdisciplinary contextualization can increase motivation, concept retention, and the practical application of Science, Technology, Engineering and Mathematics (STEM)/Science, Technology, Engineering, Mathematics and Arts (STEAM) knowledge.

***Keywords*:** Science, Technology, Engineering and Mathematics(STEM)/Science, Technology, Engineering, Mathematics and Arts (STEAM) education, flipped learning, mathematical analysis, cultural contextualization, gastronomy, higher education

## 1. Introduction

Teaching mathematics in higher education, especially in engineering programs, faces persistent challenges related to understanding, motivation, and practical application of concepts. Many students struggle to grasp fundamental mathematical analysis content, such as derivatives, critical points, and optimization, due to the highly abstract nature of the topics and the lack of real-world context (Freeman et al., 2014; Grenier-Boley & Sabra, 2022; Castillo et al., 2025). This difficulty is not limited to acquiring technical knowledge but also affects students' confidence in their own abilities, increasing anxiety and the perception of the subject's irrelevance, which contributes to demotivation and reduced engagement in the learning process (Shabab, 2024; Pei et al., 2025).

Given this situation, it becomes increasingly urgent to explore pedagogical strategies that allow students to


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perceive the practical utility of content and feel motivated to explore complex concepts independently. The integration of Science, Technology, Engineering and Mathematics (STEM)/Science, Technology, Engineering, Mathematics and Arts (STEAM) approaches has proven effective in this context by proposing tasks that not only involve solving technical problems but also encourage creativity, experimentation, and interdisciplinary application (Filipe et al., 2024; Sánchez & Cortés, 2024; Zhang & Jia, 2024). By connecting mathematics to real-world contexts, such as gastronomy, students can immediately visualize the impact of their decisions and calculations, making learning more meaningful and engaging. This contextualized approach promotes active learning, leading to greater concept retention and the development of essential soft skills, including collaboration, critical thinking, and creativity, which are highly valued in the contemporary job market (OECD, 2018; Shabab, 2024).

This research focuses on the implementation of a flipped learning activity called "Gastronomic Calculation: Portuguese Cream Cheese, Pumpkin, and Flipped Learning," administered to first-year Electrical and Computer Engineering students. The activity seeks to bridge abstract mathematical concepts with the culinary traditions of Serra da Estrela, challenging students to determine the ideal ratio of Portuguese Cream Cheese to pumpkin jam to maximize taster satisfaction. The primary research question addressed is: How does the integration of cultural context and a flipped learning approach within a STEAM activity influence the motivation, development of transversal skills, and perceived applicability of mathematical analysis in engineering students?

By integrating mathematics, local culture, and technology, the activity exemplifies how STEAM pedagogy can transform higher education, promoting meaningful, motivating learning aligned with the demands of the 21st century.

## 2. Theoretical framework

### 2.1 *STEM/STEAM education and contextualized learning*

STEM education has been widely recognized as essential for developing 21st-century skills, including complex problem-solving, critical thinking, creativity, and innovation. These areas are crucial for preparing citizens capable of tackling global challenges such as digital transition, sustainability, and economic competitiveness. However, the traditional approach to these disciplines, often fragmented and decontextualized from students' daily reality, has contributed to demotivation and learning difficulties, especially in mathematics. To address this challenge, integrated STEM learning has emerged, promoting the connection between different areas of knowledge and their application to real-world problems, encouraging active methodologies (Portillo-Blanco et al., 2024; Chiu et al., 2025). This integration not only increases student engagement but also reinforces the social and professional relevance of the content, bringing them closer to authentic and interdisciplinary contexts (Ningtyas et al., 2024). Effective implementation of the STEM approach requires innovative pedagogical strategies, adequate teacher training, and resources that enable hands-on, collaborative, and project-oriented experiences (Portillo-Blanco et al., 2025). Recent studies show that problem-based practices and interdisciplinary projects enhance technical and socio-emotional skills, preparing students for a constantly evolving job market (Wan et al., 2023; Portillo-Blanco et al., 2025).

The transition from STEM to STEAM emerges as a response to this gap, integrating the Arts into the curriculum to promote more comprehensive and creative learning. This approach recognizes that the Arts play a crucial role in the development of creativity, communication, and expression, skills equally valued in the contemporary job market. The inclusion of the artistic component is not limited to aesthetics, but contributes to design processes, critical thinking, and creative problem-solving, expanding the possibilities for innovation (Sanz-Camarero et al., 2023; Sánchez & Cortés, 2024). Recent studies show that integrating the Arts into STEM contexts promotes student motivation, improves knowledge retention, and stimulates complex cognitive skills such as observation, association, and analysis (Zhang & Jia, 2024). Furthermore, incorporating cultural and artistic elements, such as gastronomy, allows students to establish meaningful connections between theory and practice, reinforcing the social relevance of learning (Filipe et al., 2024). In higher education, STEAM projects have shown potential to develop digital skills, creativity, and collaboration, preparing students to face interdisciplinary and global challenges (Carter et al., 2021; Caridade & Pereira, 2025; Farenga et al., 2025).

## 2.2 *Flipped learning*

The Flipped Learning methodology, also known as the flipped classroom, has emerged as an innovative pedagogical strategy that aims to reconfigure the traditional role of teacher and student in the teaching-learning process. Traditionally, students are exposed to theoretical content in the classroom, while practical and applied activities are completed as homework. In the flipped approach, this dynamic is altered: students study theoretical content independently, usually through videos or readings, before class, and face-to-face time is dedicated to practical activities, discussions, and problem-solving, promoting more active and collaborative learning.  Recent studies have highlighted the benefits of Flipped Learning in promoting student autonomy and motivation. For example, a systematic review by Galindo-Domínguez and Bezanilla (2025). suggests that the methodology can foster student autonomy, especially in university settings, although results may vary depending on the specific implementation of the methodology. Furthermore, the integration of emerging technologies, such as Artificial Intelligence (AI), has enhanced the positive effects of Flipped Learning. Research conducted by Yavuz et al. (2025). indicates that combining AI with the flipped methodology can improve students' AI literacy, increase motivation, and provide personalized learning experiences, although time management challenges may also arise.

The flexibility of Flipped Learning allows it to be applied in a variety of educational contexts, including higher education, vocational education, and lifelong learning. Samaila (2025). proposes a Flipped Learning model focused on lifelong learning, highlighting the importance of adapting pedagogical practices to students' individual needs and pace, promoting continuous and adaptive learning. Despite the potential benefits, the effective implementation of Flipped Learning faces significant challenges. A critical analysis by Young (2023) points out that, although the methodology has shown benefits in some studies, its effectiveness can be limited by inconsistent implementation and a lack of adequate preparation of teachers and students. Furthermore, factors such as resistance to change, the need for ongoing professional development, and adequate technological infrastructure are essential to the methodology's success.

## 2.3 *Cultural contextualization in learning*

Cultural contextualization in education emerges as an essential pedagogical strategy for promoting meaningful and motivating learning. By integrating local cultural elements into teaching and learning processes, educators can establish deeper connections with students, valuing their identities and experiences. This approach not only enriches the curriculum but also fosters the development of cognitive and socio-emotional skills. Recent literature emphasizes the benefits of cultural contextualization in education. According to Perin (2011), contextualizing teaching allows students to perceive the relevance of the content learned, linking it to their realities and interests. Furthermore, research by Anyichie et al. (2023) highlights that the integration of culturally responsive pedagogical practices, combined with self-regulated learning strategies, can significantly increase student engagement and motivation in complex tasks. Cultural contextualization is also seen to combat "pedagogical colonialism", where dominant cultural paradigms marginalize local knowledge. In this sense, Ibiloye (2025) proposes the Culturally Contextualized Pedagogical Integration (CCPI) model, which emphasizes conceptual anchoring, relational learning, and practical application, promoting a more inclusive education connected to local communities.

# 3. Methodology

## 3.1 *Participants*

The activity was applied to first-year students of the Electrical and Computer Engineering degree program at the Coimbra Higher Institute of Engineering, in two classes of approximately 35 students, organized into groups of three. The intervention took place in October 2025, as part of the Mathematical Analysis course, during a phase of the program dedicated to the study of derivatives, with particular emphasis on the derivatives of inverse trigonometric functions. It should be noted that while 70 students participated in the face-to-face activity and collaborative work, the final perception questionnaire (Section 3.3) was voluntary, resulting in 41 respondents (a response rate of 58.6%). This limitation regarding self-reported data is considered in the analysis of the results.

The activity was structured in two complementary phases. The day before, the students completed individual online preparation using a flipped learning approach, which included watching an explanatory video about the derivative of the *arcsin* (*x*) function and completing a short self-assessment quiz available on the Moodle platform. This phase aimed to diagnose initial understanding and promote the autonomous consolidation of theoretical concepts, allowing each student to reflect on the content at their own pace and ensuring readiness for the practical session. The following day, a three-hour in-person classroom session took place, during which the groups applied their acquired knowledge to solve the problem proposed by the "Confraria do Requeijão com Doce de Abóbora". This combined methodology (prior theoretical preparation and collaborative practical application) sought to reinforce the connection between mathematical rigor and its contextualized application, enhancing participants' autonomy, communication, and critical thinking.

## 3.2 *Activity structure*

The Gastronomic Calculus activity was designed to integrate the concept of mathematical optimization (derivatives and critical points) within a local cultural context. The chosen context was the "Confraria do Requeijão com Doce de Abóbora" (2025) (Portuguese Cream Cheese Confraternity with Pumpkin Jam), a cultural association in Seia dedicated to preserving this emblematic delicacy from the Serra da Estrela region. This dessert, composed of artisanal cream cheese and pumpkin jam, served as the anchor for contextualization. The integration of this theme provided a unique opportunity for students to apply mathematical concepts in a real-world and culturally meaningful setting. The central task challenged students to analyze a mathematical function representing consumer satisfaction (taster satisfaction) concerning the ingredient proportions. Through this analysis, students explored the function's derivative, identified critical points, and discussed their gastronomic interpretation, promoting active and contextualized learning. As a final product, groups had to develop original recipe proposals that included the respective mathematical optimization function. Additionally, the use of Artificial Intelligence tools to create illustrative images of the recipes contributed to the development of digital and innovative skills."

The activity plan was designed to foster a connection between theory and practice, involving three complementary phases:

1. Theoretical Ingredients: What can't be missing,
2. Fire Test: Serving Math with Portuguese Cream Cheese and Pumpkin Jam, and
3. Culinary Challenge: Portuguese Cream Cheese Meets Pumpkin Jam.

This three-phase structure (Figure 1) allowed for the integration of autonomous learning, collaborative application, and contextualized creative production, in accordance with the principles of the STEAM model and the flipped learning methodology.

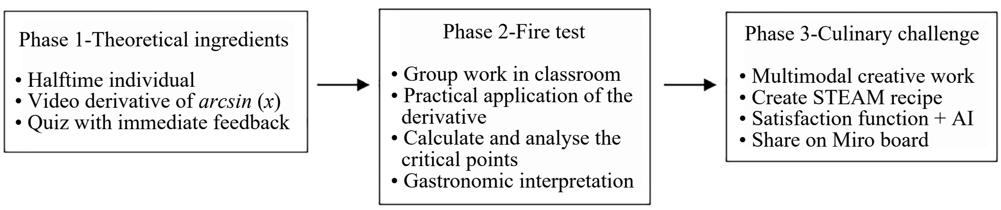


**Figure 1.** Activity structure defined by 3 phases: Phase 1-Theoretical Ingredients, Phase 2-Fire Test and Phase 3-Culinary challenge

Phase 1 is a preparatory phase, where students completed asynchronous flipped learning activities to consolidate theoretical foundations before group work. Tasks included:

• Watching a short video (5-8 minutes) about the derivative of the *arcsin* (*x*) function, with simple examples and a qualitative interpretation of the concept.

• A self-assessment quiz (5-10 minutes) with two multiple-choice questions (one of elementary complexity and one of more advanced complexity) and immediate automatic feedback, allowing students to reflect on any errors and consolidate their learning.

Both resources were available on the Moodle platform (Figure 2), providing flexibility and autonomy in the learning process.

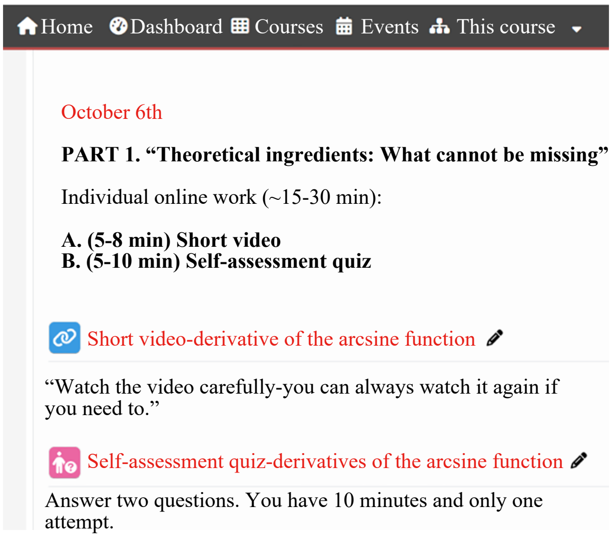


**Figure 2.** Resources available in moodle (video and quiz)

During the in-person meeting, during phase 2, students were invited to apply their acquired knowledge to solve a contextualized mathematical problem inspired by the culinary traditions of Serra da Estrela. After a brief cultural introduction to the Confraternity and the importance of Portuguese Cream Cheese and pumpkin jam, a review of the concepts of derivatives and critical points was provided. The groups then performed the following steps:

• Calculation of the derivative of the satisfaction function:

$$S(x) = 2\arcsin\left(\frac{x}{\sqrt{200}}\right) - 0.01x^2 + 80;$$

• Determination of critical points, solving $S'(x) = 0$;

• Identification of the ideal amount of pumpkin jam (in grams) that maximizes taster satisfaction;

• Gastronomic and cultural interpretation of the results, relating the optimum point to the harmony of flavours and regional tradition.

Figure 3 shows two examples of solutions to the second phase of the activity, developed by different groups. This stage consisted of applying mathematical concepts to determine the optimal amount of pumpkin jam to add to the fixed portion of Portuguese Cream Cheese, to maximize the tasters' satisfaction function $S(x)$ for the new gourmet product. The solutions illustrate different calculation strategies, including function definition, differentiation to find the critical point, and verification of the maximum condition. These examples highlight the diversity of approaches adopted by the students and the practical integration of mathematics in a real-world and culturally meaningful context.

In addition to the mathematical solution, the groups were challenged to interpret the results obtained considering the cultural and gastronomic identity of "Serra da Estrela". A preliminary thematic analysis of student reflections revealed two main themes related to the application of mathematics in this context:

*Theme 1: Sensory Balance and Mathematical Optimization. Students successfully articulated the concept of optimization with sensory experience. For instance:*

*"The derivative helped us find the ratio that translates into perfect sensory balance. At its optimum point, the pumpkin jam enhances the flavour of the Portuguese Cream Cheese without overpowering it. The result mathematically translates what chefs intuitively seek: harmony of flavours, texture, and colour. Thus, mathematics becomes a tool for translating sensations into measurable values" (group X).*

*Theme 2: Mathematics as a Cultural Language. Students viewed the function as a link between science and cultural heritage:*

*"The sweet spot shows that even in the kitchen, the principles of mathematical analysis apply finding the point*

*where maximum pleasure is achieved. But this numerical value only becomes meaningful when we associate it with culinary art and local gastronomic heritage. Thus, the satisfaction function is a bridge between science and culture, between calculation and sensitivity" (group y).*

*"We discovered that the sweet spot of our function isn't just a number, it's a sensory experience. It's the moment when the pumpkin jam gently covers the Portuguese Cream Cheese, like the sun setting over the mountains. This balance translates into maximum satisfaction, but also a celebration of our regional identity: simple, authentic, and just the right amount of sweetness" (group z).*

The maximum

$$\left(\frac{2}{\sqrt{200-x^2}}\right)-0,02x=0$$

$$\left(\frac{2}{\sqrt{200-x^2}}\right)=0,02x$$

$$\left(\frac{2}{\sqrt{200-x^2}}\right)=0,02x$$

$$2=0,02x\times\sqrt{200-x^2}$$

$$\frac{2}{0,02}=x\times\sqrt{200-x^2}$$

$$100=x\times\sqrt{200-x^2}$$

$$(100)^2=\left(x\times\sqrt{200-x^2}\right)^2$$

$$10000=x^2\times\left(200-x^2\right)$$

$$x^4-200\times x^2+10000=0$$

$$y^2-200\times y+10000=0,\ \text{mudança de variável } y=x^2$$

$$y=\frac{200\pm\sqrt{(-200)^2-4\times1\times10000}}{2}$$

$$y=100,\ x^2=100$$

$$x=10$$

Starting from the initial function $S(x)$ and differentiating, we obtain

$$S'(x)=\frac{2\left(\frac{x}{\sqrt{200}}\right)'}{\sqrt{1-\left(\frac{x}{\sqrt{200}}\right)^2}}-0,02x=\frac{\frac{2}{\sqrt{200}}}{\sqrt{1-\frac{x^2}{200}}}-0,02x=\frac{2}{\sqrt{200-x^2}}-0,02x.$$

Where the zeros are given by

$$S'(x)=0\Leftrightarrow\frac{2}{\sqrt{200-x^2}}-0.02x=0\Leftrightarrow\frac{2-0.02x\sqrt{200-x^2}}{\sqrt{200-x^2}}=0.$$

For this equation to be zero, it will have to

$$2-0.02x\sqrt{200-x^2}=0 \text{ and } 200-x^2\neq0$$

i.e.

$$0,02x\sqrt{200-x^2}=2 \Leftrightarrow (0,02x)^2\left(200-x^2\right)=4 \Leftrightarrow -0,0004x^4+0,08x^2-4=0$$

$$\text{and } x\neq\mp\sqrt{200}$$

Given $y=x^2$, we obtain

$$-0.0004y^2+0.08y-4=0\Leftrightarrow=-0.0004\left(y^2-200y+10000\right)=0$$

whose solution is $y = 100$, so $x = 10$, since $x\in[0, 30]$. On the other hand, in $y = 100$ the function reaches a maximum, because

| | $-\infty$ | 100 | $+\infty$ |
|---|---|---|---|
| $0.0004y^2+0.08y-4$ | + | 0 | - |
| | ↑ | Maximum | ↓ |

As soon as $y = 100$, $x = 10$, and therefore the maximum satisfaction of the function $S(x)$ isreached at this value. The result indicates that the tasters' satisfaction reaches itsmaximum when the amount of pumpkin jam is around 10 g for the fixed dose of creamcheese.

**Figure 3.** Two examples of the work produced by the groups in phase 2

These quotes highlight how the integration of mathematics, culture, and gastronomy can transform an academic activity into a meaningful experience, reinforcing the relevance of STEAM and contextualized approaches. This moment was essential to promote analytical thinking, collaborative work, and scientific communication, allowing students to experience mathematical reasoning in a meaningful and creative context.

The third and final phase had a creative and integrative nature, bringing mathematics closer to cultural and technological expressions. Inspired by the Confraternity itself, this stage consisted of a thematic competition in which each group of students was challenged to create and present an original recipe proposal that combined gastronomic, mathematical, and digital elements.

Each group developed a proposal composed of the following elements:

• Recipe name.

• List of ingredients.

• Instructions (5-6 lines).

• Mathematical satisfaction function, inspired by the optimization model previously developed or created originally.

• Illustrative image of the recipe, generated through Artificial Intelligence (AI) tools.

All proposals were organized and shared on a collaborative cooking eBook on Miro, promoting a collaborative and visual dimension to the learning process (Figure 4). The "Confraria do Requeijão com Doce de Abóbora" (symbolized by the teacher) evaluated the proposals based on criteria of creativity, authenticity, and connection to regional tradition. Following the launch of the eBook featuring students' creative and delicious recipes, the "Confraria do Requeijão com Doce de Abóbora" proudly presents the finalist recipes, selected for their originality, harmonious flavors, and visual appeal. Figure 5 shows two of the finalist recipes, accompanied by their names, images, and brief descriptions.

• Pipo-Style Portuguese Creamy Cream Cheese: Creamy layers of cream cheese meet velvety pumpkin jam, creating a dessert of perfect contrasts: sweet and savoury, smooth and striking. Visually charming, with golden hues and a cinnamon aroma, it's the kind of dessert that warms the palate and the heart.

• Portuguese Cream Cheese Pie with Pumpkin Jam and Walnuts: A traditional Portuguese dessert that combines the smooth, creamy flavour of cottage cheese with the enveloping sweetness of pumpkin jam. The walnuts add a crunchy, aromatic touch that perfectly balances the soft texture of the filling.

2. Recipes-Class 1

Group 13

| "Golden cup of the brotherhood" | |
|---|---|
| A creamy golden dessert that combines smooth ricotta cheese with the intense sweetness of pumpkin jam in a perfect balance of tradition and flavor. | |
| Authors | Nelson Teixeira (2025153007)<br>Pedro Barbosa (2025136186)<br>António Batista (2025101877) |
| Ingredients | 200 g creamy ricotta cheese<br>120 g pumpkin jam<br>1 tablespoon honey<br>1 teaspoon ground cinnamon<br>1 teaspoon lemon zest<br>Sliced almonds, as needed |
| Preparation method | Mix the ricotta cheese with the honey and lemon zest until a smooth cream forms. Distribute the pumpkin jam at the bottom of small bowls. Add the ricotta cream on top and sprinkle with cinnamon and almonds. Refrigerate for 15 minutes to firm up. Serve chilled, decorated with a drizzle of honey. |
| A | $S(x) = 80 + 15(1 - e^{-0.2x}) - 0.03x^2$ |

Group 14

| "Golden cream cheese and pumpkin jam tart with walnut crust" | |
|---|---|
| The Golden Cream Cheese and Pumpkin Pie combines the smoothness of cream cheese with the intense sweetness of pumpkin jam. It has a golden and shiny appearance, with a crunchy walnut crust and a delicate aroma of honey and orange. The texture is creamy inside and crunchy outside, resulting in a perfect balance of residential and comforting flavors. | |
| Authors | Mário Livinogue a202510036<br>William Monteiro a2025163124<br>Natã Têmere a2025105365 |
| Ingredients | 250 g fresh ricotta cheese<br>200 g pumpkin jam<br>2 eggs<br>1 shortcrust pastry base<br>50 g chopped walnuts<br>1 teaspoon honey<br>Orange zest to taste |
| Preparation method | Line a baking dish with the shortcrust pastry and prick the bottom with a fork. Mix the ricotta cheese, eggs, honey and orange zest until you have a smooth cream.<br>Spread the pumpkin jam over the base and cover with the ricotta cream.<br>Sprinkle with chopped walnuts and drizzle with honey. |

Group 15

| "Cheesecake with ricotta and pumpkin" | |
|---|---|
| Authors | Miguel Silva<br>Martim Malta<br>Diogo Maria |
| Ingredients | 300 g Maria biscuits<br>120 g melted butter<br>400 g cream cheese<br>200 ml whipping cream<br>5 sheets of unflavored gelatin (or 8 g powdered gelatin)<br>200 g pumpkin jam<br>1 teaspoon ground cinnamon<br>Zest of 1 orange (optional, but adds a fresh touch)<br>2 tablespoons honey or sugar |
| Preparation method | Crush the cookies and mix with the melted butter until a spinning pan a crumbly press firmly. Refrigerate for 15 minutes. Mix the cream cheese, heavy cream, and honey until you obtain a smooth cream.<br>Dissolve the gelatin in hot water and add to the mixture, mixing well.<br>Pour the cream over the base and refrigerate for 4 to 6 hours until set.<br>Spread the pumpkin jam on top, sprinkle with cinnamon and orange zest before serving. |

2. Recipes-Class 2

Group 1

Group 2

Group 3


| “Pumpkin pie” | |
|---|---|
| Authors | |
| Ingredients | 300 g fresh ricotta cheese<br>200 g homemade pumpkin jam<br>1 shortcrust pastry base<br>2 eggs<br>100 g brown sugar<br>1 teaspoon cinnamon<br>Orange zest to taste |
| Preparation method | Preheat the oven to 180 °C (350 °F). Line a baking dish with the shortcrust pastry. Beat the cream cheese with the eggs, sugar, cinnamon, and orange zest until smooth. Pour this mixture into the pastry-lined dish. Using a piping bag or spoon, pipe a spiral of pumpkin jam over the top of the tart. Bake for 35 minutes or until golden. Serve warm or cold. |
| A mathematical function that represents satisfaction. | $S(x, y) = -0.2(x - 5)2 - 0.1(y - 6)2 + 10$<br>• $x$ = quantity (in spoons) of pumpkin jam<br>• $y$ = quantity (in grams) of cream cheese<br>This function reaches a maximum value of 10 when $x = 5$ spoons and $y = 6$ spoons (approximately 120 g), that is, the perfect balance between sweet and creamy. |

| “Cup of the mountain range” | |
|---|---|
| Authors | Leonardo Nunes, António Gonçalves, João Santos |
| Ingredients | 1 fixed portion of creamy ricotta cheese (50 g)<br>20 g of homemade pumpkin jam<br>1 teaspoon of honey<br>Lemon zest<br>Toasted almonds for decoration |
| Preparation method | In a glass or small bowl, place a layer of creamy ricotta cheese. Add the pumpkin jam on top, spreading it evenly. Drizzle with honey and finish with lemon zest to balance the flavor. Sprinkle with toasted almonds to add texture and aroma. Serve chilled, highlighting the traditional products of the Serra da Estrela region. |
| A mathematical function that represents revenue satisfaction. | $S(x) = 1.8 \arcsin\left(\frac{x}{15}\right) - 0.008x^2 + 82$<br>$x$ represents the amount of pumpkin candy (in grams). It maintains the same type of initial growth (the arc sine), but the scale and coefficients are different. It will also have a maximum point between $x = 8$ and 12 g, consistent with the context of the problem. |

| “Layered mountain delight” | |
|---|---|
| Authors | Guilherme Urbano, Francisco Pessoa e Duarte Fernandes |
| Ingredients | 1 portion of fresh cream cheese (60 g)<br>15 g of homemade pumpkin jam<br>1 crushed Maria biscuit<br>1 teaspoon of chopped walnuts<br>Ground cinnamon to taste<br>A drizzle of homemade honey |
| Preparation method | In a clear bowl, place a thin layer of crushed biscuits on the bottom. Spread the cream cheese on top and cover the pumpkin jam. Add the chopped walnuts and sprinkle lightly with cinnamon. Finish with a drizzle of honey to enhance the flavor. Refrigerate for 15 minutes before serving to accentuate the creamy texture and aroma of the spices. |
| A mathematical function thatre presents revenue satisfaction. | $S(x) = 2\ln(x + 1) - 0.012x^2 + 83$<br>It uses logarithms instead of arcsine, simulating the rapid increase in satisfaction at the beginning and the drop when there is an excess of sweetness. It’s a simpler function to work with, but it maintains the same “optimal balance” reasoning. |

**Figure 4.** Collaborative class mural on Miro with some of the recipes presented by the students

Recipe name
Pipo-style creamy cream cheese

Creamy layers of cream cheese meet velvety pumpkin jam, creating a dessert of perfect contrasts: sweet and savoury, smooth and striking. Visually charming, with golden hues and a cinnamon aroma, it’s the kind of dessert that warms the palate and the heart.

Recipe name
Cottage cheese pie with pumpkin jam and walnuts

A traditional Portuguese dessert that combines the smooth, creamy flavour of cottage cheese with the enveloping sweetness of pumpkin jam. The walnuts add a crunchy, aromatic touch that perfectly balances the soft texture of the filling.

**Figure 5.** Two of the finalist recipes with portuguese cream cheese and pumpkin jam

In the final phase of the activity, the Portuguese Cream Cheese with Pumpkin Jam Confraternity Challenge, students were challenged to design a mathematical satisfaction function associated with their original recipe, integrating gastronomic, cultural, and emotional elements. This task aimed to apply the concepts of derivatives and modelling to creative contexts, encouraging students to reflect on how variables influence sensory experience and gastronomic pleasure. The functions presented by the different groups revealed great conceptual and symbolic diversity, demonstrating the students' ability to translate mathematical reasoning into everyday situations and value qualitative dimensions of pleasure, such as conviviality, tradition, or simplicity. Some functions followed more analytical structures, involving trigonometric or polynomial expressions, while others favoured qualitative models, where each variable represented a subjective aspect of the gastronomic experience.

Figure 6 presents two representative examples of the taster satisfaction function proposals developed by the students: On the left, there is the satisfaction function associated with Stone Soup, a traditional Portuguese dish deeply rooted in popular culture. The proposed function, S represents the overall level of satisfaction, Increases with flavor (*I*), Temperature (*T*), and ingredient Quality (*Q*), but decreases with Effort (*E*) and lack of Company (*C*). The k factor reflects the cultural and emotional value of the tradition, recognizing that the gastronomic experience is not limited to the physical dimension but also includes sharing, memory, and social context. This example demonstrates an integrated understanding of the function as a mathematical representation for human experience, where optimization is not only quantitative but also symbolic. On the right, a different function, more symbolic and qualitative in nature, is created to represent the concept of "Earth-Earth Flavor": In this model, the function *S* represents the overall intensity of the "Earth-Earth" flavor, influenced by three main dimensions: Authenticity (*A*), or the degree to which the dish maintains the traditional and natural characteristics of the ingredients; Nostalgia (*N*), related to taste memory and the emotional value that the flavor evokes; simplicity (*Sp*), which refers to the clarity of flavors and the absence of artificial exaggerations. This formulation illustrates a more emotional and cultural view of mathematical modeling, in which the function becomes a symbol of the harmony between traditional knowledge and the aesthetics of simplicity. Both examples reflect students' ability to use mathematical language as a tool for creative and interpretative expression, combining logical reasoning with aesthetic sensitivity and an appreciation of regional identity. These productions also highlight the potential of the STEAM approach to transform mathematics into a real-world reading tool, fostering critical thinking skills, interdisciplinarity, and cultural appreciation.

| | |
|---|---|
| $S(x) = k\frac{I \times T \times Q^2}{(E + C)}$<br>Soup enjoyment is represented by the *S* function, where pleasure increases with flavor (*I*), temperature (*T*), and ingredient quality (*Q*), but decreases with effort (*E*) and lack of company (*C*). The *k* factor reflects the cultural and emotional value of the tradition, because good soup is as much about sharing as it is about savoring. | $S(x) = \frac{A + N + Sp}{3}$<br>The overall intensity of the "Earth-Earth" flavor is represented by the *S* function, where *A* represents authenticity (the degree to which the dish maintains the traditional and natural characteristics of the ingredients); *N* represents nostalgia (the emotional connection and taste memory that the flavor awakens), and *Sp* represents simplicity (clarity of flavors and the absence of artificial exaggerations). |

**Figure 6.** Two representative examples of the taster satisfaction function proposals developed by the students

## 3.3 *Assessment instruments*

The activity assessment was designed in a formative and integrated manner, encompassing all phases of the learning process, from individual preparation to execution and final reflection. Thus, evidence collection considered multiple dimensions, combining direct observation, product analysis, and assessment of digital participation.

The first stage involved analysing the online quiz completed by students prior to the in-person class. This instrument was essentially diagnostic and self-regulatory, allowing the teacher to assess the level of understanding of the theoretical content and identify any difficulties in the derivation of the *arcsin* ($x$) function. Data were collected on the number of attempts, response time, and accuracy rate, which provided indicators of individual engagement and progress.

During the in-person session, the assessment focused on direct observation of group performance, focusing on aspects such as collaboration among members, the ability to reason mathematically, the application of the concepts of derivatives and critical points, and the integration of these concepts in solving the problem proposed by the "Confraria do Requeijão com Doce de Abóbora". This qualitative observation allowed us to identify evidence of autonomy, communication, and creativity, as well as the degree of student engagement in the collective discussion. At the same time, students were instructed to record their responses and reasoning in a worksheet, which was later submitted to the Moodle platform, which allowed for a more detailed analysis of conceptual understanding and thought processes during the collaborative work.

Subsequently, the products submitted to the Miro wall were analysed, including the mathematical function of satisfaction, the recipe created, and the illustrative image developed using Artificial Intelligence tools. These works were evaluated based on criteria of mathematical correctness, conceptual coherence, creativity, originality, and cultural relevance reflecting the interdisciplinary nature of the activity and its framework within the STEAM model.

Finally, the students conducted a qualitative reflection on the experience, sharing insights regarding the integration of mathematics, culture, and technology. This reflection, gathered through a brief questionnaire and oral comments at the end of the session, was essential for understanding the impact of the flipped learning methodology on key transversal skills such as critical thinking, problem-solving, and communication, and its influence on motivation and autonomy.

## 4. Results

Of the 70 students who participated in the activity, 50 completed the first phase individually at home the day before the in-person session by watching a video and answering the quiz. Analysis of the results reveals that one student obtained no correct answers, 11 students answered one of the two questions correctly, and 38 students answered both correctly. This data indicates that most participants already demonstrated initial understanding of the content covered, which may have positively influenced their performance in the subsequent activity. The high accuracy rate also suggests that the quiz was effective in identifying content readiness, serving as an initial diagnostic tool.

Additionally, data was collected through a final questionnaire. Of the 70 students involved in the activity, only 41 completed the final questionnaire, corresponding to a response rate of approximately 58.5%. It is crucial to interpret these perception results considering this 58.5% response rate ($n$ = 41), which limits generalization to the entire cohort. Although not representative of the entire class, this number is sufficient to highlight relevant trends regarding the motivational and didactic impact of the proposal. Regarding the first phase of the activity, most students considered the video provided clear and useful for understanding the content, with 63.4% giving it the highest score (5), 29.3% giving it a "4", and 7.3% giving it a "3" on a scale of 1 to 5. These results demonstrate that the audiovisual resource was well received and played a significant role in consolidating theoretical concepts before class.

Regarding the difficulty experienced in solving the quiz, 65.9% of students considered the level of difficulty adequate, 19.5% rated it as easy, 9.8% as difficult, and 4.9% as very difficult, revealing a balanced perception of the complexity of the proposed questions. Finally, when asked if they felt prepared for the practical activity after self-study at home, 43.9% said they "completely agree" (score 5), 39% "agree" (score 4), 12.2% remained neutral (score 3), and only 4.9% indicated they "completely disagree" (score 1). These results suggest that prior preparation was effective for most students, helping them present themselves confident and motivated in the in-person session. Taken together, the quantitative and qualitative data indicate that the initial phase of the activity, based on the flipped learning model, fulfilled its purpose of facilitating theoretical understanding and promoting autonomy in learning, creating favourable conditions for the success of the following stages.

In the in-person session, phase 2, the activity sought to promote the practical application of mathematics, stimulate creativity, and foster collaborative work. Of the 41 responses obtained in the final questionnaire, it was observed that regarding the question "The activity helped me apply mathematical concepts in a practical way", the data show that 43.9% of students gave it a grade of 4 and 39% gave it the highest grade (5), indicating a very positive perception of the activity's usefulness in consolidating mathematical content. Only 12.2% gave it a grade of 3 and 4.9% a grade of 1, representing a minority with a less favourable view. Regarding the group work dynamics, the results were particularly impressive: 78% of students considered it excellent, 19.5% good, and only 2.4% average. These data reinforce the importance of collaborative work as a motivating and facilitating element of learning. The next question evaluated the pedagogical proposal itself: "The proposal to create a mathematically based recipe was motivating and creative". Most students responded very positively, with 53.7% giving the highest score (5) and 36.6% a score of 4. Only 9.8% gave a score of 3, with no responses in the lower categories.

The survey results indicate that the activity contributed to the development of several transversal skills (Figure 7). The most cited skill among students was collaborative work (87.8%), highlighting the importance of interaction and group task management. This was followed by practical application of mathematics (75.6%), suggesting that contextualization helped make the content more understandable and relevant. Communication and creativity skills were equally valued (68.3% each), reflecting the need to articulate ideas clearly and propose original solutions when developing the recipe and the satisfaction function. Finally, 34.1% of students mentioned the appreciation of regional identity, demonstrating that the integration of cultural elements strengthened the connection with the local gastronomic heritage. Overall, the results show that the activity simultaneously fostered technical, social, and cultural skills, reinforcing the relevance of interdisciplinary approaches in higher education.

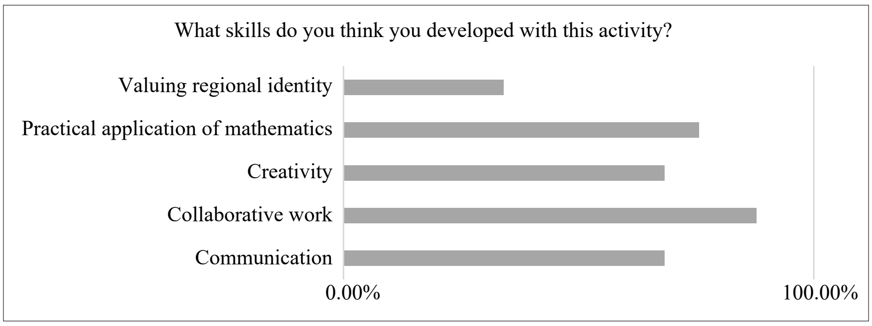


**Figure 7.** The skills that students identified as having developed with the activity

In the next question, "Am I satisfied with how the activity was organized and conducted?" the data reveal a high level of satisfaction among students (Figure 8). The majority (63.4%) gave the activity a maximum score (5), indicating that they considered it very well organized and conducted. Another 34.1% gave it a 4, reinforcing a positive perception, although with small opportunities for improvement. Only 2.4% gave it a score of 3, with no responses in the lower categories, demonstrating the absence of significant dissatisfaction.

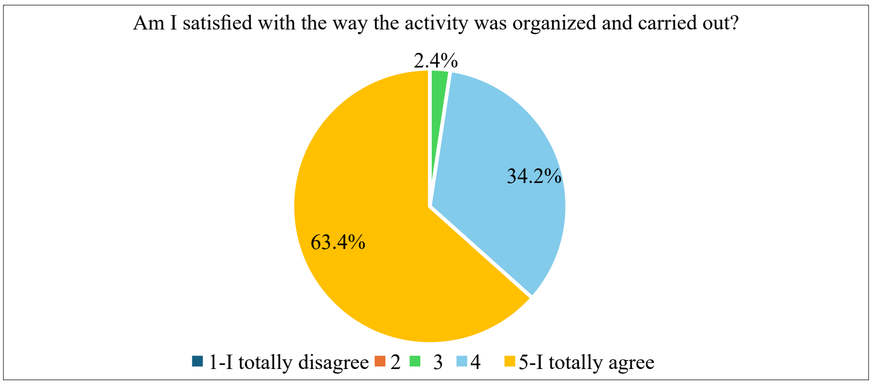


**Figure 8.** Answers to the question "Am I satisfied with the way the activity was organized and carried out?" (1-I completely disagree to 5-I completely agree)

The responses to the question "What did you like most about the activity?" reveal a strong appreciation for collaboration and creativity (Figure 9). The words "group", "creating", "recipe", "working", and "math" were the most frequent, indicating that students enjoyed working in teams, creating original solutions, and applying mathematical concepts in a practical and contextualized way. These elements reinforce the idea that the activity promoted active engagement and meaningful learning. On the other hand, in the question “What could be improved for future editions?”, the most common words were “nothing”, “larger groups”, and “don’t know”. This pattern suggests that most participants did not identify any relevant aspects for improvement, confirming an overall positive perception. However, the reference to larger groups indicates that some students would like to work in larger groups, possibly to increase the diversity of ideas and collaboration.

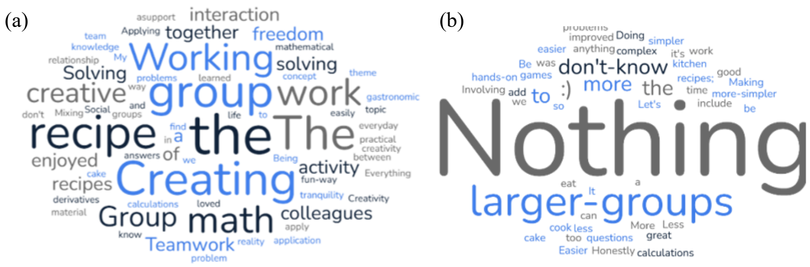


**Figure 9.** Word cloud with answers to the questions: (a) What did you like most about the activity? and (b) What could be improved for future editions?

In addition to the data collected through the questionnaire, the teacher conducted direct observation throughout the classes, allowing us to capture qualitative aspects of student engagement. The groups demonstrated great enthusiasm throughout the different stages of the activity. From solving the mathematical problem to determine the ideal amount of pumpkin jam to add to the fixed portion of Portuguese Cream Cheese to maximize taster satisfaction in the new gourmet product, to the final stage of the competition to select the best recipe, the students demonstrated commitment and creativity. This challenge brought an authentic and cultural dimension to the experience, reinforcing the connection between theory and practice. The final phase, dedicated to the culinary competition, proved particularly motivating, as it allowed students to apply mathematical knowledge in a real-life context while simultaneously valuing regional identity. Overall, the observation confirms the questionnaire results: the activity fostered not only technical skills, such as the practical application of mathematics, but also social, cultural, and creative skills in a dynamic and collaborative environment.

From the analysis of the evaluations carried out throughout the three phases, we found that students achieved an average score of 62% on a scale from 0 to 100%. The highest score recorded was 94%, while the lowest was 15%, corresponding to students who only completed the first phase and correctly answered one of the two exercises in the quiz before dropping out. The standard deviation was 24%, which demonstrates a wide dispersion in performance levels.

Notably, 55 students scored above 50%, which shows that a significant portion of the participants were able to engage meaningfully with the activity and achieve solid results. This variation reflects the diversity of student engagement and progression throughout the activity, highlighting the importance of sustained participation and the motivational impact of contextualized learning experiences.

# 5. Discussions

## 5.1 *Triangulation of evidence*

The positive findings from quantitative data were strongly corroborated by the qualitative evidence, achieving data triangulation. The high level of student satisfaction reported in the questionnaire (with 63.4% giving the maximum score for organization) is directly supported by the direct observation notes, which recorded “great enthusiasm” and commitment throughout all phases of the activity. Furthermore, the questionnaire results highlighting the development of creativity and practical application of mathematics (cited by 68.3% and 75.6% of students, respectively) are tangibly demonstrated in the analysis of the final work products. The functions created by the students, such as the Stone Soup and Earth-Earth Flavor models (Figure 6), show sophisticated mathematical modeling skills combined with conceptual coherence and a creative interpretation of regional identity. This convergence of self-reported perceptions, observed behavior, and tangible work output strengthens the evidence base for the pedagogical value of the activity.

## 5.2 *Linking findings to theoretical framework*

The success of the "Gastronomic Calculus" activity can be explicitly linked back to the theoretical frameworks supporting its design. The high levels of motivation and perceived practical application confirm the value of Cultural Contextualization in making abstract mathematical concepts relevant (Perin, 2011). The positive feedback regarding preparation and autonomy reinforces the efficacy of the Flipped Learning model in promoting student readiness and self-regulated learning (Galindo-Domínguez & Bezanilla, 2025). Moreover, the integrated development of technical (calculus) and transversal (creativity, collaboration) skills confirms the potential of the STEAM approach to foster holistic learning that aligns with 21st-century demands, extending beyond traditional STEM outcomes (Zhang & Jia, 2024).

The activity's use of local gastronomy did more than merely provide an interesting backdrop; it appears to have genuinely triggered a different mode of cognitive engagement, supporting the deep educational value of the 'A' in STEAM. The student reflections demonstrated that the cultural context facilitated analogical thinking (e.g., comparing the maximum function to "perfect sensory balance" or "the moment when the pumpkin jam gently covers the Portuguese Cream Cheese") and value association (linking the mathematical result to regional identity and tradition). The function models presented in the final challenge, which deliberately included non-quantitative variables like "nostalgia" and "cultural value", serve as clear evidence that students used mathematical language as a tool for interpreting complex human and cultural dimensions. This suggests that incorporating such profound cultural elements actively shifts the cognitive process from abstract calculation to meaningful interpretation, exceeding a simple contextual frame.

## 5.3 *Comparative discussion with recent research*

The positive outcomes regarding student motivation and concept application resonate with recent empirical research in interdisciplinary education. Specifically, studies on Flipped Learning in higher engineering education (Samaila, 2025) report similar increases in student readiness and engagement during collaborative sessions. Our findings, particularly the successful application of calculus to optimization problems, offer further empirical support for the methodology's effectiveness in promoting active technical skills development, contrasting with the often-generalized results cited in broader reviews. Furthermore, research integrating arts and culture into STEM contexts regarding motivation enhancement (Maričić & Lavicza, 2024; Filipe et al., 2024) is mirrored by our data, where 68.3% of students cited creativity as a developed skill. We also extend the existing body of work on gastronomy as a learning context (Ibiloye, 2025; Anyichie et al., 2023) by providing explicit qualitative evidence of conceptual transfer difficulty being overcome through culturally relevant problem-solving. Finally, regarding practical implementation challenges, our findings prompt reflection on how such a carefully designed activity can be routinized. Future studies should consider the demands on teachers' time and interdisciplinary knowledge, a challenge noted in the literature (Grenier-Boley & Sabra, 2022), to ensure scalability and sustainability beyond a single intervention.

## 5.4 *Methodological limitations and future work*

It is essential to acknowledge the limitations of this study. The design relies on an exploratory single-cohort case study without a control or comparison group, which limits the robustness of causal claims regarding the absolute effectiveness of the flipped STEAM intervention compared to traditional methods. Furthermore, the heavy reliance on self-reported data (perceptions) and the partial data coverage (58.5% response rate in the final questionnaire) may introduce response bias and affect the representativeness of the results.

Beyond methodological robustness, the findings highlight implementation-level challenges that warrant future research. Scalability, the significant time demands on the instructor for creating such a high-fidelity, interdisciplinary, and culturally relevant task, and the need for interdisciplinary knowledge are critical factors to be addressed. Future work must aim to enhance empirical rigor by introducing objective measures (e.g., rubric-based performance assessments, pre-/post-tests for conceptual gains) and explore strategies for routinizing and scaling this activity, possibly through shared digital resources or professional development countermeasures.

## 6. Conclusion

The "Gastronomic Calculation: Portuguese Cream Cheese, Pumpkin and Flipper learning" activity confirms that it is possible to integrate mathematics, gastronomy, and local culture through active methodologies, such as flipped learning, creating more meaningful learning experiences. The practical and interdisciplinary context proved to be a key factor in increasing motivation, promoting autonomy, and developing cognitive and social skills in engineering students.

The proposal was strongly validated by the high level of student satisfaction (63.4% maximum score for organization) and the qualitative evidence of engagement, reinforcing the relevance of the combined STEAM and Flipped Learning approach. The core contributions were demonstrated through:

• Meaningful Application: The use of the satisfaction function effectively modeled a real-world problem (optimization of regional food proportions), directly linking theoretical calculus concepts to practical, culturally relevant applications.

• Skill Development: The activity fostered significant development in transversal skills, especially collaborative work, creativity, and the application of mathematics (cited by 87.8%, 68.3%, and 75.6% of students, respectively).

• Cultural and Motivational Impact: The integration of the regional tradition (Serra da Estrela) and the competitive final phase reinforced student engagement, turning an academic task into a playful and culturally valuable experience.

• Flipped Learning Efficacy: The prior preparation at home proved effective in ensuring content readiness and promoting autonomy, optimizing the in-person collaborative time.

These results are consistent with recent studies showing that cultural and interdisciplinary contextualization in STEM/STEAM education enhances students' retention, engagement, and conceptual understanding (Filipe et al., 2024; Maričić & Lavicza, 2024). Moreover, research continues to demonstrate that culturally relevant approaches increase the perceived value of learning (Vasconcelos & Santos, 2023), active methodologies foster motivation and participation (Prince, 2024), and STEAM-based activities stimulate creativity and critical thinking (Ellianawati et al., 2025; Pinar et al., 2025).

As future perspectives, it is noted that future studies must address the limitation of the exploratory design with more robust methods (e.g., pre-/post-tests, comparison groups), as previously mentioned, to strengthen causal claims. We suggest exploring new cultural and gastronomic themes, adjusting group sizes according to student preferences, and integrating digital tools to enhance interaction and assessment. Overall, the experience demonstrates that combining science, culture, and creativity is an effective strategy for making learning more engaging and meaningful.


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## Conflict of interest

The authors, Cristina M.R. Caridade and Verónica Pereira, hereby declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. No specific grants from funding agencies in the public, commercial, or not-for-profit sectors were received for this specific work, and there are no financial interests to disclose.

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