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STEAMING AHEAD

FOSTERING CRITICAL THINKING, PROBLEM-SOLVING AND CREATIVITY

STEAM ing ahead

EDITED BY
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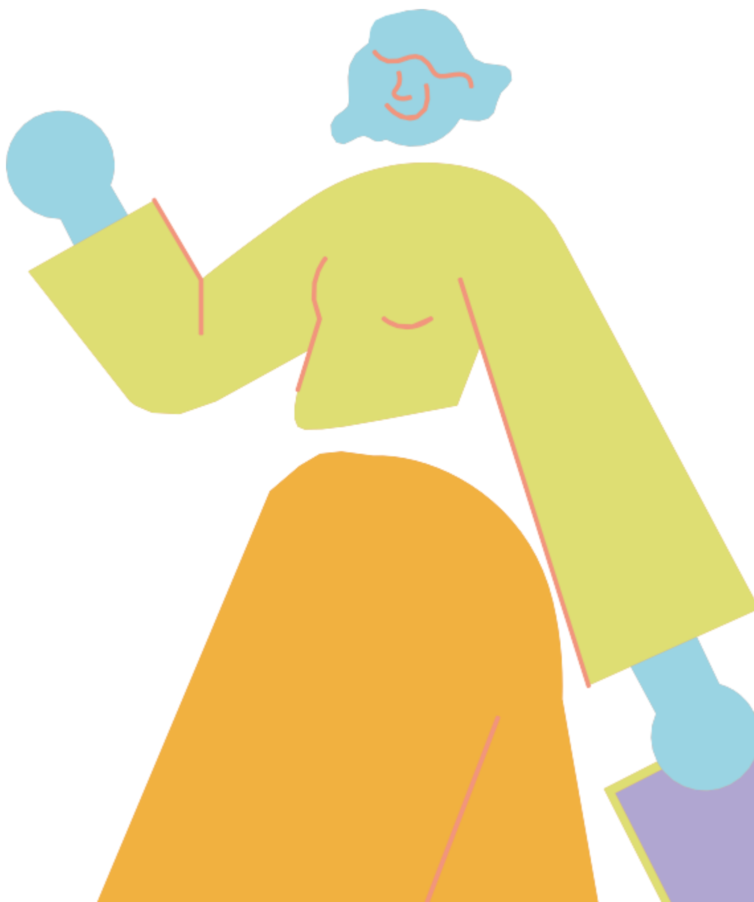

Foreword

It's Tuesday, January 30, 2035.

Maria sub vocalized, "what time is it?" and for her ears only, the answer came, "It's 13:30."

"How am I doing?" she asked, and her wellness dashboard popped up into her vision. She was well rested; her heart rate and blood pressure were strong. Her connections with family and friends were active and robust, and her social was high. Her cognitive index indicated there was very little prefrontal cortex activity.

Maria heard, "things are looking good. Your mental stimulation has been a little low, so you might want to activate your workstream. Shall I go ahead and show you the possibilities?".

She remembered when she was growing up and her parents went to a workplace for a set 40 hours a week in order to draw a paycheck. Now work could be done anywhere and anytime. Work now was measured less in hours and more by the value of what you accomplished. Everyone was required to work, but they had more freedom to choose what they worked on, how long, where, and when. Just like entertainment, you now streamed your work when you want to.

She decided now was as good as any to stream her work.

Maria subvocalized "Show me the data about how we are doing in healthcare." She waved through a few different indicators. No major issues, but a few of the trending numbers caught her eye. Her background as a video game esports competitor really helped here. One of her strengths was to be able to look over data and information which did not seem connected, and rapidly make connections, draw inferences, and simulate possible interventions to head off situations before they became problems. In this case there seemed to be an increase in the time it took to treat gastrointestinal complaints, and a few infectious disease waste treatment numbers seemed to trend up. This could be the beginning of some contagion.

She switched into intervention simulation mode. What if we tweaked some of the inputs in food production, could the nutritional benefits help reduce incidences of gastrointestinal issues that seemed to be rising? She simulated the results. No, that was not going to work.

She heard the AI ask her, "you may want to bring some others in. There are four people available now with backgrounds that could complement your strengths. Do you want me to join you all up?"

She subvocalized, "OK" and their avatars all united in a virtual meeting room.

"Marco, what do you think we should try?" she asked.

Shaheen interjected, "Who put you in charge? Shouldn't we be exploring what the issues are and define the problem first?"

Maria was glad that her education included a lot of practice and coaching in conflict resolution, team building, and collaboration. She knew how to turn this potentially destructive conflict into one that built a collaborative solution.

"Sure, Shaheen, thank you for raising that. Why don't you start off and lead that discussion and then we can figure out what we work on next and who leads that section?" And they were off and running.

As they discussed the medical results analyzed by the health database, correlated it to weather, nutrition, travel, and social conditions, monitored for any manufacturing or possible transport changes, the issues started to converge. She loved these meetings with others who also had been educated as problem solvers.

Work was very different now than it was even 10 years ago. Artificial intelligence and robotics could handle most manufacturing, office work, healthcare, and analysis, but there were key synthesis, critical thinking, and creative skills that were unique to humans.

She thought back to her schooling years. Luckily, she had been educated in an integrated learning environment, one based on learning through problem-solving that combined science, technology, engineering, arts, and math, what her teachers called STEAM. That's the way all education was conducted now, in the year 2035, but back 10-15 years ago, most schools still operated based on didactic pedagogy that was focused on vertical academic disciplines. Technology integration was spotty. Most schools seemed to concentrate more on test results than on critical thinking, flexibility, creativity, and collaboration. As if real life or the human brain actually worked that way.

That's why most of the people of her generation were struggling to adapt to the free form types of work that existed today; they could only work on well-defined problems based on explicit instructions or rules. AI and robots had taken over all of that work 5 or 6 years ago.

The AI whispered in her ear to nudge her back, "are you reminiscing or thinking?"

It seemed like in no time their ad-hoc group of five successfully isolated the causes of the potential outbreak, and the simulations of one potential solution were showing real promise. Engineering design was so much like game development!

It looked like the problem solving and design phases were over, and it was time to deploy and monitor. She loved these types of meetings and looked down to see the time: 17:30. What seemed like 15 minutes had actually been almost four hours. Maria took a look at her wellness dashboard again. Her cognitive index was soaring. And the intervention seemed to be working. Life was good.

Maria bid farewell to her teammates. Now it was time to connect to friends, family, and food.

She suddenly realized how hungry she was.

How do we prepare kids today for a world like this that might exist in 10-15 years? By STEAMing ahead.

How will technologies like robotics, artificial intelligence, and augmented reality affect tomorrow's workplace? What changes will sustainable or even regenerative cultures mean for human societies? What will the political spectrum look like?

No one knows. Yet we still have to prepare this next generation with the cognitive and social skills to thrive during change and uncertainty.

We need to pull together flexible classroom environments, conduct learning activities that develop creative, cognitive, and metacognitive skills, integrate academic disciplines around problem solving, prepare educators with pedagogical techniques that combine technologies such as games, AI, Robots, digital storytelling, and Augmented Reality, and integrate the arts and design thinking skills across education, from kindergarten through elementary schools, secondary, and university.

That's exactly what José Alberto Lencastre and Marco Bento, and their team of talented educators and researchers have assembled in this seminal book. We all know that the old ways aren't working. We already know that teachers are the secret superpower of education. 'STEAMing Ahead: Fostering critical thinking, problem-solving and creativity' uses the latest practical research and proven techniques to provide a blueprint for teachers and schools to prepare the Marias of the world with the foundation to be successful for the rest of their lives.

You're going to love this book!

Mitch Weisburgh

Mitch cofounded Academic Business Advisors in 2005, which helps organizations develop business strategies to align their products and services with the ways purchasing decisions are made and technology is used in schools and districts so that they can scale and make a difference to kids and educators.

Mitch blogs on the PILOTed blog about ways to inspire the mind to learn. He is COO of 3DBear Inc, the US Division of the Finnish AR/VR company 3DBear OY, where he works with educators around the world on strategies to use AR and VR to engage and motivate students of all ages.

Since 2018, Mitch has been creating content and teaching Mindshifting and Sensemaking. Persistence, self-initiative, critical thinking, creative thinking and innovation, collaboration, communication, and their opposites all begin in the mind. When we learn to recognize how the mind operates in each of these spheres, and then learn how to move minds into resourceful mindsets, we accomplish more and recover faster from conflicts, unanticipated obstacles, and detrimental emotional responses. Imagine if our kids could master these abilities as they grew into adults

If you are at all interested in what Mitch did before 2005, buy him a glass of wine and ask.

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Editors' Introduction

In the ever-evolving landscape of education and innovation, the intersection of Science, Technology, Engineering, Arts, and Mathematics (STEAM) has emerged as a powerful catalyst for shaping the minds of tomorrow with a unique blend of critical thinking, problem-solving, and creativity skills.

Critical thinking, the cornerstone of intellectual growth, finds fertile ground at the crossroads of STEAM disciplines. By encouraging students to explore the relationships between scientific principles and artistic expression, technological advancements and engineering marvels, and the mathematical foundations that underpin them all, STEAM fosters a cognitive flexibility that transcends traditional educational silos. Students become adept at navigating the fluid knowledge landscape, recognizing patterns, and making connections essential for problem-solving in a rapidly changing world.

At the core of STEAM lies the philosophy that knowledge is not a series of isolated subjects but a spectrum of interconnected ideas waiting to be explored. Science, the vanguard of inquiry, collides with the imaginative realms of the Arts, sparking a symphony of creativity. Technology and Engineering, the architects of innovation, join forces with Mathematics, the language of patterns and precision, creating a dynamic synergy that propels us into uncharted territories of discovery.

One of the critical strengths of STEAM lies in its capacity to nurture creativity. In a world where innovation is the heartbeat of progress, creativity is the lifeblood that sustains it. The Arts inject the spirit of imagination into scientific exploration and engineering endeavours, turning abstract concepts into tangible, innovative solutions. When harnessed within the framework of STEAM, creativity becomes a dynamic force, propelling individuals to think beyond the boundaries of convention and envision possibilities that might otherwise remain hidden.

Moreover, STEAM education cultivates a mindset of collaboration. In the future professional landscape, success is not merely the product of individual brilliance. However, the result of collective ingenuity. By integrating these diverse disciplines, STEAM encourages students to work collaboratively, leveraging the strengths of each field to tackle complex challenges. In doing so, students learn the importance of diverse perspectives and the enrichment of working alongside individuals with different expertise.

The intersection of STEAM is not merely an educational paradigm; it is a transformative force shaping the minds of tomorrow. Through STEAM, we empower individuals to think critically, solve problems creatively, and navigate the complexities of our interconnected world. The journey into the future is STEAMing ahead, and those who embrace its principles will undoubtedly find themselves at the forefront of innovation, driving progress and shaping a brighter and more dynamic tomorrow.

The real-world applications of STEAM are evident in the innovations that have shaped our modern society. From breakthroughs in medical technology to the design of sustainable infrastructure and from the creation of visually stunning digital art to the development of *sophisticated algorithms, the influence of STEAM is omnipresent. As we look toward the future, the demand for individuals versed in the holistic principles of STEAM is only set to grow, as the challenges we face demand creative solutions that draw upon a spectrum of knowledge.*

The "STEAMing Ahead" project, the reason for this book, encapsulates this spirit of progress and transformation as we embark on a journey to cultivate critical thinking and problem-solving skills and unleash the boundless realms of creativity within our students. This project seeks to transcend traditional school boundaries, embracing the holistic integration of disciplines to prepare individuals for the challenges and opportunities of the 21st century. Through the lens of STEAM, we delve into a realm where scientific inquiry converges with artistic expression, technological prowess intertwines with engineering ingenuity, and mathematical reasoning harmonizes with creative problem-solving.

As we navigate this dynamic landscape, "STEAMing Ahead" becomes more than just a title—it embodies a mindset and a commitment to fostering a generation of thinkers, innovators, and creators who will adapt to change and drive it. Join us on this exciting journey as we explore the multifaceted world of STEAM, where curiosity knows no bounds, and the pursuit of knowledge is marked by collaboration, and the relentless pursuit of excellence.

This book is divided into different chapters for educationalists to embark on a transformative expedition, "STEAMing Ahead" into a future where the fusion of critical thinking, problem-solving, and creativity opens doors to a realm of boundless possibilities. As we navigate this evolving landscape, the harmonious integration of diverse areas propels us towards a horizon where intellect meets imagination, and challenges are met with inventive solutions. Embrace the synergy of STEAMing Ahead and become teachers of a world where the possibilities are as limitless as the student's capacity to dream and create.

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Institute of Education of the University of Minho, Portugal

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Chapters' Abstracts

Chapter 1

The Relationship Between Art and Design Thinking Skills in STEAM Education: A Systematic Review

Bilge Has Erdoğan

The importance of 21st century skills, which include processes such as making sense of rapidly spreading information and creating creative ideas and products, is increasing. In this context, one of the important pedagogical approaches for students to develop these skills and become productive individuals is STEAM education. This research was conducted to identify certain common points from STEAM education research, which varies with different definitions and applications, and to contribute to the literature. The research has shown that the reasons for A (art) integration into STEAM education are diverse. In addition, an attempt was made to reach a general conclusion by examining the contexts of use of design thinking skills.

Chapter 2

Active Learning Classrooms: The Alignment Between Teaching and Space from The Perspective of Institutional Management

Éder Lima & José Alberto Lencastre

This article explored the relationship between teaching, the physical learning environment and the institutional organization in the André Cruz de Carvalho Active Learning Room at the University of Minho. The study followed a qualitative and interpretative approach. It included an interview with a member of the institutional management of the University of Minho who was involved in designing the Active Learning Room. The results highlighted the importance of alignment between teaching and the teaching space to create an engaging learning experience in the Active Learning Room. Furthermore, research has highlighted the importance of considering the perspectives of different stakeholders when planning innovative educational environments. The Active Learning Room at the University of Minho is an inspiring example of how this integration can create an environment conducive to high-quality education, highlighting the importance of collaboration, flexibility, and interoperability.

Chapter 3

Active Learning Classrooms: What pedagogical practices should teachers adopt for their activities?

Joana Soares & José Alberto Lencastre

In the 21st century, many Higher Education institutions have built Active Learning Classrooms, which aim to amplify educational impact by combining flexible space layouts, technology, and innovative pedagogies to encourage active student participation in the learning process. The University of Minho took up this challenge by creating the André Cruz de Carvalho Classroom. This study aimed to understand how teaching in this Active Learning Room influences teachers' pedagogical practices. The data collected allows us to conclude that the pedagogical practices developed in the classroom are characterized by a greater emphasis on group activities, which also allows a new role for the teacher: the teacher is the element that creates opportunities for individual and collaborative learning. With a teaching process centred on student learning, the teacher assumes the role of a mentor who helps students explore topics in greater depth. The André Cruz de Carvalho Classroom also appears to improve interaction and communication between teachers and students, even between students.

Chapter 4

Active Learning Classrooms: The use of digital technologies in the development of new pedagogical practices

Vera Lourenço & Maria Altina Ramos

Universities worldwide invest in new learning spaces promoting active methodologies and student-centred teaching. With this purpose, the University of Minho created the André Cruz de Carvalho Active Learning Classroom. This research had as its research question: To what extent is technology used in the André Cruz de Carvalho Room? The methodological option followed was qualitative, with a case study design, having as participants the teachers who most often requested the Active Learning Room during the academic year 2021/2022 and students who also used the space. The results allow us to conclude that teachers value the active learning room because of its space with flexible furniture and innovative and up-to-date technology. The results also help to conclude that the interviewed teachers use technologies in active pedagogical practices, but not precisely the unique Solstice Active Learning technology in the room. These data are relevant to highlight the importance of raising teachers' awareness to undergo training on the pedagogical use of this software, which is unique in Portugal.

Chapter 5

THE STEAMing Ahead L.I.V.E.: Lively-Inclusive-Vertical-Exciting

Susi Leo & Ornella Autetta

The STEAM disciplines, for their variety, make learning Lively, able to develop creative, cognitive, and metacognitive skills and, at the same time, social, relational, emotional, in a dimension of collaboration, Inclusion and connection with the world and with people. They are an opportunity for collective growth and the development of transversal skills in the Vertical curriculum starting from kindergarten school. The Exciting aspect of STEAM disciplines has been working with smart technologies. In particular, what fascinated our students was the study of Golden ratio and the awareness of its double nature, that is, the quantitative aspect and the aesthetic one. In fact, it has the ability to make beautiful and harmonious objects and in particular everything what affects our senses, making many elements of nature live.

Chapter 6

Transforming Mathematics Education: The Power of Digital Tools in Active Learning

Celestino Magalhães

This paper delves into how digital tools can be harnessed to facilitate active learning in mathematics education, promoting higher-order thinking skills such as analysis, synthesis, and evaluation. The paper begins by providing an overview of active learning, highlighting its benefits. It then transitions into a discussion on the role of digital technology in education, with a specific focus on mathematics. The paper's core presents a series of examples where digital tools have been successfully implemented to foster active learning in mathematics. These examples span different educational levels, from elementary education and different mathematical topics, from basic arithmetic to complex calculus. The paper concludes with a discussion of the challenges in implementing digital tools for active learning in mathematics. It emphasizes the importance of teacher training, infrastructure development, and curriculum redesign to integrate digital technology into mathematics education effectively effectively.

Chapter 7

The effect of in-service training in mobile technologies on teachers' teaching practice

Sara Cruz, Marco Bento & José Alberto Lencastre

This article describes an in-service training course for teachers from different education levels conducted in four schools and involving sixty-nine teachers. The training course aimed to promote innovative pedagogical methodologies such as gamification and augmented reality combined with flipped learning. Thus, we tried to answer the following research question: How can teachers use gamification combined with flipped learning? This paper described the training course and analysed teachers' perceptions regarding mobile learning in educational settings. A pilot study, as well as a subsequent literature review, was conducted. The research method was a quantitative and qualitative exploratory study based on triangulation of field observations, qualitative and quantitative data obtained in a pre-test and a post-test, and documentary material. The data collection done by teachers during the training helped them understand how they dealt with technology and their perception of the mobile learning process. Findings show that mobile learning motivated most teachers positively. Teachers could use the technologies presented; they understood that gamification and flipped learning could be used together for learning purposes, admit advantages, and create teaching material to use with their students.

Chapter 8

Learn to teach in early childhood education with scientific video tutorials

Isabel Dans Álvarez de Sotomayor

Digital creativity in science, technology, engineering, art and mathematics (STEAM) finds its beginning in the Early Childhood Education stage. In an audiovisual culture, the use of educational video to narrate science stands out. The proposal presented deals with the digital competence of future early childhood education teachers, a public that is a regular consumer of videos, but with little practice in the creation of audiovisuals for educational purposes. The general objective is to explore the use of educational technology in future Early Childhood Education teachers through the creation of scientific video tutorials aimed at children. Part of the shortcomings of STEAM should be solved with a greater investment in proposals from university studies that train future teachers. In this didactic experience, they are proposed to create storytelling with scientific content, providing them with tools for design and editing, as well as didactic guidelines to ensure effective learning after viewing.

Chapter 9

Innovating Pedagogical Practices in Elementary Schools through Educational Robotics: REFEPESEC – an internship teacher training project

José Miguel Sacramento, Marco Bento & Fernando Martins

The increasing influence of digital technologies in schools, as well as how Digital Natives see them, emphasise the significance of educating children about technology careers while simultaneously emphasising the development of cross-cutting abilities for full citizenship, providing them with opportunities to develop the 21st-century skills needed to thrive in the modern workplace (eMedia. (2019, NYAS, http://www.nyas.org).Using Educational Robotics in collaborative learning environments, in an interdisciplinary approach, can promote abilities including computational thinking, ICT skills, critical thinking, and social skills like, communication, and collaboration, between others. It also allows the integration of students' knowledge with STEAM subjects (eMedia, 2019, NYAS, www.nyas.org). The integration of Educational Robotics into the teaching and learning process can create a conducive environment for meaningful learning, using the creative, critical, and collaborative abilities of students (Perignat & Katz-Buonincontro, 2019). Additionally, it promotes interdisciplinarity, establishing connections between various STEAM disciplines and students' prior knowledge (Athanasiou et al., 2019; Kuhl et al., 2019)

Chapter 10

The Exploration of the SuperDoc Robot Through an Exploratory Teaching Model

Carina Silva, Catarina Mendonça, Joana Cadima, Rita Neves Rodrigues, José Miguel Sacramento, Elisabete Pires, Yelitza Freitas, Cecília Costa & Fernando Martins

The present work aims primarily to develop: mathematical learnings within the subtopic of Spatial Orientation in the Geometry and Measurement theme; the theme of Data and Probabilities, and the dimensions of Computational Thinking. To this end, a set of tasks was energized that encompasses not only the curricular area of Mathematics but also Portuguese and Environmental Studies. This set of tasks was designed for the 2nd-grade class that the trainee teachers followed within the context of Supervised Practice in Primary Education. To respond to the students' interests, they decided to also introduce Educational Robotics (RE), as this pedagogical tool promotes significant learning (Pedro et al., 2017). The tasks are divided into three sessions, each organized according to the four phases of the Exploratory Teaching model (Stein et al., 2008, cited by Canavarro et al., 2013). As it would be the first time the class would engage with this teaching model and considering that the head teacher does not set a specific time for task completion, they decided it would be important to maintain this dynamic.

STEAM
ing ahead

Fostering critical thinking, problem-solving and creativity

1

ART AND DESIGN THINKING IN STEAM EDUCATION

I. The Relationship Between Art and Design Thinking Skills in STEAM Education

A Systematic Review

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Introduction

Changing world conditions and changing expectations from modern people have naturally caused education systems to change their approach to students. Of course, this change has been happening for centuries. However, today's rapidly accumulating information and even faster developing technology have caused this change to be experienced at a visible and perceptible level. In this regard, in education systems where student development is handled holistically, integrated teaching approaches, especially the STEM approach, which is formed by the integration of Science (S), Technology (T), Engineering (E) and Mathematics (M) disciplines, have come to the fore. STEM education continues to develop by being significantly affected by this rapid change. While the focus on success was more evident in these disciplines, which were initially mentioned one by one, later the boundaries of these disciplines, which gave their name to the approach, became more blurred and a focus on course design began with a holistic approach to achieve a common goal. But this change was not deemed sufficient. It has begun to be felt that solving problems or creating products with the help of the disciplines in the STEM approach requires a critical perspective and innovation beyond existing knowledge (Maeda, 2013). Especially after criticism that students' creativity skills were not sufficiently addressed, art (A) was included in the STEM approach and its name began to be called STEAM.

It can be said that art integration in the STEAM approach creates a bilateral benefit situation. While STEM disciplines lack creativity, different thinking, and abstract reasoning skills, art producers have failed to benefit from rapidly developing technology and the opportunities it provides (McAuliffe, 2016). For this reason, it is likely that the STEAM approach will begin to become an important pedagogical phenomenon in terms of art education. On the other hand, art, like design, appears to be an important tool for idea generation, conceptualization, study and exchange of ideas (Keane & Keane, 2016). Thanks to art, every work done and every product created not only increases its value but can also gain an aesthetic appearance. Art can also help visualize ideas or dreams, turn them into sound or text, and sometimes create moving performances that combine all of them (Mercin, 2019). However, considering art as equal to design in the STEAM approach has been criticized as a reductionist approach to the function of art. Graham (2020) emphasizes that the art integration in the STEAM approach should not ignore the design dimension of art, as well as the free spirit that questions, objects and resists impositions.

From a holistic perspective, it becomes a phenomenon that appears to serve a greater purpose than the sum of the disciplines in STEAM education. In this direction, the necessity of creative individuals who can integrate all these disciplines and use the relevant information has come to the fore. Since creativity is seen to be related to the fluency, flexibility and originality of scientific knowledge, it is considered very important for future scientists to have this skill, both in terms of the comprehensiveness of the knowledge they are likely to produce and the quality of the products they will produce (Madden at al., 2013). In fact, it can be said that the most important element that makes products different and unique from others in the rapidly increasing production world is the artistic perspective they reflect (Mercin, 2019). In this context, the STEAM approach focuses on the education of future individuals who can address real-life problems with creative solutions and handle this process with an interdisciplinary approach.

One of the most effective ways to transform students into individuals who can produce creative and functional solutions to existing problems is to implement the STEAM approach in a design-oriented manner. Henriksen (2017) suggests that, design thinking can offer guidance and structure that will bring together analytical and intuitive, artistic and scientific elements in equal measure.

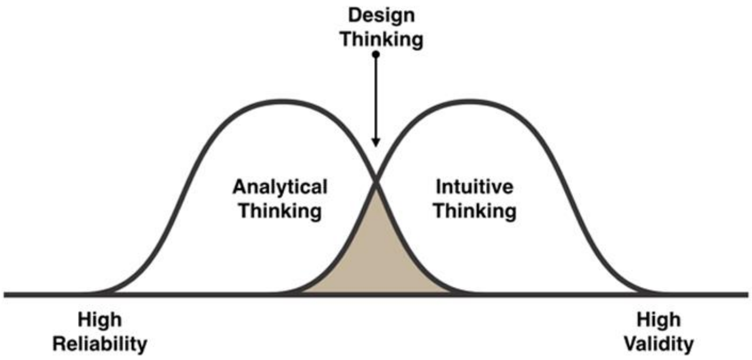

Figure 1. Design thinking (Henriksen, 2017)

Design thinking is often used to refer to an approach that goes beyond design and encompasses many tools and frameworks of ideas based on real people and their needs (Gobble, 2014). Design thinking can be very effective in developing students' critical, reflective and creative thinking skills. In addition, in this process, students employ many skills such as drawing, brainstorming, prototyping, aesthetics, and mental focus, which are effectively used in the process of creating new products and ideas (Ananda, Rahmawati & Khairi, 2013). In an effort to explain the design thinking process used for problem solving, the "double diamond model" was first defined by the British Design Council (2005). The model was revised by Norman (2013) and was finally given its final form by Lin, Hong and Chai (2020) and expressed as shown in Figure 2.

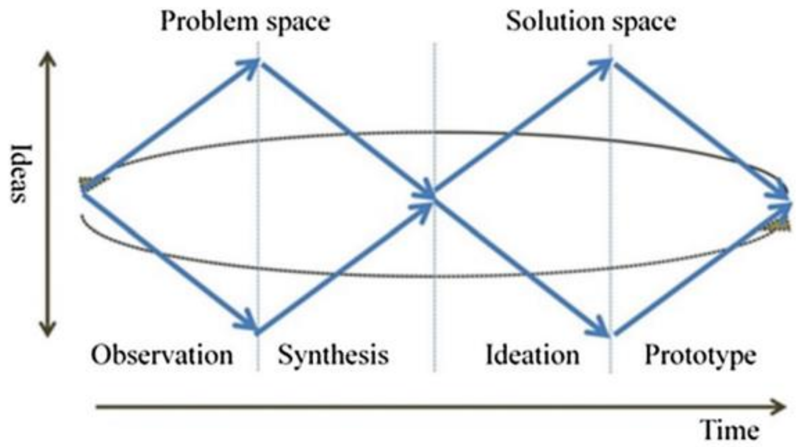

Figure 2. The design thinking process (Lin, Hong & Chai, 2020)

According to the double diamond model, there are two working areas: problem and solution. While working on the problem area, after determining the ideas related to the discovery and definition of the problem, the first syntheses of the ideas related to the problem are put forward. In the solution field, solutions are developed based on various ideas suitable for the problem and prototypes for these solutions are expected to be developed. Many models have taken their place in the literature in terms of explaining the design thinking process and guiding teachers as practitioners. When we look at the examples of these models that explain the process in three to ten steps, it can be seen that idea generation and prototyping are included in each model (Waidelich, Richter, Kölmel & Bulander, 2018).

In order to obtain information about the content and results of studies on STEAM education and to summarize the literature, answers were sought to the following questions:

Which age groups have curriculum development and implementations been carried out in STEAM education research in the literature?
What are the purposes of integrating A (Art) in STEAM education studies in the literature?
In what context is design thinking used in STEAM research in the literature?
What are the skills and competencies examined in the STEAM research in the literature whether the STEAM approach has an impact or not?

Method

A systematic literature review was used in this research. Systematic literature review is research conducted to avoid researcher judgment and to help see the common points emphasized by studies in a field and the ideas they differ from (Petticrew & Roberts, 2008). In order to avoid researcher bias in this research, this research method was chosen because it is a type of research with certain limits and can be repeated, and because there are many studies with different perspectives and results regarding the STEAM approach.

PRISMA flow was used to systematically and reproducibly determine the studies to be examined in the research. In the PRISMA flow, the databases in which the studies to be examined will be searched with which keywords, the inclusion and exclusion status of the studies are clearly and understandably stated, and the application steps are shared in detail (Moher, at al., 2009). In this regard, databases namely Web of Science (WOS), Scopus index, Education Resource Information Center (ERIC) and EBSCO Databases were searched with the keywords shown in Figure 3.

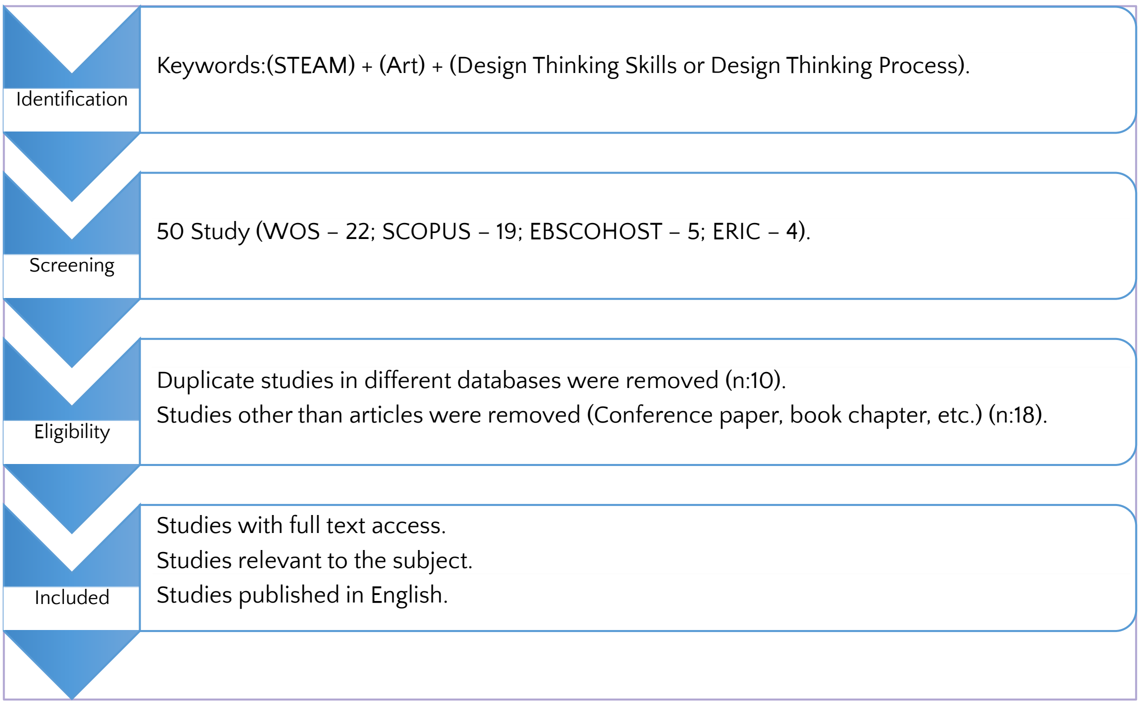

Figure 3. PRISMA process steps

Among the studies accessed from databases, non-article studies (Conference paper, book chapter, etc.) and duplicate studies in different databases were excluded from the research without examination. Among the remaining studies, those whose full text was accessible, published in English, and related to the subject were included in the study. At the end of this entire process, 19 articles were analysed according to the determined criteria.

Findings

In 12 of the 19 articles examined through systematic screening, the effects of the STEAM approach on various skill developments were examined while applying it in different age groups. In addition, it was seen that model development studies were carried out in 4 studies and curriculum development studies were carried out in 3 studies. Detailed information about the studies examined in order to find answers to the research sub-problems is shared in Table 1.

Table 1. Results of Systematic Review on STEAM Approach (N=19 Articles)

Focus	Result	n	Articles
Target groups of the STEAM application	Primary school	2	Gross & Gross, 2016; Lu, Lo & Syu, 2022
	Secondary school	4	Ladachart, Radchanet, Phothong & Ladachart, 2023; Thuneberg, Salmi & Bogner, 2018; Ramey, Stevens & Uttal, 2020; Apriandi, Krisdiana, Suprapto & Megantara, 2023
	High school	1	Ananda, Rahmawati & Khairi, 2023
	Undergraduate	6	Wiarta, 2023; Wannapiroon & Pimdee, 2022; Mardiah, Rahmawati, Harun & Hadiana, 2022; Qian, Ye & Zheng, 2023; Sidekerskiene & Damaševicius, 2023; Imaduddin, Ihsan, Shofyan, Shofa, Riza, Fitriani & Dewi, 2022
The reason for integrating "Art" into the STEAM approach	Integrate Science, Technology, Engineering and Mathematics courses with other disciplines to improve student achievement	3	Aguayo, Videla, Lopez-Cortes, Roshel & Ibacache, 2023; Sidekerskiene & Damaševicius, 2023; Apriandi, Krisdiana, Suprapto & Megantara, 2023; Imaduddin, Ihsan, Shofyan, Shofa, Riza, Fitriani & Dewi, 2022
	To contribute to the development of design and innovation skills	6	Wiarta, 2023; Juškevičienė, Dagienė & Dolgopolovas, 2020; Ramey, Stevens & Uttal, 2020; McAuliffe, 2016; Reddy, McDonagh, Harris & Rogers, 2022; Gross & Gross, 2016
	To improve students' soft skills (communication, observation, listening, collaboration, insight)	1	Wannapiroon & Pimdee, 2022
	In order to transfer creativity, emotion and	2	Mardiah, Rahmawati, Harun & Hadiana, 2022; Wilson, 2018

	ethical values to designs		
	To provide an aesthetic perspective to the design	2	Ladachart, Radchanet, Phothong & Ladachart, 2023; Lu, Lo & Syu, 2022;
	To gain creativity and artistic perspective	4	Qian, Ye & Zheng, 2023; Thuneberg, Salmi & Bogner, 2018; Ananda, Rahmawati & Khairi, 2023; Knochel & Meeken, 2021
The context of design thinking in studies	As a pedagogical technique (Design Thinking Process) during the implementation and development phase of courses suitable for the STEAM approach	10	Wiarta, 2023; Mardiah, Rahmawati, Harun & Hadiana, 2022; Ladachart, Radchanet, Phothong & Ladachart, 2023; Juškevičienė, Dagienė & Dolgopolovas, 2020; McAuliffe, 2016; Ananda, Rahmawati & Khairi, 2023; Imaduddin, Ihsan, Shofyan, Shofa, Riza, Fitriani & Dewi, 2022; Reddy, McDonagh, Harris & Rogers, 2022; Knochel & Meeken, 2021; Gross & Gross, 2016
	The process of creating design products in STEAM applications (industrial, artistic, etc.)	3	Wilson, 2018; Qian, Ye & Zheng, 2023; Ramey, Stevens & Uttal, 2020
	Student skill outcomes of courses taught with the STEAM approach (Design Thinking Skills)	1	McAuliffe, 2016
The effects of STEAM applications on students' skills and achievements	Creativity skills	6	Wiarta, 2023; Wannapiroon & Pimdee, 2022; Ladachart, Radchanet, Phothong & Ladachart, 2023; Lu, Lo & Syu, 2022; Thuneberg, Salmi & Bogner, 2018; Apriandi, Krisdiana, Suprapto & Megantara, 2023

	Problem solving skills	2	Mardiah, Rahmawati, Harun & Hadiana, 2022; Ramey, Stevens & Uttal, 2020
	Critical thinking skills	2	Wiarta, 2023; Ananda, Rahmawati & Khairi, 2023
	Analytical thinking skills	1	Wiarta, 2023
	Transfer skills	1	Mardiah, Rahmawati, Harun & Hadiana, 2022
	Innovation skills	1	Wannapiroon & Pimdee, 2022;
	Research skills	1	Imaduddin, Ihsan, Shofyan, Shofa, Riza, Fitriani & Dewi, 2022

STEAM target groups

It was observed that the examined studies were conducted with a high proportion of students attending undergraduate and associate degree programs. This intensity was followed by studies conducted with secondary school, primary school and high school students. Since the target groups are quite diverse, it can be interpreted that the STEAM approach can be suitable for the education of students of almost all levels, with a curriculum suitable for the level to be prepared. While there are studies in the literature that support this conclusion and reflect the perspective that all ages can be suitable in STEAM education (Mataric, Koenig & Feil-Seifer, 2007), it can be seen that many studies focus on the benefits of starting at an early age (Wahyuningsih, 2020; DeJarnette, 2018; Aktürk & Demircan, 2017).

Reasons for integrating A (Art) in the STEAM approach

It has been observed that the studies examined during the evolution from the STEM approach to STEAM reflect quite different perspectives. It has been determined that the integration of art into this approach is based on different causal foundations in the analysed studies. Most prominently, the prediction that art integration could contribute to students' design and innovation skills came to the fore. It has been observed that studies focusing on gaining and developing creativity and artistic perspective, which may seem similar but may have very different reflections in practice, rank second in research. It has been found that the main reason for the integration of art into the STEAM approach, as a necessity to increase student success, is that there is a significant proportion of research with a more general approach. With all these requirements explained, it has been observed in relatively few studies that the necessity of art integration is based on providing students with an aesthetic perspective and creativity in designs and developing students' soft skills. From here, the main reasons for art integration are; In some studies, it is stated that focusing on students' ability to reflect their creativity and aesthetic perspectives on designs. However, it interpreted that in some studies, rather than reflecting these skills on designs, they generally attribute them to the development of students' creativity, aesthetic perspective and soft skills.

The context of design thinking in studies

Just as it is used in many studies, design thinking is also widely used in studies on the STEAM approach with different contexts and definitions. In the studies examined in this research, it was determined that design thinking was used in three different contexts. Accordingly, in the research, design thinking has been processed at the highest rate as the design thinking process as a pedagogical approach in the implementation and development of courses. Design thinking, as a pedagogical approach, can be explained as being active in learning processes by using thinking steps in a cyclical or linear manner (Juškevičienė, Dagienė & Dolgopolovas, 2020; McAuliffe, 2016). In the second group of studies, the design thinking process is contextualized as the steps to be followed in the process of creating an industrial or artistic product. In the third group of studies, research on how the STEAM approach will improve students' design thinking skill levels was contextualized. Although it is seen from the research reviewed here that design thinking skills are used in different contexts, it has been determined that design thinking steps intersect at the point that they are steps that students should use, whether it is a pedagogical approach, product development process or learning outcome.

The effects of STEAM applications on students' skills and achievements

The processes in which the STEAM approach is examined through experimental research can be seen as very important in terms of containing clues about its effects on student outcomes. With the studies examined in this research, it has been seen that the application of the STEAM approach provides data and results regarding students' creativity, problem solving, critical thinking, analytical thinking, transfer, innovation and research skills.

Conclusion

In this research, STEAM education research was examined with a systematic review. The analysis showed that the grade levels of the target groups in STEAM education practices were diverse, covering all levels of education. Considering that 21st century skills include important skills based on higher order thinking, the reason for this diversification may be obvious. It can be interpreted that it is important to start STEAM education at an early age, especially considering that the development of higher-order thinking skills develops in an important process.

One of the important results of this research was that it was determined that the justification for art integration was handled quite differently. It may be important to summarize this situation, which may have a significant impact on instructional design processes, in understandable results for prospective teachers by scanning it with more general keywords.

In addition, although the thinking steps of research and design thinking are similar, their use in different contexts may cause confusion for both the literature and teachers. For this reason, increasing the number of academic literatures in which the context of analytical thinking is explained more clearly and understandably may be beneficial for practitioners, instructional designers, and indirectly, for other educational stakeholders.

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STEAMing ahead

Fostering critical thinking, problem-solving and creativity

2 ACTIVE LEARNING CLASSROOMS I

II. Active Learning Classrooms I

The Alignment Between Teaching and Space from The Perspective of Institutional Management

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Introduction

Active learning classrooms are being implemented worldwide with the aim of improving 21st-century learning skills such as creativity and collaboration. However, for these classrooms to function as intended and become spaces for enhancing pedagogical practices, three elements must be aligned: teaching (the teacher), space (the designer), and organization (institutional management).

This was exemplified in a case study at a Danish school, where a design process model was used in an attempt to involve all participants in the process of designing a new active learning classroom and, through this, create alignment between teaching, space, and organization to ensure a common goal: innovative learning. The Full Engagement in the Danish Doctrine demonstrates this principle, exemplified by the Ideation Course in which all participants are involved in developing a new and active learning lesson. This approach aims to demonstrate the connection between education, space, and management while pursuing the goal of low-cost innovative learning. However, experience has shown that changing the space does not automatically alter pedagogical practices.

Teachers rarely participate in the design process and, as a consequence, do not know the intentions of the space nor how to use it. Based on this, ideally, all stakeholders should be involved in the design process from the start-up phase to align teaching, space, and the organization of the institution. Thus, taking advantage of the fact that the University of Minho (UMinho) has inaugurated an active learning classroom called Sala André Cruz de Carvalho (SACC), this study aims to understand how user involvement was managed to improve the understanding of their needs.

Research Question

The organization's management plays an important role in approving and appointing members for active training. They provide resources, training, and support for teachers and foster an institutional culture that values and encourages active learning. In this way, active learning provides a dynamic and engaging approach in which students are encouraged to actively report, influence peers, and manage real-world news.

This approach promotes the development of life skills while preparing students to face the challenges of the current universe. The objective of this challenge is to answer the following question: How was the alignment between teaching (the teacher), space (the designer), and organization (institutional management) made in the case of the André Cruz de Carvalho Active Learning Classroom (SACC)?

Study Objective

Based on this research question, the following objective was defined: To analyze the ideas of Uminho's management in the design of the André Cruz de Carvalho classroom (SACC).

Literature Review

Data Mapping The selection of studies followed a rigorous and systematic approach, ensuring the inclusion of only relevant scientific articles, which will contribute to the validity and reliability of the results in subsequent analyses. From 169 articles initially identified, it was necessary to develop clear and well-founded criteria to include and exclude articles, ensuring the internal validity and relevance of the results in line with the different global research themes of the articles.

After this phase, 10 articles remained for information extraction by synthesizing and interpreting qualitative data, as per Arksey and O'Malley (2005) (See Table 1 below). The emphasis was on extracting information to be collected for each article: title, year of publication, author, publication, database(s) in which it was found, and whether it contained explicit objectives and methods.

Analysis, Summary, and Presentation of Data

Effective teaching means not only providing subject knowledge and associated skills but also offering multiple sources and appropriate spaces for the student. In turn, educators, trainers, or teachers understand the importance of students' active participation in their education, and students tend to build new knowledge upon prior knowledge when they engage in activities that allow it. However, this is a complex activity that uses various tools and techniques (Jha, 2016).

On the other hand, the assumption that classroom design reflects a teacher's educational philosophy and influences student participation and engagement has existed for about 40 years. Thus, student control over their seating arrangement is important, as it affects participation and engagement, which, in turn, influences the student's own learning experience. Giving students a choice in how they learn increases their motivation, provides a safe and comfortable environment, and encourages creativity and innovation (Krajewski & Khoury, 2021). According to Park and Choi (2014), classrooms are one of the key elements that support student learning, so academic architecture has its own status and importance. Therefore, learning can be greatly influenced by how classrooms are designed and constructed.

Table 2. Articles for Information Abstraction

	Article	Year	Author(s)	Publication	Database
String 1: "teach" or "active learning classroom" – "space" or "active learning spaces" – "university", "organization", "college" or "higher education"					
1	Transformation of classroom spaces: traditional versus active-learning classroom in colleges	2014	Park, E.L., Choi, B.K.	Higher Education	ERIC
2	Classroom Re-Design to Facilitate Student Learning: A Case Study of Changes to a University Classroom	2016	Perks, Tom; Orr, Doug; Alomari, Elham	Journal of the Scholarship of Teaching and Learning, v16 n1 pp. 53-68, Feb 2016. 16 pp.	ERIC
3	Innovation in Higher Education: The Influence of Classroom Design and Instructional Technology	2016	Siegel, Christine; Claydon, Jennifer	Journal on School Educational Technology	ERIC
4	Institutional resources centres and design education	2016	Jha, B.	Library Review	SCOPUS
5	'Space and Consequences': The Influence of the Roundtable Classroom Design on Student Dialogue	2016	Parsons, Caroline S.	Journal of Learning Spaces, v5 n2 pp. 15-25, 2016. 11 pp.	ERIC
6	Active Learning Success by Partnering Across the Institution	2018	Byron, D. Reed	SIGUCCS '18: Proceedings of the 2018 ACM SIGUCCS Annual Conference	RESEARCH GATE
7	Learning the Ropes: The Influence of the Roundtable Classroom Design on Socialization	2018	Parsons, Caroline S.	Journal of Learning Spaces	ERIC
8	A space for learning: An analysis of research on active learning spaces	2019	Talbert,Robert., Avib-Mor, Anat.	Heliyon	SCIENCE DIRECT
9	An Active Learning Classroom in Construction Management Education: Student Perceptions of Engagement and Learning	2021	Farrow, C.B., Wetzel, E.	International Journal of Construction Education and Research	RESEARCH GATE
10	Daring spaces: Creating multi-sensory learning environments	2021	Krajewski, S., Khoury, M.	Learning and Teaching	ERIC

As Farrow and Wetzel (2021) state, learning spaces with active student participation are becoming increasingly common, designed to elevate conspiracy among students as they engage in problem deliberation, communion, and teamwork. In general, a classroom should elevate the direction of active learning action, which can purify the species of the experiment through a certain tracking layout and rich reciprocity, positively purifying the space.

Traditionally, the focus of teaching and learning has been to provide content information and teach it, so the educational approach places teachers in the role of content sharing specialists and students as passive recipients. Therefore, since the past, classrooms have been designed to encourage this approach, with teachers positioned at the front of the room and students seated row by row, facing the teacher. However, in today's recommendation- and technology-oriented relationship, participation is existing and easily accessible, so it's trapped that today's high school and higher education students know not only information but are also able to spend this information to speak in various ways and solve problems in various areas. Good manners should, therefore, provide more than just religious content, and education should include more innovative learning methods (Siegel and Claydon, 2016). In recent years, there has been a pedagogical shift from traditional content-based models to more active learning models, where students participate more in interactive interpretations in the classroom. Seeing this, traditional unidirectional teaching alone is not sufficient to meet the new and more diverse teaching and learning practices, and teaching and learning objectives must constantly evolve and complement each other.

According to Park and Choi (2014), the educational environment influences students' learning attitudes, and the classroom conveys the educational philosophy. In this sense, the traditional design of classrooms is often based on teaching spaces that first appeared in medieval universities. Thus, educational spaces convey an image of educational philosophy about teaching and learning, so a standard classroom with fixed chairs all facing the board can represent an existentialist educational philosophy, which focuses more on just transmitting knowledge to students than on making teaching a form of skill and experience creation. In turn, education remains at the interface of cognitive thought and creativity, so in an academic context, the structure and definition of education are widely accepted. Thus, it presents itself as a complex, conscious and unconscious, planned and spontaneous creative experience, so the teaching and learning process usually requires exploring different forms of communication (Jha, 2016).

According to Siegel and Claydon (2016), innovative classroom design and the latest teaching technology are influencing college professors' experiences and perspectives on classroom teaching. Thus, for example, with simple devices and wireless resources, teachers routinely incorporate different types of technology into their classrooms. Thus, the integration of technology may not be enough to band students in the lesson class, imperfection is important to agree on the current technological advancements with innovative layout and flexible lowering solutions, which can anoint the case of the lesson class. Moreover, these pedagogical changes, caused by improvements in layout and classroom technology, bring motor and satisfaction in teaching and new learning perspectives of students by piece of teachers. According to the approach of advantages and it turns out that soon changes made internally in the lesson class, there is a significant improvement in student satisfaction reported with the physical sphere, including perceptions of the lesson class as a more effective and engaging learning space.

On the other hand, teachers themselves also report similar improvement perceptions. In this sense, classroom design can prove essential, being considered in a way to support and even improve teaching and learning. Thus, exploring the fit between learning theory and physical space should influence the design of learning environments, and it is essential to create a public for communication activities and use concrete examples (Krajewski & Khoury, 2021).

The study by Parsons (2016) aimed to investigate how the design of physical and virtual learning spaces influences student interaction in contemporary universities. However, although the consultation produced results that support the awareness of how physical and virtual anchoring spaces have a positive impact on student engagement, the results do not support the purpose and reason for deliberately designed and communicated virtual anchoring spaces (e.g., the use of educational technology).

Also, according to Parsons (2018), university students learn the norms, rules, and rituals of their future professions by participating in anchoring spaces that promote communication, thereby developing a sense of community that produces higher levels of mystical engagement and persistence. On the other hand, teacher feedback plays an important and necessary socializing function for students. This is evident because by providing feedback during classes, teachers lead students to new ways of thinking and provide the intellectual vocabulary needed for success. Roundtable classrooms have also been shown to have a strong impact on socialization.

Teachers should consider including other effective techniques for using themes and teaching, and how school leaders can provide support to teachers and encourage the building of communities to share resources and support. This consideration will help increase feedback and community diversity. From the approach of Krajewski and Khoury (2021), the physical classroom cannot be replaced by a virtual space, and as the classroom experience, positive anchoring, and directed practice are important for the maturation and improvement of student growth.

Furthermore, this approach shows how educationally relevant, multifunctional, and ideally multisensory bonding spaces should be. These spaces should be flexible in terms of learning approaches, and each approach should be shared by the teams. Additionally, the learning environment should be as diverse, flexible, and quick as the changes in learning in the digital age. Moreover, classroom spaces should have a variety of physical stimuli, multisensory devices, and access to digital resources, which should be tested and used over time.

Finally, it is possible to say that different learning approaches fit into different physical and online spaces, but learning theory does not specifically consider these contexts. Thus, those planning school facilities must have the idealization that this is a constantly changing learning environment, and thus the spatial requirements must be consistent with educational specifications. Ideally, room planning should be done in collaboration with staff, teachers, and students, at least when new schools and classrooms are being planned and designed (Krajewski & Khoury, 2021).

Organization – (Institutional Management)

Globalization and technology, as well as the need to adapt to changes in conditions during the pandemic, have significantly changed the landscape of education and higher education in recent years. While the virus encouraged students and teachers to participate in online learning, it also exposed several vulnerabilities related to digital divides, unmet expectations, and unforeseen obstacles (Krajewski, S., Khoury, M., 2021). As previously mentioned, the classroom is one of the main aspects that contribute to student learning (Park, E.L., Choi, B.K., 2014). The University of North Carolina (NCSU) is one of the most notable examples of disruptive classroom design with its Student-Centred Active Learning Environment (SCALE-UP) plans for undergraduate programs led by physics professor Robert J. Beichner. Adopted by the U.S. Department of Education, National Science Foundation, Hewlett-Packard, Apple Computer, and Pasco Scientific, the main goal of the plan is to create an educational environment that allows and promotes interaction between students and teachers.

According to Beichner's pioneering practice, enlarged classrooms improve students' problem-solving skills, facilitate conceptual interpretation, improve learning and perception of important physical concepts, and improve their attitudes, especially with women's rates among minorities, Beichner (2003).

The University of Minnesota was one of the pioneers in implementing ALCs in higher education, inspired by models such as SCALE-UP and TEAL, which were developed at other institutions. The University of Minnesota's ALCs were designed to meet the specific needs of each course and discipline and were evaluated through an institutional rubric that considers aspects such as student engagement, quality of learning, and teacher satisfaction. The results showed that the ALCs contributed to improving students' academic performance, reducing dropout and failure rates, and increasing interest and motivation for the content covered (Park, E.L., Choi, B.K., 2014).

According to Park and Choi (2014), higher education institutions should prioritize application in healthy learning environments and place more emphasis on the educational impulses of student classroom approaches. Examine the following three questions before starting a new school project:

What is the educational goal of the institution, and is it willing to build an efficient classroom?
Are the university, its teachers, and its students willing to test a newly built classroom?

Would the extra space be paid for while still meeting the goal of having adequate classrooms and naturally blending in with the student population and culture? These form the basis for dialogue within the organization about the efficiency and future.

Conceptual Map of Organisation

Methodology

The methodological choice is qualitative and interpretative (Creswell, 2009). According to Creswell (2009), qualitative and interpretative approaches aim to understand how individuals give meaning to their experiences. The focus, therefore, is on recognizing these meanings and how they affect attitudes. For the researcher, the goal is to decipher the data and recognize the different perspectives of the participants by providing a holistic interpretation of what is happening. Yin (2015) emphasizes the meticulous consideration in conceptualizing processes, causal pathways, and contextual dynamics.

Participants

The study participant was a member of the UMinho Management, who also played the role as one of the developers of the SACC room.

Data Collection Method and Techniques

The data was collected through an individual interview with a UMinho management member via Zoom on June 30, 2023. Recording the interview required accepting the participant's consent.

Data Analysis Method and Techniques

For data analysis, we prioritize thematic scanning (Braun and Clarke, 2006), a widely used data analysis technique to identify, analyze, decipher, and enumerate patterns and situational themes in qualitative data. Although the development of data-based themes is anticipated, this approach recognizes that themes can be defined and refined as the tracking progresses (Coutinho, 2013). Therefore, data mining includes various phases, such as data preparation, conducting multiple analyses, deepening the understanding of the data, data simulation, and comprehensive understanding.

Presentation of the SACC

Located on the upper floor of Building 2 of the Gualtar campus in Braga, the SACC is an irregularly shaped space that can accommodate up to 35 people. The chairs, tables, and floor display different shades of gray. The floor is carpeted, and the chairs are adjustable in height and format, highlighting the concern for ergonomics. Due to the limitation of floor connections, the tables cannot be configured differently. They are round and cannot be reconfigured, with a diameter of approximately 2 meters. The tables have an open center for cable passage and a built-in support underneath for cable storage. They also have an extension with five outlets and two USB connections for charging students' devices, as the room follows the Bring Your Own Device (BYOD) methodology.

The room is equipped with six LCD screens scattered throughout the space, with a tablet displaying the equipment management software. Students can project their work from their devices by installing the Mersive Solstice program. With this app installed and using a combination of keys, they can broadcast their work to one or all six 75-inch NEC screens suspended from the ceiling and scattered throughout the room. There is also a wirelessly charging tablet, with the charger located at station 41 for the teacher. The tablet has the "Solstice Active Learning" software installed, allowing messages to be sent to the whole class or specific groups, as well as controlling and connecting to the various LCD screens. The tablet can be passed between students and the teacher, depending on who needs to project. It can project to a single device or select multiple devices simultaneously. Each LCD screen has a POD underneath, allowing the device to be connected to the desired screen via an HDMI cable. Students connect their devices to the LCD screens using Wi-Fi, allowing up to three devices to be connected simultaneously. To increase security, a changing code appears on the LCD screen, which students must enter to establish a connection between the two devices. The sound volume of the LCD screens is controlled individually using a remote control.

The room is equipped with wireless internet through a Cisco router mounted on the wall opposite the entrance. The screen can be used by students and the teacher, depending on who needs to project. The front wall of the room has six acrylic boards, and the back wall has three additional boards. For temperature control, the room is equipped with two air-conditioning units and a fan coil unit that helps to regenerate the air. In terms of lighting, there is a complete wall of windows with adjustable blinds to control natural light, as well as blackout curtains without an interior. The room has several sources of white artificial light, but its regulation is limited, which can cause some discomfort and make it difficult to control over the LCD screens and boards, with some lights even positioned directly above the screens. The room's configuration allows it to be adapted to different disciplines, except for technical laboratories that require specific benches.

Interview with a member of UMinho management for the design of the SACC

Qn *How does the design and functionality of the SACC differ from other conventional classrooms?*

GU What we have concluded from our observations and interactions with the teachers who use the room is that it's very interesting that the teachers often value and use more frequently not the technological part, but the furniture and the wall boards. At the moment, according to what we can gather for most people who use the room - and I think we have about 60 people stepping into the room - the physical equipment is more important than the technological equipment. And that is exactly the perspective!

Qn *Will the innovative classroom design model be used in other areas of the university in the future?*

GU We have indeed now planned to intervene in about 40 rooms across the two campuses, where the essential and key point is not the technology. The essential and key point is indeed the organization of the furniture in the space. But with the idea of movable chairs, we will have tables with wheels, we will have the possibility in some rooms, for example, to have panels to divide large rooms into small groups. We will have such puffs in some rooms. We are in the process of doing this at the moment, which is already underway. As I said, my expectation, and I would like to believe, is that everything will be ready at the beginning of 2024. We will have another 30, 45, 40 rooms, with other typologies, but all focused on providing teachers, students, and everyone, a different interaction with the classroom.

Qn *How did teachers, designers, and the academic institution collaborate on the conception of the SACC?*

GU With what it had outside the UMinho IDEIA Center, the Teacher Training Center here at the University of Minho, which is a team of teachers from various units of the university, with various disciplines represented, who have worked together since 2017 on everything that is the transformation of teaching into an opportunity for the creation of a room, the creation of a new space. And so, there was certainly some participation of these colleagues. The design of the project and information about what the room could be like had the participation of the IDEIA Center and the technological operationalization. It certainly had much to do with the service unit that supports teaching technologies, which is part of the deregulation, and it was up to me to make it from the perspective of the pro-rector, in the sense of simplifying everything that was possible to simplify but respecting all the processes of the university.

Qn *How did you arrive at the choice of furniture, equipment, and technology for the SACC?*

GU The design of the space was indeed done by an architect here at the university, and the choice of furniture. The concept was worked on from an educational point of view by us. The space was worked on in conjunction with the UMinho team of architects, and so when we arrived at a proposal, however, for the definition of space, the definition of furniture, and so on, these aspects that have to do, in fact, with the choice of elements for the space, it was very much with interaction with the architects, and so from there, in a process of conversation, of very, very productive meetings, we managed to create something like we don't have.

Qn *What challenges were faced in the conception of the SACC and how did you overcome them?*

GU Once the model was decided, once the type of experiences we wanted to occur within the room was decided, it was relatively easy to get to what we observed naturally on websites, sometimes what happened in other institutions, and so we also learned from them. We also had in the center the idea of a colleague, a certain professor, who had also experience in the design of active spaces in pre-university teaching. So, there were no major problems!

Qn *As a professor, do you see ongoing improvements and updates in the SACC?*

GU From the users, we receive a lot of praise, there have been very few suggestions and even fewer concrete ideas for doing something different. I would like the room to have a variety of spaces, for example, at the moment the room, in terms of inviting the students to sit, they all sit at round tables with the same number of chairs. I would like to imagine there being more flexible spaces where students could sit differently, where there might be some equipment where they could be comfortable, more standing up, more in a perspective of sitting lower like what we call puffs. I would like to add some of these spaces there if possible. In terms of improvements at the moment, the space we reserve for the teacher, which also isn't a space that can be much, can be better utilized, that is, we have there a very tiny table for the teacher to place the computer, the notes, and so on, what we would also like, perhaps to imagine that he could have other types of equipment, perhaps a table with one or two chairs for the teacher to also sit there from time to time, to talk with one or two students, to observe their performance, some small improvements that can be made. What we have at this moment, and we are in the process of acquiring furniture and other furnishings to equip other rooms of the university. We will have a room with a capacity for 100 students to do this type of work. There is an example. We will have two rooms with a capacity for 50 or 55. To do this type of work in Gualtar and we will have rooms like these also on the Azurem campus. What we are doing is multiplying that room and also multiplying in terms of capacity, type of interaction. So, not only with dialogue as it is already in development.

Analysing the ideas of UMinho management for the SACC design

The analysis of the responses presented by the management for the design of the SACC reveals a comprehensive and careful approach to creating an innovative educational environment. The emphasis on valuing physical elements over technological ones, as evidenced by GU, highlights the importance attributed by teachers to furniture and wall boards. This perspective underscores the relevance of the physical environment in the teaching and learning experience.

The intention to intervene in 40 additional rooms, as planned by the university management, reflects a vision centered on the organization of furniture in space. The implementation of movable chairs, tables with wheels, dividing panels, and puffs indicates a commitment to flexibility and adaptation to the varied needs of interaction in the classroom. The focus not only on quantity but on the quality of interaction highlights the concern in providing a differentiated experience for teachers, students, and other users of the rooms.

The active participation of the IDEIA Center and technological support units in the project's conception highlights the interdisciplinary collaboration and integration of different perspectives in transforming teaching. The joint action since 2017 shows a long-term commitment to educational innovation at the university.

The involvement of university architects in the design of the space and the choice of furniture, coupled with the faculty's contribution to developing the educational concept, illustrates the successful integration of pedagogical and architectural knowledge. The collaborative approach, as described by GU, resulted in creative and original proposals that seek to meet the specific needs of the learning environment.

The satisfaction expressed by the users, marked by praise and few suggestions, suggests that the initial implementation of the SACC was well-received. However, the willingness for improvements, especially regarding the diversification of spaces for students and the enhancement of the space designated for teachers, demonstrates an ongoing commitment to excellence and adaptation to constantly evolving needs.

In conclusion, the ideas of teachers, designers, and management of the University of Minho, as presented by GU, reflect an integrated and visionary approach in the design of the SACC. The commitment to innovation, interdisciplinary collaboration, and attention to detail suggest that this project not only meets current demands but also establishes a solid foundation for the future of the educational environment at the institution. As GU stated, "everything will be ready at the beginning of 2024," indicating an optimistic expectation for the project's completion and full implementation.

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STEAM ing ahead

Fostering critical thinking, problem-solving and creativity

3 ACTIVE LEARNING CLASSROOMS II

III. The Active Learning Classrooms II

What pedagogical practices should teachers adopt for their activities?

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Introduction

The Covid-19 pandemic closed schools and Higher Education institutions and affected about 90% of the world's students (UNESCO, 2020). In the university context, this situation highlighted the importance of educational institutions and intensified the challenges for teachers, students, and other educational agents. Themes such as digitalization, distance education, and digital literacy, previously present in the evolutionary agenda of education, were prematurely addressed due to the social isolation caused by the Covid-19 outbreak (Pascoal, 2020).

In the long term, the pandemic highlighted the need for renewed educational approaches, models, and solutions. The contextual, technological, scientific, and social changes of recent years pressure institutions and professionals to evolve, highlighting the complexity but also the urgency of changes in teaching and learning practices (Pedro & Matos, 2016).

The world is changing, and education must keep up with these changes in order to develop in students and teachers the necessary competencies for the 21st century. There is evidence that the educational environment influences students' learning attitudes, and the classroom conveys the educational philosophy (Park & Choi, 2014). Some authors even mention that space can promote - or inhibit - different styles of teaching and learning (Donovan et al. 1999; NLII White Paper 2004 cited by Park & Choi, 2014). Over time, learning spaces have evolved, but only with minor adaptations considering the number of participants.

However, in the 21st century, with a society influenced by countless and rapid social and technological changes, the debate about the design of learning spaces has gained visibility and is seen as a challenge for Higher Education, with several institutions seeking to implement innovative approaches. Key themes identified by some authors in this area refer to institutions' reaction to changes, available tools, and the configuration of classrooms to incorporate these transformations (Ibidem). Thus, it is essential to reflect, not only on digital pedagogical competencies, but also on educational spaces, considering their design, architecture, and technology integration.

In the face of rapid social and technological changes, the design of learning spaces emerges as a critical challenge for Higher Education, with various institutions, including the University of Minho (UMinho), seeking to adopt innovative approaches.

In May 2021, the University inaugurated the André Cruz de Carvalho Active Learning Room (SACC), equipped with innovative technology to promote active learning among students. The flexible space, designed based on Active Learning Classroom models, reflects UMinho's search for innovative educational methods that better prepare its students for the future. This study, part of a larger project supported by UMinho, involves several researchers, and focuses on understanding how teaching in the SACC influences pedagogy and teachers' practices. The project addresses the SACC from various perspectives and dimensions, seeking to explore the impact of this new learning environment on the evolution of teaching in the institution.

Research Question

In this article, we seek to answer the following research question: Do teachers who use the André Cruz de Carvalho Active Learning Room tend to modify their educational practices, leaning more frequently towards active learning models?

Study Objectives

Based on the selected research question, the following four specific objectives were defined:

1. Identify what constitutes an active learning room in the literature.
2. Identify how the recommended pedagogical dynamics integrate and use the technological component, both by teachers and students.
3. Identify the characteristics of teaching and learning activities developed in the André Cruz de Carvalho Active Learning Room (SACC).
4. Analyse to what extent the teaching and learning activities developed in the SACC differ from those carried out in traditional classrooms.

Methodology

The research adopted a qualitative and interpretive approach, as proposed by Creswell (2009), combined with Yin's (2014) Case Study methodology.

Participants included seven teachers from the University of Minho who used the SACC during the 2021/22 academic year, as well as students who attended the room. Various data collection techniques were used, such as document analysis, questionnaire survey, non-participant observation of a class in the SACC, and focus group interviews.

Data analysis included: descriptive statistical analysis using MS Excel, descriptive analysis of observation records, thematic analysis, and frequency and context analysis of themes and sub-themes through NVIVO. This multifaceted approach allowed for a comprehensive understanding of the impact of the SACC on teachers' pedagogical practices and the student learning experience.

Analysis and Conclusions

An essential element in any research is the theoretical foundation that supports it. In this sense, we began the process with a scoping review, a valuable approach to synthesizing research data and often used to map the existing literature in a specific field, exploring its nature, characteristics, and volume. This methodology allowed us to identify the fundamental concepts related to Active Learning Classrooms (ALC), as well as the main sources and types of evidence available.

Regarding the first research objective - identifying the characteristics of an active learning room in the literature - there is an absence of a consensual definition among different authors. However, ALCs share common characteristics, being formal classrooms intended for educational activities, and distinguished from informal spaces. Their architectural and design particularities are deliberately configured to promote active learning, including mobile furniture, various writing surfaces, a polycentric or acentric layout without a defined front, and easy access to infrastructural technologies and digital and analogue tools. The SACC was developed based on these characteristics, inspired by similar international experiences, and incorporates innovative technology in Portugal to promote active student learning. Regarding teachers using ALCs, the analysis of articles indicates a trend towards modifying educational practices and perceptions of the teacher's role, with an inclination to adopt active learning models compared to traditional classrooms. Over time, teachers seem to effectively integrate the special features of ALCs into their teaching, incorporating reconfigurable tables, vertical writing, and ubiquitous digital technology. The studies analysed highlight the importance of teachers' theoretical and practical perceptions, as well as the acceptance and control of technological space in ALCs. This type of room can not only alter teacher-student relationships, influencing the change of the teacher's role to guide/facilitator of learning, but also has the potential to drive a new culture of learning, exerting a transformative power on institutional cultures.

Regarding the second objective of identifying how pedagogical dynamics integrate the technological component, both by teachers and students, the data obtained reveal, at times, a certain disinterest in the available technology. This may occur due to a lack of mastery and difficulty in solving technical problems, resulting, in some situations, in the non-use of technology. Some teachers also report difficulties with internet access and sharing on the PODs, mentioning that in some cases "they do not work". User surveys also reflected this trend, highlighting technology as a point for improvement, with specific references to the internet and PODs. These references align with some previous studies, such as that of Haines and Takerei (2019), which emphasizes that technology can be an initial barrier to the use of active learning rooms by teachers, complicated by the initial prototype nature of the rooms and the ongoing need for problem-solving. We observed a similar trend as pointed out by these authors during the focus group, where some participants expressed frustration with the technology, leading them to resort to the use of what was identified as "low technology", such as manual whiteboards. These participants also indicated the intention to explore more advanced technological options "as soon as everything worked smoothly" in the future. However, it is important to mention that during the observed class, no incidents with technology occurred, and all PODs were used by both student groups and the teacher. In the class, the use and appropriation of technology by students were evident. These findings, despite apparently contradicting the reports of teachers, may be related to the level of mastery, control, and technological proficiency of both teachers and students, as well as the equipment used, considering that the room adopts a BYOD (Bring Your Own Device) model.

Regarding the third objective of this study, which aims to identify the characteristics of teaching and learning activities in the André Cruz de Carvalho Active Learning Room, the results indicate that activities in this space are characterized as follows: i) A predominance of group activities, driven by the room's layout, where teachers positively highlight the availability of round tables and movable chairs; ii) Greater flexibility of movement and space utilization, both by students and the teacher; iii) Increased use of technology, although some teachers still resort to simpler forms, including panels for vertical writing; iv) Improvements in interaction and communication between teacher and students, as well as among the students themselves, facilitated by the room's design and various resources and technologies available. The data collected points to general user satisfaction (expressed in surveys and focus groups) regarding the experience in the room and its various features. There is also an emphasis on the possibility of greater interactivity in SACC classes and the promotion of group work. Teachers also emphasize that the room layout stimulates, promotes, and facilitates collaborative and cooperative work, providing opportunities for diverse pedagogical choices.

Finally, regarding the fourth and last objective, which proposes to analyse the extent to which teaching and learning activities carried out in the SACC differ from those conducted in traditional classrooms, we sought to systematize the distinctive characteristics in the table below.

Table 3. Comparison Between Traditional Classrooms and the SACC (Active Learning Classroom André Cruz de Carvalho).

Activities	Traditional Classrooms	SACC (i.e., non-traditional)
Teacher Positioning	Front of the room, centre of attention	Undefined positioning, circulation is privileged
Role of the Teacher	Source of information and transmitter	Facilitate, guide, and support the student in navigating the learning process
Responsibility for the Learning Process	Teacher	Student

Activities	Traditional Classrooms	SACC (i.e., non-traditional)
Control of the Class by the Teacher	High	Reduced
Knowledge	Transmission	Co-construction
Student Engagement	Passive	Active
Personalization and Relationships	Superficial	Deeper
Interactivity and Communication	Bidirectional	Multidirectional
Mobility of Student and Teachers	Difficult or non-existent	Encouraged and enhanced by wheeled chairs and various resources
Collaborative and Cooperative Work	Difficult to implement	Easy to implement and enhanced
Collaboration, Cooperation, Idea Sharing, and Feedback	Difficult to implement	Stimulated and enhanced by layout and technology
Technology and Available Resources	Single screen/board, controlled by the teacher	6 screens with Solstice System, vertical writing boards, infrastructural technology...
Flexibility	Reduced	High

In the SACC, the positioning of the teacher is fluid, favouring their movement around the room. The traditional role of the teacher as a source of information and transmitter of knowledge is transformed in the SACC, where they assume the role of facilitator, guiding and supporting students in navigating the learning process in a technological environment, encouraging active knowledge construction. This change transfers control and responsibility for the learning process from the teacher to the student, who plays an active role in constructing their own knowledge. Knowledge, previously transmitted unidirectionally in traditional classrooms, is now co-constructed collaboratively between students and the teacher. These changes aim to promote greater student engagement and less passivity in the SACC, being implemented gradually so that students understand and adapt to changes in the room environment, available resources, activities, and dynamics. Unlike traditional classrooms, which may be perceived as more rigid, the SACC provides greater flexibility and mobility for all users, allowing the appropriation of space and the exploration of various available resources. Finally, the SACC demonstrates the complex interconnection between pedagogy, space, and technology, emphasizing the crucial role of technology in exposing students to a rich and stimulating environment. The importance of integrating technology into pedagogical models is also highlighted, not just as a tool but as a structured support for learning.

Final Considerations

At the start of this study, our goal was to understand the impact of teaching in the SACC on teachers' pedagogical practices. The literature review, although a meticulous process, proved enlightening, confirming that the SACC incorporates the distinctive characteristics of ALCs mentioned in the literature, including furniture conducive to group work, walls with glass writing surfaces, multiple electrical outlets, and the absence of a defined front of the room.

These characteristics positively influence teachers, encouraging the adoption of active learning models compared to conventional classrooms. The SACC promotes activities centred on group work, where the teacher plays the role of facilitator who creates opportunities for individual and collaborative learning. The improvement in interaction and communication between teachers and students, as well as among the students themselves, is evident, facilitated by the room's layout and the available technological resources.

Despite some teachers expressing disinterest in technology, we observed that some use it proficiently, highlighting the need for ongoing updates and training to overcome potential barriers. We also conclude that for innovative pedagogy, it is essential to have innovative digital technologies, with the SACC being an environment that challenges and meets students' expectations regarding the use of technology.

Study Limitations and Future Research Perspectives

One of the main limitations of this study is the fact that the SACC is still very recent, and thus, there is still a limited number of users, both teachers and students, who have had contact with it so far. We would like to expand this study to include a larger number of teachers and obtain more comprehensive feedback from students. This would allow the collection of additional data to validate, modify, or even challenge the presented conclusions. The expansion of this study can explore various directions, such as:

- Investigating the perspectives and practices of teachers of different age groups and career stages, addressing not only the use of the SACC but also issues related to their initial and ongoing training, motivations, and values.

- Developing a training action that supports the pedagogical use of the SACC, through an action-research approach involving teachers, enabling practical implementation and the creation of a supportive community of practice.

- Analysing the digital competencies of teachers and evaluating how these competencies influence the pedagogical use of technology in practices in the SACC.

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4 ACTIVE LEARNING CLASSROOMS III

IV. The Active Learning Classrooms III

The use of digital technologies in the development of new pedagogical practices

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Introduction

Since the late twentieth century, the traditional classroom has been undergoing physical changes due to technological, scientific, and social changes that have taken place in recent decades. These changes have forced not only educational institutions to change their spaces but also pedagogical practices, to foster collaborative learning among students supported by digital technologies. Indeed, the development of active learning classrooms is related to a broader movement in education in which students are involved and committed to their learning (Clinton & Wilson, 2019), with the fundamental aim to enable students to transform, interact, learn, and engage.

Therefore, universities are committed to creating a dynamic learning environment, with Active Learning Classrooms (ALC) being established in various university institutions under various names such as Active Learning Centers, Future Classroom Labs, Learning Spaces, and Learning Environments. All these spaces promote "a powerful kind of learning experience not easily accessed in any other way" (Baepler et al., 2016, p. ix), as active learning rooms use digital technology to promote student participation and interaction, cooperative learning, and problem-solving. Learning spaces should allow physical movement and interaction between teachers and students, since content exposition is almost non-existent (Nolan, 2010).

Thus, many rooms have been renovated to provide students with active practices, as has happened in many universities around the world, including at the University of Minho (UMinho) with the André Cruz de Carvalho Room (SACC), where students are encouraged to generate knowledge, with evidence that students perform better in active learning environments. A change in the curriculum content of course units and in teaching models to encourage active learning is also intended (Baepler et al., 2016; Hair et al., 2017).

However, for the design and evaluation of learning spaces, three essential dimensions must be considered: pedagogy, space, and technology, because pedagogy is enabled by space and amplified by technology, space encourages pedagogy and incorporates technology;

and technology enhances and encourages a certain pedagogy and expands the space (Casanova & Mitchell, 2017; Lee et al., 2018).

Problem Identification

Today's students are highly dependent on technology (Donkin & Kynn, 2021). For these digital-era students, the line separating technology for learning and technology for fun is blurred, as is the line separating learning inside and outside the classroom (Clinton & Wilson, 2019). With smartphones always at hand, digital-era students have come to rely on technology for communication and collaboration. Nonetheless, the trend of constant connection is unlikely to diminish over time, and teachers must find ways to incorporate this type of virtual collaboration and communication into teaching and learning processes. This is what digital-era students want, and it will happen with or without teachers' guidance (Clinton & Wilson, 2019).

In May 2021, the University of Minho (UMinho) inaugurated the SACC, an ALC with unique technology in Portugal for sharing devices on and between screens. In this space, with round tables and acrylic boards on the walls that allow sharing ideas among the different work groups formed during the class, students can use their digital mobile devices during teaching activities to enhance active learning, promoting teamwork and privileging learning through discovery (IDEA, 2021). Thereby, the student plays a central role in the class. The intention is that this space fosters a new form of relationship between teachers and students and knowledge and new learning pedagogies, clearly centred on the students.

In this room, the use of digital devices such as mobile phones, tablets, and computers will be a means of promoting and sharing experiences, as well as the professional, cognitive, and academic development of students. The use of students' personal mobile devices brings the classroom work closer to the real world, allowing students to actively discover solutions for problems and challenges posed by teachers. The spatial arrangement and the use of technologies may optimize the learning process which aims to equip students with important skills for their lives, namely critical thinking and the ability to solve contemporary world problems (IDEA, 2021).

Indeed, this research seeks to understand how teachers use the technology available to them in the SACC and which active pedagogical practices the technologies promote.

Research Question

From this problem, this research seeks to answer the following research question: To what extent is digital technology used in the André Cruz de Carvalho Room to promote active pedagogical practices?

Study Objectives

Regarding the objectives of the study, we selected:

1. Characterize the SACC as an active learning room from the perspective of the existing technology.

2. Identify how teachers integrate innovative technology available at the SACC into the teaching and learning processes.

3. Determine whether the fact that teachers teach in the SACC enhances the use of technology in active pedagogical practices.

Methodology

Regarding the methodological choice, we have opted for a qualitative paradigm (Creswell, 2009) and a case study approach (Yin, 2014). The study participants are the five professors from UMinho, as well as the students who used SAAC in the 2021/2022 academic year; an observer also took part.

Analysis and Conclusions

When we started this research, our goal was to understand the impact of technology available in SAAC on the innovation process in the pedagogical practices of teachers who requested it most during the academic year 2021/2022. At the end of this work, it is urgent to revisit this concern, which we will address by revisiting the specific objectives set out and based on the constructed theoretical framework and the empirical data collected.

Regarding the first specific objective – Characterize SAAC as an active learning classroom from the standpoint of existing technology. The literature indicates that an active learning classroom, in addition to flexible furniture, must include up-to-date technological resources such as displays with specialized software allowing wireless projection and screen sharing, both fixed and mobile, as well as a device controller, wireless internet, and an adjustable power strip hub (Lam et al., 2019; Lee et al., 2018; Li et al., 2019; Poellhuber et al., 2018; Ramsay et al., 2017). This category of technological resources may also include the availability of laptops, an interactive multimedia whiteboard, an advanced sound system, a web camera, or a multifunction printer.

It was understood that SAAC possesses the expected artifacts to be considered an active learning classroom, notably, flexible furniture and innovative and updated technology: six panels (displays) with Pod installed with the Solstice Active Learning screen-sharing software, as well as a tablet with display control software, high-quality wireless internet connection, and a power strip hub at each table with five inputs and two USB ports, as shown in the annex.

The room does not provide laptops, as it has chosen a BYOD approach to encourage students to use their own devices, which they are more familiar with and are often more up to date. This is also pointed out by Eickholt et al. (2019), who emphasize that BYOD enhances the authenticity of student work and increases collaboration among students.

Regarding the second specific objective - Identify how teachers integrate the innovative technology available in SAAC into their teaching and learning processes – the data collected from the focus group show that the teachers' preference for this active learning classroom is due to its flexible furniture rather than the innovative technology present.

The teachers state they use the panels (displays) as projection devices for the entire room due to the ease of use of the tablet with display control software but not specifically the

Solstice Active Learning screen-sharing software, which allows content to be shared by and among students. They also mention that their lack of use of the Solstice Active Learning software is due to a lack of confidence in its use, which may stem from technical ignorance or insecurity with the technology (in case something goes wrong). Quick and always available technical support can empower teachers by giving them the confidence needed for its use in teaching practices. Therefore, we can conclude that the use of the panels is not, for the time being, by these teachers, very different from what they have been doing with multimedia projectors that equip all the classrooms of the UMinho Pedagogical Complexes.

This conclusion aligns with Poellhuber et al. (2018), who point out the importance of specialized screen-sharing software and indicate that this feature is the hardest to use in the classroom, being almost always handled by teachers rather than students. The same is reported by Ungar et al. (2018), when they present data on the use of an active learning classroom considering a teacher's technological knowledge. Often, the teacher uses the active learning classroom in the same way as a more traditional classroom, where the role of technology is more passive, as they use technology to support their speech while students listen.

Regarding the third specific objective - Investigate whether teaching in SAAC encourages the use of technology in active pedagogical practices. Ramsay et al. (2017) claim that the reason rooms like SAAC are called Active Learning Classrooms is due to being technologically rich environments that promote active pedagogical practices, such as interaction, collaboration, and co-construction of knowledge among teachers and students and among students themselves.

Findings from Focus Group Interviews

The data from the focus group interviews tell us that these teachers always use some form of technology in their classes, which is also the case when they are in the SACC (Active Learning and Collaborative Classroom). The most commonly used technologies include Padlet, Blackboard, Zoom, and more recently, mobile devices (ARS). According to Ungar et al. (2018), it is perfectly natural for these teachers to use technologies they are familiar with, especially after two years of working online. These authors note that in technologically rich environments, there is often an initial hesitation to take technological risks.

Often, technology is used as a direct substitute for older technology simply because the new technology has features and/or functionalities do not present in the previous one, but without pedagogical gains in terms of a change in student learning. Ungar et al. (2018) mention that once a teacher feels comfortable with a more advanced use of technology, it becomes a facilitating factor in learning, and students will use technology actively. Once this happens, the class will be task-based, students resort to technology throughout the process, and produce their own learning product.

We can conclude that the use of technology in active pedagogical practices is somewhat slower on the part of teachers, often due to a lack of knowledge about the technology itself or fear that it may not work as intended (as seen in the response to the previous objective).

We can possibly infer that these teachers advocate active pedagogical practices, which is why they requested the SACC so much in the current academic year.

Final Considerations

Traditional classrooms, where students are all aligned and focused on a single point of attention, usually the place where the board is located for the teacher to interact with the class, do not fit with active pedagogical practices. Since the end of the 20th century, this traditional classroom has undergone changes, greatly due to technological shifts in recent decades that promote new pedagogical practices. This is because active pedagogical practices require students to have space to move and interact with one another, with technology, particularly digital technologies, present for collaborative problem-solving initiated by the teacher.

Active learning classrooms are technologically rich environments, characterized by flexible layouts, interactive screens with screen-sharing capabilities, wireless projection, capacity to charge multiple devices, and the ability to alter the room according to the activities promoted by the teacher. Students take advantage of cutting-edge technologies to benefit from rich learning experiences.

The SACC is an active learning classroom designed to be a space that promotes active pedagogical practices with technology. During the 2021/2022 academic year, many UMinho teachers requested this space because they wished to energize activities that promote problem-based learning, cooperative learning, collaborative learning, project work, group, pair or tutorial activities, strategies for conceptual change, research-based learning, discovery learning, and technology-enhanced learning experiences. Indeed, the development of active learning classrooms like the SACC is related to a new learning paradigm in which students are involved and committed to their learning.

Our research on the use of technology in the SACC has allowed us to understand that the interviewed teachers use technologies in their classes, but not specifically on an innovative technology in Portugal like the Solstice Active Learning software. This fact is important for signalling the need to raise awareness among teachers to train in the pedagogical use of this Solstice Active Learning software.

The fact that we are coming out of two years of a pandemic, where a lot of technology was introduced to teachers, such as Padlet, Blackboard, Zoom, and mobile devices (ARS), justifies the fact that they have appropriated some of these technologies and do not feel (yet) the need to explore pedagogically a technology that is innovative in Portugal. One of the teachers who received training emphasized that he would like to plan a curricular unit for the SACC in the future, making the most of active methodologies and the technology available there.

Limitations of the Study

Due to the difficulty of gathering all the teachers who most requested the room at the same time in a single focus group, we had to conduct these collective interviews at three different times. Although this is a methodologically possible option (Coutinho, 2013), we think it would have been interesting to have a simultaneous discussion with all participants.

Another limitation is related to the fact that only one classroom observation in the SACC was made for one of the focus group participants. Although it was a good example of the use of technology in active pedagogical practices, we only got one perspective and it would have been very interesting to observe more teachers and students in the room.

We consider an even more decisive limitation to be the following: after capturing the teachers' perception of technology, it would have been beneficial to also consider the students' perspective. However, as this is the first study of a larger research project, future steps will certainly aim to consult students to determine how they appropriate the technology in the room and the added value they find in using it.

Finally, the conclusions of this investigation are limited by the fact that it is a case study, based only on the SACC, and therefore with conclusions that are difficult to generalize.

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5 STEAM EDUCATION LIVES AND BREATHES

V. STEAM Education LIVEs and Breathes

Making it Lively, Inclusive, Vertical and Exciting (LIVE) for Students

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Introduction

Much more than an acronym, the word STEM refers to an engaging and inclusive educational approach for girls and boys, aimed at bridging the gender gap in these disciplines. It is an approach to teaching/learning, where greater emphasis is placed on critical thinking (asking questions, not taking things for granted), creative thinking (imagining alternatives and looking from multiple perspectives), and performative thinking (translating thoughts into actions with real and constructive impact), with the goal of creating tomorrow's problem-solvers. It's a matter of mentality and method before content. The scientific method is at the heart of the STEM approach. In the strict sense: question, observation, hypothesis, experimentation, measurement, formalization, public and continuous comparison. In a broader sense: a curious openness towards reality, critical towards all imposed knowledge, tolerance towards every position as long as it is supported by rational arguments. Just as in science it is not enough to declare, but necessary to demonstrate and be able to do, the same applies to teaching inspired by the STEM approach. It's not enough to read and repeat, but one must get hands-on and show results: if students don't try first-hand, if they don't engage themselves, starting from a problem and based on solving hypotheses, with visible results, how can we claim they are truly capable of doing something? If they know things but can't put them into practice, how can we talk about authentic learning?

Activities Undertaken

Participating in this project, our students were involved in various activities that saw them operate in different contexts. They discovered the golden ratio and its application in multiple fields, from art to architecture to botany, etc.

1. **Matart:** The journey began with Mondrian's painting to understand what the golden ratio is and how it is applied in geometry to obtain particular shapes: the golden rectangles.
2. **Touch Screen Pen:** Discovery of current-conducting materials.
3. **3D Food Pyramid**: Created to explain in a simplified way which foods should be consumed more or less often to maintain good health.

4. **Structure Of DNA (3D Model)**: DNA is the fundamental substance of the gene and is responsible for the transmission of hereditary traits.
5. **Suspended Garden**: The structuring of a vertical school garden aimed to promote in students: ecological education to reconnect them with the importance of water; principles of environmental education through activities of planting, care, and composting; physical and psychological well-being; care of their own territory and respect for the planet's resources; well-being and socialization, necessary factors in the formation of sustainable communities.
6. **The War**: While addressing the theme of war, the golden ratio was discovered even in the arrangement of barbed wire!
7. **The Sea and the Golden Ratio**: The design of the waves, originated by marine currents, reminds us of a golden ratio, as do other "inhabitants" of the marine depths.
8. **Archaeology and Golden Ratio**: In a location very close to us, we found a golden rectangle and thus our dear golden ratio applied to the architecture of many years ago!

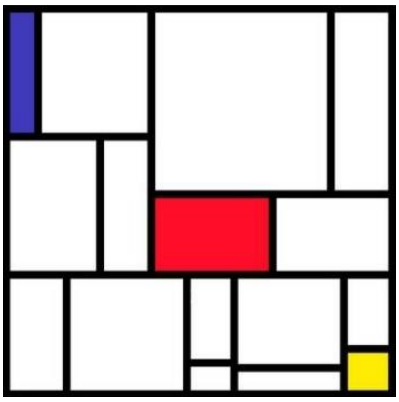
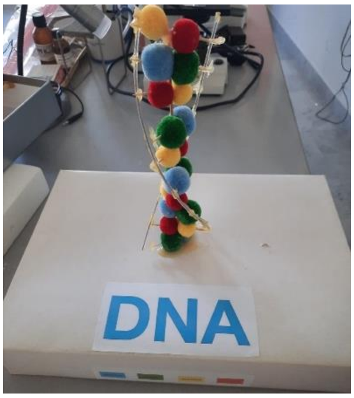


Image 1. Activity 1: Matart.

Image 2. Activity 2. Touch Screen Pen.

Image 3. Activity 3. 3D Food Pyramid.



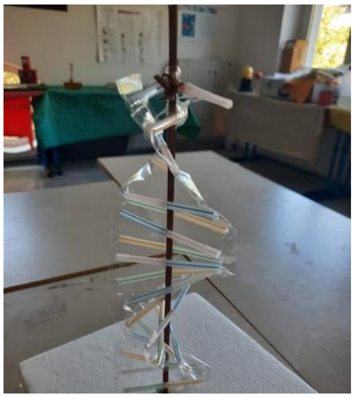


Image 4. Activity 4. Structure Of DNA (3D Model).

Image 5. Activity 5. Suspended Garden.

Image 6. Activity 6. The war.

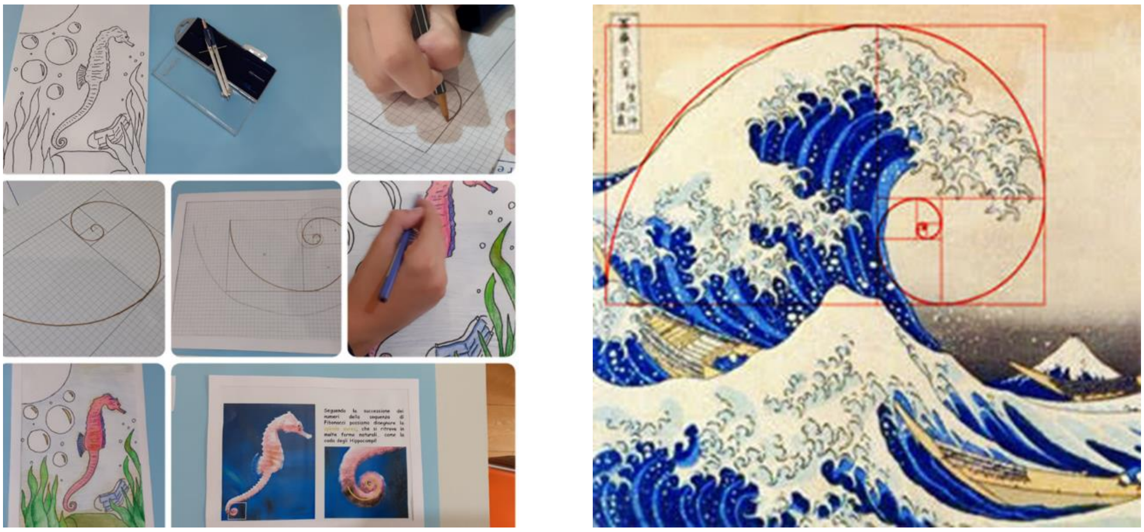


Image 7. Activity 7. The sea and the Golden Ratio

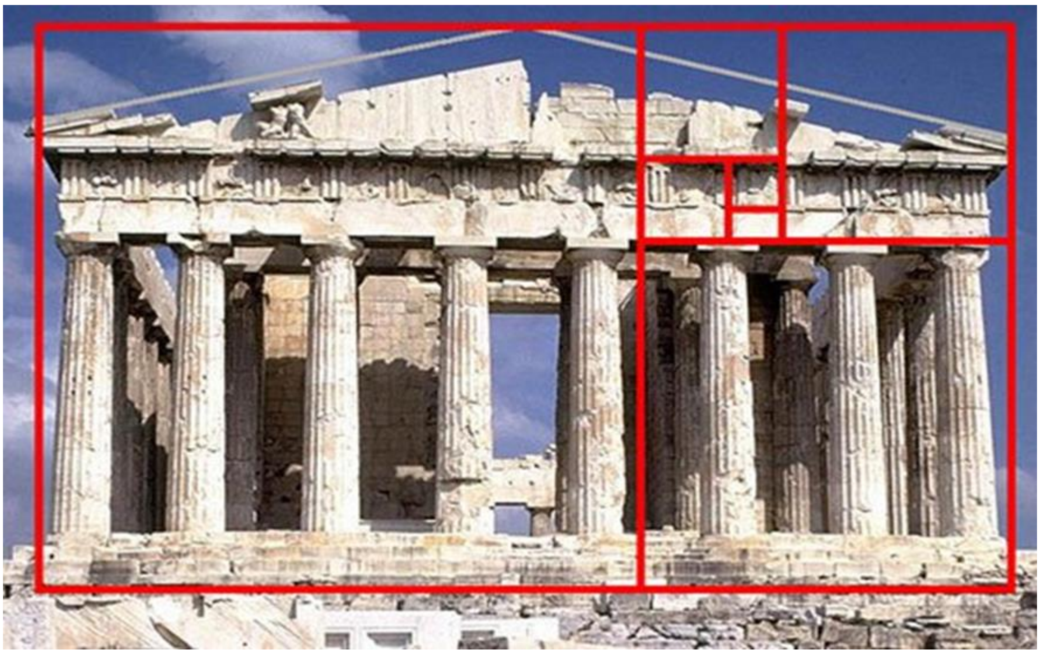


Image 8. Activity 8. Archaeology and Golden Ratio

Student Feedback

The three fundamental phases of STEM activities carried out with the students were:

- **Heart**: The engagement phase, where teachers must capture the attention of the students and propose the activity, launching it as both a cognitive and practical challenge.
- **Hands**: The exploration and elaboration phase, in which students carry out the task/project, usually divided into groups, trying to follow the essential steps of the scientific method and using technical-engineering applications to achieve visible products that attract the students and make them proud, as they are created by them.
- **Head**: The Lecture phase, which is about systematizing what has been taught to the students, elevating them to a more general conceptual framework, reserving time for the presentation and re-elaboration of results to be tested and evaluated.

The students showed responsibility, effective and constructive collaboration, attracted by the new methodology that made them protagonists in the proposed activities. The opportunity to achieve a unique and personal result – to create something they have designed and planned – instils a sense of ownership, pride, and personal responsibility, and the perseverance to succeed.

The key to these desirable attributes emerging lies in the pedagogical decision to abandon step-by-step prescribed models and processes and to allow students the personal choice of designing their learning path creatively. Approaching learning in a context where there are no boundaries between subjects and where the focus is only on asking and seeking answers encourages natural curiosity in students. Segregating knowledge into unconnected categories is harmful to our students because, in the real world, everything blends together. When a topic triggers curiosity, that is the first step of inquiry-based learning.

Students drive their learning through the questions they ask, discovering answers for themselves. They also share and reflect on what they learn, taking ownership of their learning at every step. In inquiry-based learning, the teacher serves as an educational guide, not as a sage on the stage. Teachers are there to monitor student progress, provide structural support when needed, and ensure that the focus remains on the students' questions and observations.

Students were given greater autonomy, which contributed to developing their critical thinking and problem-solving skills.

Teacher Experiences

The forms of activity that a teacher must have clearly in mind when planning and that allow this intertwining between Know-what and Know-how are essentially three types:

- **Problems:** A Problem is something that is not well understood and needs to be resolved.

- **Tasks:** A Task is something that must be done to achieve a certain result or fulfil a certain role.
- **Projects:** A Project is a process of ideation and realization that leads to a certain product.

To apply this type of teaching methodology, teachers need time, space, and resources to plan in groups. They must be willing to take risks and try new paths, distancing themselves when necessary from the comfortable frontal lesson, while maintaining the essential objectives of their teaching activity and finding the right balance with the more traditional aspects of teaching, which may still be difficult to abandon. The approach of individual teachers to activities thought out in a laboratory and active, interdisciplinary manner linked to strategies of problem posing and problem-solving is calibrated and diversified according to the educational background of each teacher and their training.

Teacher training is of great importance, as well as their motivation and willingness to follow paths of self-training, often essential in every teacher's journey. The cross-disciplinary or soft skills are recognized worldwide as essential in work and life. However, their importance has increased exponentially due to the accelerated rate of change in society we are experiencing today globally, particularly the transformative and pervasive impact of digital technology and the internet, combined with the effects of globalization. The main cross-disciplinary skills that are most relevant for STEAM activities are:

- Reflective Thinking and Problem Solving
- Collaboration and Communication
- Learning to Learn
- Digital Competencies and Mindset
- Initiative and Independent Thinking
- Creativity
- Self-Directed Learning
- Social Skills

Therefore, in the development of cross-disciplinary competencies through the application of various educational methodologies included in the STEAM approach, the student is an active subject in the learning process, tends to show greater motivation to learn, and is more likely to realize their potential and abilities. This change from traditional education emphasizes the interests, skills, and learning styles of each student, placing the teacher as a co-agent of learning.

Cabability Through Inclusion

Within the Erasmus project "STEAMing Ahead," the IC Battipaglia Salvemini participated in the design and realization of STEAM activities. Various classes were involved, including students with disabilities of varying severity. Each activity required full and active participation from all students, without the need for special accommodations and with a limited number of compensatory tools.

The students involved reasoned, formulated hypotheses, brought various reflections, discussed with their peers, and stimulated the curiosity and interest of all. During the activities, each student developed positive attitudes and learned to interact with their classmates, respecting everyone's learning pace.

STEAM disciplines proved to be an effective educational tool for promoting equality, valuing individual differences as opportunities for collective growth, and developing cross-disciplinary skills. They favoured the integrated construction of personal and professional identity. From this perspective, they were an opportunity for emergence and realization for all those students with disabilities and introverted personalities.

Our school was able to apply "STEAMing Ahead" as a vehicle for the inclusion of students with disability in the STEAM process. IC Battipaglia identified a 'winning partnership' for achieving the fundamental goal of our educational paths – "Being Capable…". Given the right conditions, tools, and methodological approach, these students gained awareness of their abilities and the possibility to fully realize their individual characteristics. STEAM activities played a fundamental role in including those students who struggle to emerge in competitive contexts or group dynamics. The collaborative approach allowed us to nourish and complete our ideas through exchanges with others and develop aspects of emotional intelligence related to relational effectiveness.

The results highlighted the attention of the new generations towards individual difficulties and possible concrete solutions. STEAM methodologies have managed to modify a largely traditional practice, enriching everyday teaching with more engaging and stimulating approaches for both students with disabilities and those who, despite not having certified disorders, often expressed boredom with schoolwork.

Conclusions

In today's world, preparing students for future success means introducing them to these disciplines in a holistic manner to develop their critical thinking skills. Teaching STEAM subjects prepares students for life, as they are central to their future employment and the development of modern society. The integration of STEAM activities into school curricula has great potential in providing a richer educational experience. Students can acquire a different way of thinking based on the idea that the more one fails, the more one wins. Education can be playful and natural, showing them the relationships between subjects and real life, thus increasing their sense of motivation, self-efficacy, and problem-solving abilities. These skills can be used throughout life to help them overcome difficult moments and seize opportunities whenever they arise. The project we developed believes that teachers and schools can leverage this "revolution" to make curricula more relevant, inclusive, and useful. This process needs not only expert teachers but passionate people interested in giving students the best possible education.

The STEAM approach is a valid educational strategy for enhancing the resilience, anti-fragility, and learning capabilities of the most vulnerable students. Activating STEAM educational paths within the project has allowed confirming the discovery made during the exploratory phase, which concerns the possible correlation between the realization of holistic educational paths that involve both humanities and scientific disciplines and the resilience level of students. This trend identified during the exploratory phase was supplemented by an even more specific observation concerning the achievement of the most satisfying results by the most vulnerable categories. Educating in STEAM, enhancing knowledge, awareness, and problem-solving skills are important prerequisites for improving capabilities, reducing vulnerabilities and educational poverty, and building a culture of safety and resilience at all levels to face the challenges of our time, such as disasters and multiculturalism. The exploratory phase allowed us to consider the results of this research as an indication of a trend starting from a pilot project focused on an interdisciplinary STEAM educational path. However, to hypothesize and study significant variables that can influence the contrast to educational poverty and identify the co-causes that fuel school and professional failure, this educational experience has posed the need to open up to research that, starting from the experience carried out, guides and serves as a guide to the construction and validation of a possible meta-model of educational offer design.

The topics addressed certainly represent the challenges that the school of the future will have to face to ensure an educational space functional for innovative and inclusive teaching, capable of combating educational poverty. Indeed, the varied topics selected following a well-defined logic and educational strategy were intertwined in the network of the interdisciplinary STEAM approach. STEAM, therefore, in light of this educational experience and through a fruitful dialogue between the humanities, social, physical, mathematical, and natural sciences, engineering, and the use of new technologies, seem to offer original and innovative insights and educational strategies to reduce educational poverty and stimulate the resilience and anti-fragility of students in more vulnerable conditions.

STEAMing ahead

Fostering critical thinking, problem-solving and creativity

6 TRANSFORMING MATHEMATICS EDUCATION

VI. Transforming Mathematics Education

The Power of Digital Tools in Active Learning

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Introduction

Background on the Evolution of Mathematics Education

Mathematics, often termed the "language of the universe", has been a cornerstone of education for centuries. Traditional methods of teaching mathematics have relied heavily on rote memorization and repetitive exercises. However, as the educational landscape has evolved, so too have the methodologies and approaches to teaching this critical subject. The shift from passive to active learning in mathematics is not just a trend but a response to the changing needs of students in the 21st century. (Li & Schoenfeld, 2019)

Emergence of Digital Tools in Education

The dawn of the digital age has brought about a revolution in many sectors, and education is no exception. The last few decades have witnessed an exponential growth in the integration of technology in classrooms. From simple calculators to advanced computer simulations, digital tools have transformed the way educators approach teaching and how students learn (Papert, 1980). These tools offer dynamic, interactive, and personalized learning experiences, making education more accessible and engaging (Borba & Llinares, 2020).

Using digital as a means of supporting student learning can offer several advantages, such as:

- **Accessibility:** Digital tools can be adapted to meet each student's specific needs, allowing students to access information and resources more easily and quickly.
- **Interactive features:** Digital tools can offer interactive features, such as educational games and simulation activities, that can be fun and motivating for students, which can help maintain students' attention and interest.
- **Communication:** Digital allows students to communicate with other students and teachers more easily and quickly, which can help improve inclusion and integration in the classroom.
- **Follow-up:** Digital allows teachers to monitor and evaluate students' progress in real time, identifying their individual needs and adapting the teaching methodology to meet their needs.

- **Customization:** Digital allows teachers to create and adapt content and activities to meet students' individual needs, making learning more effective and relevant.

- **Autonomy:** Digital allows students to work autonomously and at their own pace, which can increase their confidence and self-esteem.

- **Flexibility:** Digital allows students to work anywhere, anytime, which can make it easier to adapt to their individual needs. This can be particularly useful for those students who need more time to complete certain tasks or need extra help.

- **Adaptive learning:** Digital allows teachers to adapt learning content according to the needs of each student, making it more effective and efficient, allowing these students to advance in their academic paths (Crompton & Burke, 2018).

Significance of Active Learning in the Modern Educational Landscape

Active learning, characterized by student engagement and participation, has been shown to significantly enhance understanding and retention (Bonwell, 2017)). In the realm of mathematics, where abstract concepts can often be challenging to grasp, active learning strategies, facilitated by digital tools, can make a profound difference. The combination of active learning with digital technology offers a promising avenue for transforming mathematics education, making it more relevant, interactive, and effective for students of all ages (Kivunja, 2019).

Overview of Active Learning

Definition and Characteristics of Active Learning

Active learning is an instructional approach that actively engages students in the learning process, requiring them to participate and take responsibility for their own learning. Unlike traditional passive learning methods where students are mere recipients of information, active learning emphasizes student-centered activities such as discussions, problem-solving, and group work. This approach fosters a deeper understanding of the material, as students are encouraged to analyze, synthesize, and evaluate information (Huggett & Jeffries, 2021).

Benefits of Active Learning

Research has consistently shown that active learning strategies lead to improved student outcomes. Some of the key benefits include:

- **Enhanced Understanding:** Active learning promotes critical thinking and helps students grasp complex concepts by allowing them to apply theoretical knowledge in practical scenarios.

- **Improved Retention:** Students are more likely to remember information when they actively engage with it, as opposed to passively listening to a lecture.

- **Development of Higher-Order Thinking Skills:** Activities such as discussions and debates encourage students to analyze and evaluate information, fostering skills like critical thinking and problem-solving.

- **Increased Student Engagement:** Active learning methods, by their very nature, require participation, leading to increased student engagement and motivation (Roberts, 2017).

Active Learning in the Context of Mathematics Education

In the realm of mathematics, active learning takes on special significance. Mathematical concepts can often be abstract and challenging to grasp. Active learning strategies, such as problem-solving sessions, group discussions on mathematical concepts, and hands-on activities, can make these abstract concepts more tangible. By actively engaging with mathematical problems, students can develop a deeper understanding and appreciation for the subject.

Challenges and Considerations

While the benefits of active learning are well-documented, implementing it effectively requires careful consideration. Some challenges include:

- **Classroom Management:** Active learning often involves group activities, which can be challenging to manage, especially in larger classes.

- **Assessment:** Traditional assessment methods may not be suitable for active learning approaches. Educators may need to develop new assessment strategies that capture the essence of active learning.

- **Resistance to Change:** Both educators and students accustomed to traditional teaching methods may initially resist the shift to active learning. It's essential to provide adequate training and support to ensure a smooth transition.

The Role of Digital Technology in Mathematics Education

Context of integrating Digital Technology in Education

The integration of digital technology into education has been one of the most transformative shifts in the 21st century. With the rapid advancement of technology, classrooms worldwide have witnessed a paradigm shift from traditional teaching methods to more interactive and dynamic approaches. Mathematics education has greatly benefited from this digital revolution, offering students a more engaging and comprehensive learning experience.

Benefits of Digital Technology in Mathematics Education

Interactive Learning: Digital tools allow students to interact with mathematical concepts in real-time, enabling them to visualize and understand abstract ideas more concretely (Bloomsbury Academic, 2014).

- **Personalized Learning:** Technology offers adaptive learning platforms that cater to individual student needs, ensuring that each student progresses at their own pace.

- **Collaborative Learning:** Digital platforms facilitate collaboration, allowing students to work together on mathematical problems, share solutions, and discuss concepts.

- **Immediate Feedback:** Online quizzes and simulations provide instant feedback, helping students identify their mistakes and rectify them immediately.

Digital Tools and Their Impact

Various digital tools have been developed specifically for mathematics education like:
Mathematical Software: Tools like GeoGebra allow students to plot graphs, solve equations, and explore mathematical concepts interactively.

- **Online Platforms:** Websites like Khan Academy and Coursera offer comprehensive mathematics courses, complete with video lectures, quizzes, and assignments.

- **Virtual Manipulatives:** These are digital versions of physical tools used in mathematics, such as number lines, geometric shapes, and algebra tiles. They help students visualize and interact with mathematical concepts.

Challenges in Integrating Digital Technology

While the benefits are numerous, there are challenges in integrating digital technology into mathematics education:

- **Equity and Access:** Not all students have access to the necessary technology, leading to disparities in learning experiences.

- **Teacher Training:** Effective integration of technology requires teachers to be well-versed with the tools, necessitating continuous professional development.

- **Distractions:** Digital devices can sometimes lead to distractions in the classroom if not used purposefully.

The role of digital technology in mathematics education is undeniable. It has the potential to transform traditional teaching methods, making mathematics more accessible, engaging, and enjoyable for students. However, careful consideration and planning are required to harness its full potential and overcome the associated challenges.

Digital Tools for Active Learning in Mathematics

The integration of digital tools in mathematics education has paved the way for innovative teaching and learning approaches. These tools not only facilitate the understanding of abstract mathematical concepts but also promote active learning, where students are at the center of the learning process, actively engaging with the content.

Interactive Learning Platforms

Virtual Reality (VR) is a platform designed to bring immersive learning experiences to classrooms. It has the potential to be an excellent platform for teaching and learning mathematics with elementary school students.

VR offers interactive, 3D experiences that allow students to engage with mathematical concepts in a hands-on way. For instance, students can explore geometric shapes, patterns, and measurements in a virtual environment. This tangible interaction can enhance understanding and retention of mathematical concepts.

The immersive nature of VR can help to capture and maintain the interest of young learners, making them more engaged in learning. When students are actively engaged, they are more likely to understand and retain mathematical concepts.

Visualization is crucial in understanding mathematical concepts, especially for elementary students. VR can help visualize abstract concepts, making them more concrete and accessible. For example, students can walk around 3D shapes, see angles, and observe patterns and sequences in a more intuitive way.

VR provides a safe and controlled environment where students can explore mathematical scenarios and problems. Students can experiment and learn from trial and error without real-world consequences, fostering a positive learning experience.

Teachers can use VR to tailor learning experiences to individual student's needs. Differentiated learning experiences can address varying learning styles and proficiency levels, allowing each student to learn at their own pace.

Many VR experiences offer opportunities for students to work together in a shared virtual space. Collaborative learning can be particularly effective for mathematics as it encourages discussion, problem-solving, and shared discovery.

VR can simulate real-world scenarios where mathematics is used, showing students the practical application of the concepts, they are learning. This real-world connection can make learning more meaningful and relevant.

Digital Games as Learning Tools

The use of digital games in education has shown promising results in promoting active learning. Games designed for mathematical learning can be both engaging and educational. They challenge students to apply mathematical concepts in various scenarios, fostering problem-solving skills and critical thinking (Catala et al., 2014).

Rubrics and Assessment Tools

Digital rubrics serve as active learning tools by providing students with clear criteria for their work, allowing them to understand expectations and self-assess their progress. These rubrics can be integrated into digital platforms, providing immediate feedback, and promoting continuous improvement (Cardoso, 2022).

Virtual Learning Scenarios

Blended and virtual learning scenarios, which combine traditional classroom teaching with online elements, have gained traction in recent years. These scenarios leverage digital tools to offer personalized learning experiences, allowing students to engage with mathematical content interactively. Such environments are especially beneficial for active learning, as they offer flexibility and adaptability to cater to individual student needs (Pirker et al., 2018).

Digital tools have undeniably transformed the landscape of mathematics education. By promoting active learning, these tools ensure that students are not just passive recipients of information but active participants in the learning process. As technology continues to evolve, it is imperative for educators to harness its potential to further enhance active learning in mathematics.

Examples of Successful Implementation of Digital Tools in Mathematics

Elementary education: Harnessing technology for geometry and algebra.

The integration of digital tools in mathematics education has been a transformative journey for many institutions and educators. Here, we will show real-world examples that highlight the successful implementation of these tools, showcasing the tangible benefits and the strategies employed to overcome challenges.

Example 1: Outdoor Learning with Technology

Outdoor learning allows students to explore the surrounding natural environment and use their imagination to create stories, games, and activities.

- Being outdoors and connecting with nature helps students be more focused and pay more attention to their tasks.
- Learning outdoors can be more fun and interesting for students, which increases their motivation and engagement.
- Learning outdoors involves physical activity, which helps develop motor skills and coordination.
- Spending time outdoors improves physical and mental health, as it helps reduce anxiety and increases exposure to natural light.
- Learning outdoors can also include practical skills such as orienteering, exploring and interacting with nature.
- Learning outdoors also helps students understand the importance of caring for the environment.

In this example conducted in a Portuguese School, the teacher brings their students outside to measure angles on the shadows of many objects. The focus was on how teachers engage with Information and Communication Technology (ICT) in their classrooms. The example highlighted that teachers who were provided with continuous training and support were more likely to integrate digital tools effectively in their teaching methods. It is also emphasized the importance of a supportive institutional framework that encourages innovation and experimentation with digital tools.

Image 9. Measuring angles outdoors with smartphones.

Example 2: Mathematics Teachers and Virtual Reality

One of the main challenges with the study of mathematics is that it is often perceived by students as difficult or abstract, with vague connections to the real world. To improve students' math skills, it is vital to make mathematics more practical and engaging. That is why we are developing innovative ways to present and work with mathematics in school to improve students' engagement with this subject.

Image 10. Evidence of activity performed with the glasses.

Curricular goals:

1. To recognize that the number of edges of a prism is triple the number of edges of the base and that the number of edges of a pyramid is twice the number of edges of the base.

2. To recognize that the number of vertices in a prism is twice the number of vertices in the base and that the number of vertices in a pyramid is equal to the number of vertices in the base added by one.

3. To design a polyhedron as "convex" when any line segment joining two points on the polyhedron is contained.

4. To recognize the Euler relation in any prism and pyramid and verify its validity in other convex polyhedra.

5. To identify solids through perspective representations on a plane.

6. To solve problems involving geometric solids and their respective flat patterns.

Assessment:

1. To identify «prism» as a polyhedron with two geometrically equal faces («prism bases») situated respectively in two parallel planes so that the rest are parallelograms, designate prisms that are not straight as «oblique prisms», the straight prisms of regular bases by «regular prisms» and correctly use the expression «side faces of the prism».

2. To identify «pyramid» as a polyhedron determined by a polygon («base of the pyramid») that constitutes one of its faces and a point («vertex of the pyramid») outside the plane containing the base in such a way that the other faces are the triangles determined by the apex of the pyramid and the sides of the base and correctly use the expression «side faces of the pyramid».

3. To designate a "regular pyramid" as a pyramid whose base is a regular polygon with equal side edges.

Class activity:

- Students edit 3D models in VR of geometric solids and learned how to characterize them. Later, they explored real-life situations where they identified geometric solids in everyday objects.

VR glasses are designed to improve math education providing emotionally engaging learning experiences. In our class activity, students can explore complex 3D geometric shapes, spatial relationships, and transformations in a virtual environment. This immersive experience improves spatial reasoning skills and allows students to understand abstract mathematical concepts.

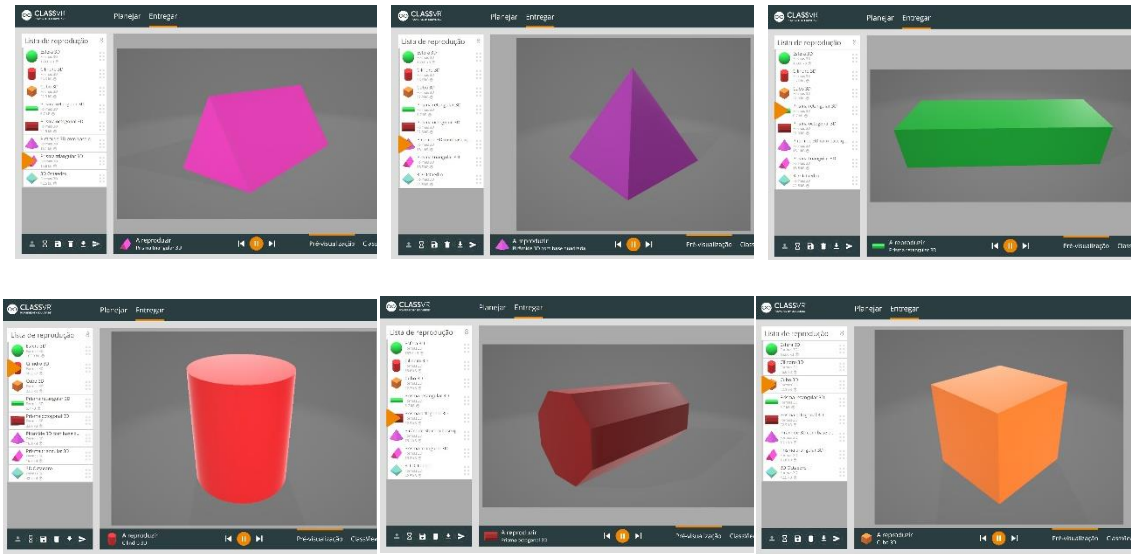

Image 11. Physical models of common 3D shapes used in VR activity.

Using VR to study math content goes beyond merely introducing a new resource. VR creates a dynamic simulation of real or imagined worlds, bridging the gap between formal and informal mathematics learning.

We realize that teachers who actively engaged with digital platforms, witnessed a significant improvement in student engagement and understanding. It`s crucial professional development programs that equip teachers with the skills and knowledge to harness the full potential of these tools.

These examples underscore the transformative potential of digital tools in mathematics education. They highlight the tangible benefits of integrating technology into the curriculum and provide valuable insights for educators and institutions looking to embark on a similar journey.

Challenges in Implementing Digital Tools

The integration of digital tools in education, while promising, is not without its challenges. As educators and institutions navigate the digital landscape, they encounter various obstacles that can hinder the effective implementation of these tools.

Infrastructure and Accessibility

One of the primary challenges in implementing digital tools is the lack of necessary infrastructure. Schools and institutions may not have the required hardware, software, or internet connectivity to support digital learning. Moreover, not all students have equal access to digital devices, leading to disparities in learning experiences (Rutherford, 2013).

Teacher Training and Professional Development

While digital tools offer innovative ways to teach, they require educators to possess a certain level of technological proficiency. Many educators, especially those accustomed to traditional teaching methods, may feel overwhelmed or ill-equipped to integrate these tools effectively. Continuous professional development and training are crucial to bridge this gap (Porter, 2016).

Pedagogical Challenges

The mere introduction of digital tools does not guarantee effective learning. Educators must align these tools with pedagogical goals, ensuring that technology serves the educational objective. There's a risk of using technology for its own sake, without considering its impact on learning outcomes (Voogt et al., 2018).

Student Engagement and Distractions

While digital tools can enhance engagement, they can also serve as sources of distraction. Without proper guidelines and monitoring, students might use these tools for non-educational purposes, detracting from the learning experience (Chellapan & van der Meer, 2016).

Assessment and Evaluation

Traditional assessment methods might not align with digital learning experiences. Educators need to devise new strategies to assess student performance, ensuring that assessments capture the essence of active learning facilitated by digital tools.

While the challenges in implementing digital tools are significant, they are not insurmountable. With careful planning, continuous training, and a clear pedagogical vision, educators can harness the full potential of digital tools, transforming the educational landscape.

Potential Solutions and Recommendations

While the challenges of implementing digital tools in education are significant, they are not insurmountable. With the right strategies and a proactive approach, educators and institutions can effectively integrate technology into the curriculum, enhancing the learning experience for students.

Infrastructure Development

- Investment in Hardware and Software: Schools and institutions should prioritize investment in necessary hardware and software to support digital learning. This includes computers, tablets, projectors, and relevant software licenses.

- Public-Private Partnerships: Collaborations between educational institutions and tech companies can facilitate access to the latest technology and digital tools at subsidized rates or even for free (Rutherford, 2013).

Professional Development and Training

- Continuous Training Programs: Institutions should offer regular training sessions for educators, ensuring they are well-versed with the latest digital tools and teaching methodologies.

- Peer Learning: Encouraging experienced teachers to mentor their peers can be an effective way to disseminate knowledge and best practices related to digital tool implementation (Porter, 2016).

Pedagogical Alignment

- Curriculum Redesign: The curriculum should be redesigned to incorporate digital tools in a way that aligns with pedagogical goals. This ensures that technology enhances, rather than detracts from, the learning experience.

- Pilot Programs: Before wide-scale implementation, pilot programs can be conducted to test the effectiveness of digital tools and gather feedback for improvement.

Engagement Strategies

- Clear Guidelines: Establishment of clear guidelines on the use of digital devices in the classroom to minimize distractions.

- Interactive Platforms: Use of platforms that promote interaction and engagement, ensuring students remain focused on the learning objectives.

Innovative Assessment Methods

- Digital Portfolios: Encouragement of students to maintain digital portfolios, showcasing their work and progress over time.

- Interactive Quizzes: Use of online platforms to conduct quizzes and assessments, providing immediate feedback and promoting continuous improvement.

The successful integration of digital tools in education (particularly in mathematics) requires a multi-faceted approach, addressing both technical and pedagogical challenges. With the right strategies and a commitment to continuous improvement, educators can harness the full potential of technology to enhance the learning experience.

Conclusion

The Digital Transformation in Mathematics Education

The integration of digital tools in mathematics education marks a significant shift in the pedagogical landscape. As we've explored throughout this paper, these tools have the potential to revolutionize the way mathematical concepts are taught and understood. From fostering active learning to personalizing educational experiences, digital technology offers a plethora of benefits that can enhance student engagement and understanding.

Key Takeaways

- Active Learning: Digital tools have proven to be instrumental in promoting active learning, a pedagogical approach that places students at the center of the learning process.

- Pedagogical Alignment: The successful integration of digital tools requires a clear alignment with pedagogical goals. Technology should serve to enhance learning, not as an end.

- Challenges and Solutions: While the challenges in implementing digital tools are significant, they are not insurmountable. With the right strategies, continuous training, and a commitment to innovation, these challenges can be effectively addressed.

- The Future of Mathematics Education: As technology continues to evolve, so will the methods and tools available for mathematics education. It is imperative for educators and policymakers to stay abreast of these developments, ensuring that students receive the best possible education in this digital age.

Final Thoughts

The journey of integrating digital tools in mathematics education is an ongoing one, filled with both challenges and opportunities. As we move forward, it is essential to approach this integration with a spirit of collaboration, innovation, and continuous improvement. By harnessing the power of digital technology, we can transform mathematics education, preparing students for the challenges and opportunities of the 21st century.

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7

METHODOLOGIES FOR THE ADOPTION OF MOBILE TECHNOLOGIES

VII. Active methodologies to increase the adoption of mobile technologies

Teachers' Insights in an in-service training course

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Introduction

Nowadays, education is undergoing a moment of methodological transformation (Curum & Khedo, 2021; Parra-González et al., 2021) where active learning is necessary for students to participate in the learning process (Niemi et al., 2016). Mobile learning, gamification, augmented reality, and flipped learning are active methodologies with excellent projections within the educational field. Also, there has been an increasing adoption of mobile devices. This learning paradigm promotes education in different contexts, which contributes to improving learning, regardless of the conditions and location of the student (Curum et al., 2021).

This paper describes a project to promote teachers' teaching process. The project aims to promote school success by positively decreasing the retention rate and dropout through in-service teacher training. This project references three key actions to be developed: (i) personalized learning spaces to function as innovative learning areas where you can join sciences to technologies. In this context, we trained teachers from various education grades in four school clusters in northern Portugal. With this training, we encourage teachers to use active methodologies such as gamification, flipped learning, augmented reality and mobile learning based on mobile devices.

The following section presents the pedagogical framework designed to support teachers in the quality and form of teaching and learning. Section 3 describes the methods used to develop our training action with teachers. In Section 4, we describe the main results, and we discuss data with teacher experiences. We conclude in Section 5 with a critical review.

Literature review

Mobile learning

In a society where technology is part of everyone's daily life, access to information through mobile devices spontaneously appears (Bernacki et al., 2020; Crompton, 2013; Curum et al., 2021; Lencastre et al., 2016). Mobile learning, or m-learning, has become a generic term for using mobile devices in teaching and learning (Gant, 2019). Mobile learning is accessing information and learning materials through mobile devices, regardless of the learning environment (Curum et al., 2021). It can be used in any student group, promotes active and personalized learning, and allows quick access to updated information in any context (Sharples, 2005). According to the mobile learning pedagogical model, learning can occur where students are (Lencastre et al., 2016). Mobile learning connects individuals through technology (Bernacki et al., 2020), allowing learning to occur beyond traditional spaces (Curum et al., 2021).

Attewell and Savill-Smith (2004) say that mobile learning has several advantages such as (i) the ease of taking information anywhere, (ii) low cost, (iii) the possibility of reusing content, (iv) the flexibility of use in different contexts, (v) promotes student-centred learning, (vi) enables learning in authentic contexts, (vii) provides students motivation, (viii) promotes collaborative work and (ix) promotes the use of smartphones and/or tablets in new learning environments learning.

According to Klimova (2019), mobile learning is a successful methodology because it can:

- Being able to use a resource and learn anytime, anywhere.
- Being able to adjust content to students' needs.
- Having immediate feedback.

The teacher can, for example, take advantage of the knowledge of the device's location and send feedback to the student about his work (Danish & Hmelo-Silver, 2020). Considering mobility as a fundamental advantage of mobile learning, it favours generalized learning and improves interactions between students and teachers to achieve better learning experiences. With mobile learning, online learning can happen anytime and anywhere, and students can also interact with learning content in real-time (Curum et al., 2021).

Mobile study support apps can support student learning and self-regulation and help teachers plan their work with students (Danish et al., 2020). Mobile learning can allow them to establish a motivating relationship with the content and allow them to differentiate communication, interaction, and collaboration. By their nature, mobile technologies can enhance learning (Greene et al., 2020).

Klimova (2019), in his study on the use of mobile devices to improve performance in the English language, showed that learning supported by smartphone applications effectively improves student engagement and performance. Through analysing contemporary research literature, Viberg et al. (2021) found that informal learning (subconscious and tacit) on mobile learning is more enriching than formal learning.

Gamification

Gamification is using game design elements in non-playful activities to engage students in learning (Kapp, 2012; Zichermann, 2012; Friedrich et al., 2020). In this implementation of game elements, gamification achieves turning learning into play through a narrative, goals, mission, points systems, rewards, or levels of difficulty, healthy competition (Lencastre et al., 2016), things which please the student (Zichermann, 2012).

Bai, Hew, and Huang (2020), in their study with 3202 participants, realized that gamification could foster enthusiasm, provide feedback on performance, and promote goal setting.

Parra-González et al. (2021), in their study, aimed to contrast the effectiveness in Physical Education and realized that it is in the phases of Basic and Secondary Education that students most value gamification.

Gamification has gained prominence in education due to its ability to improve student learning by involving students. It is expected to become more important and surpass traditional teaching (Hakak et al., 2019).

Flipped learning

Flipped learning is a pedagogical model that involves providing the content to the students before the class sessions and encouraging active learning (Tomas et al., 2019; Moreno-Guerrero et al., 2020; Birgili et al., 2021). At home or during individual study time, the student interacts with the resources provided by the teacher to learn at his own pace, anywhere and anytime, through access to online information (Sharples et al., 2014).

The flipped learning method can facilitate the teacher's work since the student regulates his learning (Parra-González et al., 2021). A mobile teaching context can promote rapid student access to information and teacher feedback. Tomas et al. (2019) that flipped learning promotes different levels of student-centred learning.

So, we can enhance flipped learning by developing practical classroom learning activities to promote higher-order thinking (Hwang et al., 2020).

Lucena et al. (2020), in their study about flipped learning in the teaching and learning processes of physical education at two educational stages, primary and secondary education, with two groups of students, an experimental group and a control group, found flipped learning is a methodology that improves autonomy.

Augmented reality

Augmented reality is a view of virtual objects in a real context, where virtual information is added and integrated into the physical world simultaneously (Pochtoviuk et al., 2020). The proliferation of affordable hardware and software has made augmented reality more affordable and desirable in many domains, including education (Elmqaddem, 2019). All it takes is an internet connection, a mobile device (smartphone or tablet) and an augmented reality application (Kysela & Štorková, 2015). Augmented reality overlays sound, videos and graphics in an environment where the user is and works as an enhanced version of the actual physical world (Iatsyshyn et al., 2020). Any classroom or school can easily create its learning environment using augmented reality. Furthermore, augmented reality objects affect attention, stimulate thinking, and increase understanding of information (Pochtoviuk et al., 2020). The fact that most students have smartphones or tablets makes learning using augmented reality accessible (Kramarenko et al., 2019). Augmented reality actively engages students and its nature brings new teaching and learning models that meet the needs of 21st-century learners (Elmqaddem, 2019).

Method

The study was developed using a quantitative methodology through a quasi-experimental research design. This training was carried out in four schools and lasted eight sessions once a month.

The course

The training course had a duration of twenty-five face-to-face hours during eight sessions. We presented the concept of learning through mobile devices, their potentialities, and their limitations. We also deliver the benefits of using mobile learning for compelling curricular flexibility, among other topics related to learning through mobile devices. We used the pedagogical flipped learning model combined with gamification in all sessions. In gamification, teacher-trainees scored for attendance, delays, or absences from training, but above all, through three levels of scoring their tasks:

- Planning a weekly intervention in their educational context based on the content covered in the previous session
- Materializing a resource to learn in its educational context

- Application and reflection in the educational context of the plan and resource rehyphenate the face-to-face session

Subsequently, each teacher had the opportunity to present their testimony in each session, and there was a joint reflection on the application in their educational context to redefine transformations in their future pedagogical practice. The strategy at the base of the entire training model was the flipped learning pedagogical approach, which assumes the teacher executes, explores, takes ownership, and only then debates with the trainer about his doubts. The content was available on the platform to be analysed, and in the following sessions, it was debated and applied by teachers with their students during the week. (Figure 1).

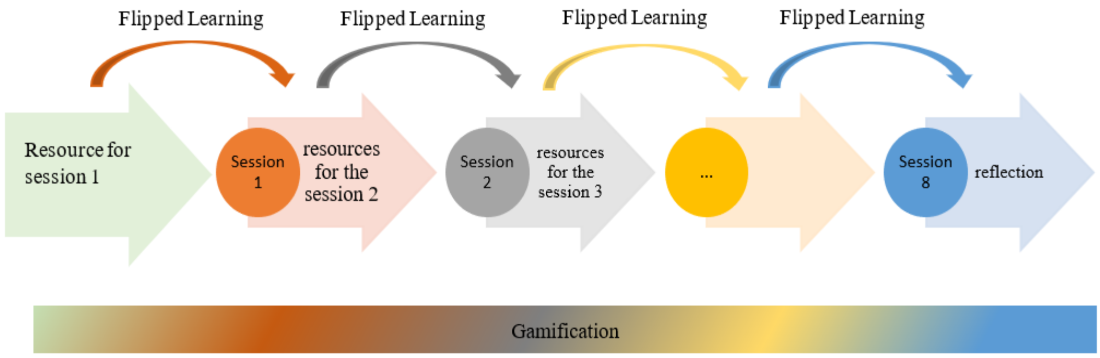

Figure 4. Process implemented in training

Each teacher created a digital diary that illustrated the entire training course, contributing to the teacher evaluation. The teachers were encouraged to move from the training course's theoretical perspective and abstract practice to the reality of their classes and respective teaching activities (Cruz et al., 2017). We designated the information of each teacher in the questionnaires Pi (i = 1 ...69). All materials and interactions since the first session were available on an online platform shared with the teachers. For training evaluation, we used a platform in which the attendance and absences were recorded to make the whole process transparent and objective. For each hour of absence from the training, the teacher loses 1 point; for each hour of training, the teacher receives 1 point. This means that the total value of points (25 corresponds to 5% of the attendance assessment).

Participants

Sixty-nine teachers (forty-nine females and twenty males) aged between twenty-six and fifty-four participated in this study. Nine of these teachers did not teach at the training time, as three were in political activity, and six teachers belonged to the board of the schools involved. Of these sixty-nine teachers, eight teach languages, thirteen teach arts, and the rest teach STEM areas (Science, Technology, Engineering and Mathematics).

Data collection

We applied two methods to collect data: (i) questionnaires and (ii) a diary to collect direct observations. The questionnaire was structured with nineteen affirmative items using the Likert scale. With these items, we seek to understand whether teachers use mobile devices and how they use them. We also sought to understand what advantages teachers attribute to mobile devices in education. The questionnaire was initially validated by experts and later with teachers not included in the sample but similar to the target audience.

We presented the study's objectives to the teachers, and We applied a questionnaire to diagnose teachers' perceptions about the use of mobile devices in the teaching and learning process. At the end of the training, we presented another questionnaire to submit the data for comparative analysis. We introduced the questionnaire to a statistical approach with which it is possible to synthesize data related to the sample (Fernandes, 1991). Both questionnaires included closed-response items using a Likert-type degree scale according to 5 points (from 1 = strongly disagree to 5 = strongly agree). The data were inserted into the SPSS (Statistical Package for the Social Sciences) software, statistical analysis, and data processing software and subjected to a descriptive analysis of the registered inputs. During the training, we directly observed all the participants involved in the tender recorded in a logbook.

Results and discussion

The constant technological evolution coupled with the need for continuous adaptation on the part of teachers puts it before concerns and challenges in their professional activity. In this context, throughout the sessions, we approached the themes of Mobile Learning, Flipped Learning and Gamification, which aroused interest in the teachers from the first session (Figure 2). These teachers were always very interested in the content presented and motivated to apply it. In general, the teachers were attentive and punctual, responsible for meeting the schedules, and most of them tried to meet the deadlines for delivering the proposed work.

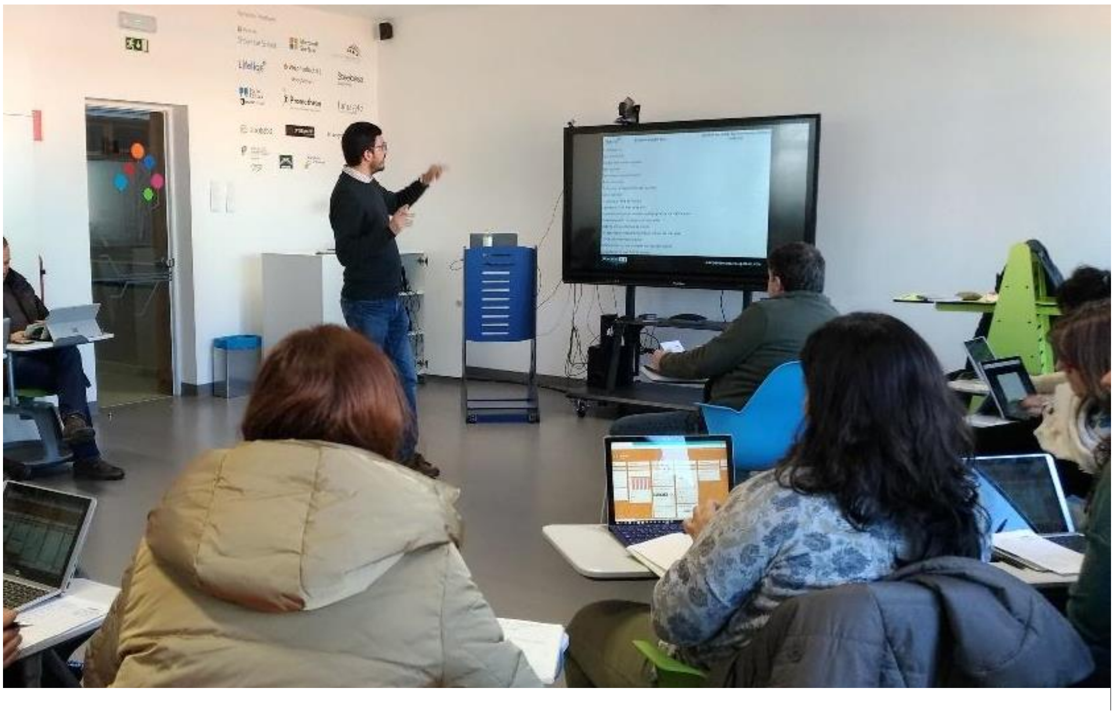

Image 12. A training session

The sessions (Figure 3) always took place in a practical, collaborative, and interactive way between the teachers, the trainer, and the training platforms. This schedule allowed each teacher to apply the content, and we managed to ensure the regularity of that application in a cyclical setup between training and practice.

Image 13. Teachers carrying out tasks with their smartphones

All teachers use the smartphone to communicate with their colleagues (calls, SMS, MMS). These teachers do not usually use certain smartphone features, such as the agenda and reminders to manage professional tasks. Regarding the use of the mobile phone to record relevant professional documents, teachers' opinions are divided, because thirty agree and four-three disagree. Most believe that the smartphone is a personal thing that we should not use in school. Despite this, fifty-eight teachers consider that we can use mobile devices in school activities. Also, sixty-two teachers see mobile smartphones as a pedagogical device that we should explore. Figure 4 shows teachers in one of the training sessions using mobile devices and an augmented reality application.

Image 14. Teachers on a task with smartphones using Augmented Reality

In the diagnostic questionnaire, teachers referred that mobile phone in the classroom can motivate students and be facilitated in tasks that support teaching. We realized that the training led teachers to know and admitted the potential of mobile phones in the classroom. Table 4 shows the responses of teachers who say that the use of mobile devices motivates learning.

Table 4. Potentialities of using mobile phones in the classroom initial questionnaire.

Dimension	Response type
Motivating	• Motivating students (P4). • Motivate students using a medium that is attractive to them and with which they feel more Comfortable working (P6). • Exploration of new pedagogical activities, more interactive and motivating (P9). • Motivate students, diversify/improve the teaching and learning process (P10). • Greater interest in the activities developed (P12). • Greater motivation and involvement (P17). • Motivate students to classes and make them more appealing (P15). • As previously mentioned, it can serve to motivate students and make classes more attractive (P23). • Students will be able to learn in a more fun way, using computer material (P24). • Capture attention (P33). • Make classes more interesting and dynamic (P57). • Motivation, greater predisposition for learning (P58).

Some teachers also consider that the use of mobile devices can improve student learning.

As for the potential, they consider that "motivates students" (P4), constitutes "a medium that is attractive to them and with which they feel more comfortable working" (P6), allows for "greater interaction with students and collaborative work" (P1), improves the "quality of teaching because students can use the information on the net and improve their knowledge, they can carry out interactive work with other colleagues and even other schools and at the international level" (P3). It also, Scarples, 2005, considers that mobile learning promotes active and personalized learning. Its use improves interactions between students and teachers to achieve better learning (Curum et al., 2021).

The use of mobile devices "favours the use of pedagogical apps and assessment of learning" (P5) allowing for "greater diversification/improvement of the teaching and learning process" (P10). In addition, "as it is a resource that is dominated by students, it can be very useful if guidance is adequate" (P17) and can keep "students motivated, sometimes" (P4, P10). The possibility for students to see information anywhere, anytime is an unquestionable advantage (Danish et al., 2019).

In Table 5 we show the responses of teachers who say that the use of mobile devices motivates learning.

Table 5. Potentialities of using mobile phones in the classroom initial questionnaire

Dimension	Response type
Knowledge	• Regardless of location, Internet or network access is available (P33). • Mobile devices open numerous possibilities to enrich the way content is transmitted, making classes much more attractive for 5G students. The use of augmented reality, for example, motivates students and improves content visualization because students can virtually experience something (P14). • Greater interaction with students and collaborative work (P1). • Improve the quality of teaching because students can use the information on the net and improve their knowledge, they can carry out interactive work with other colleagues and even other schools and at an international level (62). • Greater student involvement. Aid for project-based learning. Greater autonomy in learning and building knowledge. The element that favours learning (P45). • Quality of teaching because students can use the information on the net and improve their knowledge, can carry out interactive work with other colleagues and even other schools (P3).

	• Encourage students to learn through new technologies and create more and better means of interaction between teacher and students (63). • As it is a resource that is dominated by students, it can be very useful if the guidance is adequate (P17). • It allows gamified classes, motivating students more as this methodology is very close to their reality, allows students to have quick feedback on their learning, and diversify the methodologies in the classroom (P13). • In addition to keeping students motivated, it sometimes facilitates the teacher's work. For example, results can be automatically saved and can later be inserted into the students' assessment (P41). • The fact that students have their own material to use in the context of knowledge is fantastic for students (P25). • Use to explore resources in various applications, make videos... (P46). • Lead to student success, providing more dynamism (P51). • Access to a greater diversity of information (P36). • Augmented reality offers users an exciting time-saving experience (P41) • Students become familiarized and internalize the contents in a playful way, which enhances the acquisition of knowledge anywhere with access to the internet (P47).

Learning support platforms that "allow for gamified classes, motivating students more as this methodology is very close to their reality, allows students to have quick feedback on their learning and diversify methodologies in the classroom"

(P13), can be an "element that favours learning" (P45). Because "providing more dynamism" (P51) and "access to information and content" (63), “anywhere with access to the internet” (P47). Augmented reality not only makes mobile apps unique and innovative, but it also “offers users an exciting time-saving experience” (P41). The use of augmented reality through mobile devices can "motivates students and improves content visualization because students can virtually experience something" (P14).

Mobile devices "are the reality of the generation of students in our schools" (P22), “open up numerous possibilities to enrich the way content is transmitted, making classes much more attractive for 5G students" (P14), in addition the fact that "students have their own material to use in the context of knowledge is fantastic for students" (P25). These results are in line with Viberg et al. (2021), that through the analysis of contemporary research literature by, suggest implications for a sustainable mobile learning design. According to these authors, teachers are able to design effective mobile technology-supported learning experiences if: (i) clear are able to define well and explain the concepts of formal and informal; (ii) omitting representations related to representations of informal mobile learning like “spontaneous,” “democratic,” and “holistic,” for students; (iii) provide the solution for students in which students themselves are able to customize according to their learning habits, routines, and preferences. The world of education is working in an environment that is full of mobile devices, this finding allows mobile learning. In the mobile learning modality, students with mobile technologies in their hands, they can learn both in and out of the classroom, both at school and after school, enhancing formal and informal learning (Lencastre, et al., 2016).

We questioned the teachers again at the end of the training and the answers were the result of a reflection around Mobile Learning. According to these teachers, the use of mobile devices in an educational environment allows the development of essential functions for the 21st-century student, such as autonomy and creativity. They also admit that it can be an important aid for the teaching of their students for researching information, communication, registration, access to materials, facilitates the personalization of teaching.

Regarding the obstacles that they envisage, for more widespread use of mobile devices by teachers, they refer to "*lack of resources*" (P5), "*deficient Wifi coverage in schools*" (P10), "*lack of responsibility of students in the use of mobile devices and lack of computer knowledge by many teachers*" (P32). The "*incompatibility with the more traditional methods, expository classes, and school manual required a greater investment in the planning and preparation of classes*" (P15) or the fact that "*many teachers are not comfortable with using mobile devices in the classroom*" (P36) are pointed out by teachers as limiting the use of mobile devices. They consider that for more widespread use of mobile devices "*there should be an excellent organization of contents and tasks, so that time is profitable*" (P7), the fact that "*not everyone is prepared*" (P25) and "*lack knowledge and strategies to use them*" (P55) leads to teachers not using them. However, they consider that "*there is* *a great opening on the part of teachers to use mobile devices*" (P37) and with "*training*" (P51, P52) there will be "*preparation to deal with new technologies*" (P69). The "*constant need to create content*" (P44), the "*lack of infrastructure on the part of educational establishments*" (P6), the "*delay in assistance in the failure of equipment*" (P50), the "*lack of training for teachers for the use of mobile devices*"(P32) and "*some resistance on the part of parents and guardians*" (P25) means that mobile devices are not being used for educational purposes in schools. The following table shows the teachers' responses regarding the potential of using the mobile phone in the classroom at the end of the training (Table 6).

Table 6. Obstacles for more widespread use of mobile devices

Dimension	Response type
Equipment	• Incompatibility with more traditional methods. Requires greater investment in lesson planning (P3). • The mastery of use/work tools and strategies (P8). • The use of the mobile phone must be controlled by the teacher and this tool must be used as Delay in assistance in the failure of equipment (P50). • Some teachers do not master the new technologies (P24). • Different economic capacities of family groups, seconding the book and libraries (P17). • The biggest obstacles are the limitation of the number of mobile devices and internet access (P38). • The lack of computer material in schools and some resistance on the part of the parents (P23). • The internet network made available at the school (P54). • Deficient WIFI coverage in schools, lack of resources (P10). • Internet network failure (55).

	• The school's existing network coverage (44). • Lack of infrastructure on the part of educational establishments (P6). • Internet access difficulties in classrooms (P1). • Lack of necessary equipment for the number of users (P49). • The incompatibility with the more traditional methods, expository classes, and school manual requires a greater investment in the planning and preparation of classes (P15). • Lack of responsibility of students in the use of mobile devices and computer knowledge by many teachers, lack of training for teachers in mobile devices (P32).

Regarding the risks of using mobile learning in the classroom, the teachers refer to problems related to safety, the misuse of school resources by students, the misuse of resources, the lack of control of the class, and distraction, the misuse of social networks, the use of unauthorized internet pages.

Conclusion

This paper discusses using active methodologies such as AR, gamification and flipped learning combined with mobile learning.

The evolution of wireless technology and mobile applications is impressive, and mobile learning is exponentially playing an essential role in education today. For many teachers, mobile technology in education has become one of the most critical research and application areas because mobile devices have evolved remarkably. We noticed some teacher already use mobile phones in their teaching practice. They already recognized the importance of using mobile devices in their student engagement approach. Also, the technology students use daily can be combined with pedagogy under expert guidance. The teachers believe that the contents given in the training were excellent, and all teachers who participated in the sessions completed the training course. The unpredictability of equipment, the lack of internet access, and the lack of resources are the main difficulties teachers encounter when using mobile learning with their students. Our results are in line with the studies of Danish et al. (2020), according to which one issue that makes mobile learning challenging is the unpredictability of the learning context. Building an effective mobile learning environment for students to access anytime and anywhere can be challenging (Curum et al., 2021).

The implementation of AR is one of the emerging technologies that has aroused the most curiosity in the education sector. AR within a learning context brings many benefits as it allows learning on the real and virtual levels. Teachers showed a willingness to use mobile learning with their students; it would be relevant to understand how they do it to perceive the students' reception of this methodology. Teachers were also willing to use AR more with their students. AR should be well thought out and pedagogically appropriate (Pochtoviuk et al., 2020).

With this study, we perceive the teachers' perception; it would also be relevant to perceive the students' perception of this combination of methodologies and realize if students feel it is better for their learning.

Future investigations should focus more on analysing the combination of different active methodologies and realizing their potential. It is also recommended that in future studies, the teacher-student interaction can be perceived using these methodologies. How to take advantage of this interaction for skills development.

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STEAM ing ahead

Fostering critical thinking, problem-solving and creativity

8 EARLY CHILDHOOD & VIDEO TUTORIALS

VIII. Learn to teach in early childhood education with scientific video tutorials

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STEAM: Digital Creativity, Art, and Technology

Digital creativity in Science, Technology, Engineering, Art, and Mathematics (STEAM) begins in Early Childhood Education. This is the period when the mind prepares daily for future challenges, with and without ICT (Recio, 2021), thanks to exploration, play, socialization, manipulation, research, problem-solving, etc.

Typically, three methodologies are used in STEAM learning (Zamorano et al., 2018): education through design, project-based learning, and problem-based learning. Learning to solve problems through observation and trial-and-error experimentation will be a source of scientific competencies. When this occurs in the context of globalized activities, which allow seeing beyond the physical form, learning includes the creative view that promotes art, image, sound, and word. The transition from physical and material experience to the transcendence of the observed object and its possible meanings will be a subsequent step after early childhood education, but the foundations of this great edifice of learning and personal development can start to be laid.

Technology as a means to serve education is an aid to awaken curiosity, the first rung of the learning process. When mentioning resources used in early childhood education to work on STEAM, it's important to remember that it involves both disconnected and connected materials, as well as applications and programs.

As recently documented by researchers García-Fuentes et al. (2022), 71.2% of the content established for Early Childhood Education in Spain is related to STEAM. Therefore, they conclude that it is possible to design and apply projects since there is curricular content. However, they also point out the scarce presence of content on technology, engineering, and mathematics compared to science and art. Another important issue that should be noted in the STEM field are the stereotypes that assign these types of activities to men, due to the lack of female references (Prendes et al., 2021). Precisely, it is recommended to confront this reality with a scientific education that should start in Early Childhood Education, where the profession is also widely practiced by women.

Use of Educational Video in Audiovisual Culture

The use of educational video in audiovisual culture has supporters in favor, based on the need to develop media and informational literacy in children (Smahel et al., 2020), and opponents, due to the overexposure of children to screens (Christakis, 2018). However, the use of educational video has been a great ally in times of confinement and forced distance education due to the pandemic. It continues to be a powerful aid for people who need school reinforcement for any reason (illness, mobility, etc.) It is in this context that the flipped classroom methodology emerges (Santiago et al., 2018), as in response to school absenteeism, teachers decide to record their presentations and upload them to the Internet. The concept evolves as content increased, and while videos are used, virtual classrooms, podcasts, etc., are also incorporated. Classroom time is better optimized for research work, concept review exercises, and group work. In fact, as Talbert (2021) points out, the common mistake that leads to identifying this methodology or model with videos comes from a TED talk by the creator of the Khan Academy where he talks about using video to create a "flipped classroom."

Using videos to learn is part of the general use of technology for educational purposes. Within this rising trend, what tools do we have to work with this model? The narration of science. Storytelling is as old as humanity, but a new trend is detected in storytelling applied to the scientific field (Sánchez, 2019). It is precisely here that art and scientific content come together. There are events like the aforementioned TED talks, monologues, sessions given by teacher YouTubers, etc.

The feedback of creativity between media is something that feeds art and teachers. Professor Henry Jenkins (2012) defines this phenomenon, especially referring to the most contemporary examples, as "media convergence." According to Jenkins, this refers to the movement towards a world where every story, sound, relationship, brand, etc., is reproduced through as many channels as possible. Thus, for example, videos transcend the place where they are stored or edited to reach social networks. This phenomenon is another possible contribution to the improvement of teachers' digital identity. The new digital generations, already accustomed to media convergence as the norm, are the ones that shape an immense amount of cultural and entertainment content, as well as the way we consume it. Another relevant term in this case and related to digital content is the so-called "participatory culture," also by Jenkins. In his words, everyone is potentially a creator and producer of content (...) sharing with others what we create is mutually rewarding and gives us tremendous emotional satisfaction. This concept of participation applies directly to STEAM audiovisual creation projects, where participants do so as individual and group creators, sharing their work. Mitchel Resnick (2017) advocates a model that maintains stories, play, and imagination, which he calls “Lifelong Kindergarten” (kindergarten for life), due to its similarities with the type of learning that takes place at that educational stage.

Another opportunity for learning lies in the creation of materials. Far from requiring large budgets for materials and tools, the video creations by teachers involve minimal investment. Working with recycled and low-cost materials also supports the exercise of imagination in two ways: firstly, these limitations pose a challenge for students that will test their inventive capabilities. They must find ways to give new uses to everyday objects, extending the life of a material that would otherwise end up in the trash much sooner. Creativity and civic awareness are worked on, including the concept of a circular economy, making learning sustainable as well.

Digital Competence in Future Early Childhood Education Teachers

The need for STEAM requires investment in professional training. It is not enough to conduct motivation or dissemination campaigns, despite the growing interest in science among teachers (Chifli et al., 2020). Specific actions are necessary so that future students can develop skills that help them learn better and take care of themselves (Roig-Vila et al., 2021). Evidence of this is the impact of artificial intelligence on teaching-learning processes and the lives of minors. “One of the main challenges in this area involves linking the contents of these areas with social reality and everyday life problems.”

There are problems in the future teaching workforce with the design of STEAM activities, which according to Roig-Vila et al. (2021), should be resolved with greater investment in STEAM proposals from university studies that train future teachers. In this sense, the legal framework supports this training, as can be seen in the latest Spanish educational law (LOMLOE, 2020). Specifically for Early Childhood Education, the start of digital competence from 3 to 6 years old is noted: the process of digital literacy that involves, among others, communication and content creation through digital media. Specifically, it talks about "Experimentation and use of free and creative digital language."

For teachers, there is a Framework of Reference for Digital Teaching Competence (MRCDD), which is based on the European Framework of Digital Competence for Educators or DigCompEdu and adapts it to the Spanish context. This Framework has been recently revised (2022) in six areas: 1. Professional commitment, 2. Digital content, 3. Teaching and learning, 4. Evaluation and feedback, 5. Empowerment of students, and 6. Development of students' digital competence.

Description of the STEAM Experience

The following is a didactic experience that is part of a subject on educational technology for future Early Childhood Education teachers, named "Procesos de mellora e uso das TIC," framed in the module "Educational Processes, Learning and Development of Personality (0-6 years)." Prior to the practice described in this chapter, various digital experiences contribute to a STEAM approach. The context of the university curriculum includes different levels: legal and curricular. It starts with the Convention on the Rights of the Child (1989), which links minors with the media through their rights (freedom of expression, to be heard and to participate, to privacy, and to information); the General Comment 25 of the UN (2021) on children's rights in relation to the digital environment. The evolution of "media teaching" (UNESCO, 1982) from the famous Grünwald Declaration; at the international level, the Sustainable Development Goals (2030 Agenda), in Europe, the Digital Education Action Plan (2021-2027), and in Spain, the Recovery, Transformation and Resilience Plan (axis II of Digital Transformation): Education and Knowledge, Continuous Training and Capacity Development. C21. Modernization and digitalization of the educational system, including early education from 0 to 3 years. Within the framework of the Organic Laws 3/2018 on Personal Data Protection and guarantee of digital rights and Organic Law 8/2021 on comprehensive protection of children and adolescents against violence.

It is also fundamental to consider the priority framework in teaching provided by the educational law LOMLOE (2020), which literally states in its preamble “an integral understanding of the personal and social impact of technology, how this impact is different in women and men and an ethical reflection on the relationship between technologies, people, economy, and environment, which should be developed both in the digital competence of students and in the digital competence of teachers." At the regional level, Decree 150/22, for the organization and curriculum of early childhood education in our community of Galicia, along with the framework that governs digital teaching, such as the Digital Teaching Competence Reference Framework (2022). Along with the instrumental and curricular dimension, the knowledge base that underpins all the didactic reflection of the subject must be highlighted, along with the imprint of the Deontological Code of the Teaching Profession (2010) that accompanies teachers in their work journey.

From a curricular point of view, the university's transversal competence "Instrumental knowledge of information and communication technologies" justifies this didactic experience.

Justification of the Project

Early Childhood students see technology as something everyday, and specifically, audiovisual is present in all family devices. In fact, it is the usual mode of digital leisure: the consumption of animated videos. The inclusion of video in Early Childhood classrooms is understood, as this stage initiates children in learning all languages.

According to Royal Decree 95/2022, of February 1, which establishes the organization and minimum teachings of Early Childhood Education, the purpose of Early Childhood Education is to contribute to the integral and harmonious development of students in all their dimensions: physical, emotional, social, cognitive, and artistic, as well as education in civic values for coexistence. To this end, the following pedagogical principles are encouraged: meaningful and emotionally positive learning experiences and experimentation and play, which will be carried out in an environment of affection and trust.

Purpose and Objectives

The purpose of this project is to design a proposal that brings future early childhood educators closer to the creation of scientific video tutorials, providing them with tools for design and editing, as well as didactic guidance to ensure effective learning after viewing.

The objectives are set in relation to the subject:

- Acquire basic knowledge about audio-visual and computer media and the possibilities of ICT in education.
- Choose digital resources that contribute to the training process in minors.
- Modify existing materials to critically develop new resources with the help of digital technologies.
- Identify the main methodological trends in educational technology.
- Apply knowledge to increase digital competence in different contexts.
- Acquire training that reinforces their professional digital identity.
- Work collaboratively using digital resources.
- Create relationships of creative cooperation and service for the development of didactic resources.

- Formulate innovations and solve problems of media integration in practice.

The contents dealt with refer to the design of teaching proposals with educational software. For this, students are asked to:

1. Select area, objectives, and contents of the Early Childhood curriculum related to science.
2. Starting from the listed experiments and the book (Inexpensive Science Experiments for Young Children), select one of the following:

   - Bottles filled with cold and hot water to note the temperature difference.
   - Inflate balloons, float them with wool, and let them go. They will go upwards.
   - Use an overhead projector, place objects and recognize them by their shadow.
   - Recognize sounds of different materials.
   - Blow feathers, windmills, ping pong balls.
   - Build a telephone with 2 plastic cups and talk through it.
   - Make soap bubbles and blow through straws of different materials.
   - Inflate a balloon and release it.
   - Look through magnifying glasses.
   - Place paper clips on a paper. Pass a magnet behind and see how they move.
   - Recognize foods by smell.
   - Recognize objects by touch.
   - Objects that float and sink.
   - Plant beans, lentils...
   - Drop water with food colouring on the table and blow with a straw to move it.
   - In a glass jar, put sand, shells, water, and blue dye to see the ocean.
   - Crumple a newspaper and put it in an empty glass, tightly enough so that when turned upside down, it does not fall. Hold the glass upside down and dip it in a container with water. The newspaper comes out dry.
   - In a wide transparent jar, put 30ml of water, 30ml of oil, and 30ml of honey. Each liquid separates: the honey sinks, the oil floats, and the water stays in the middle.
   - A ball in a small bucket, tie a rope to the bucket handle and spin it in the air as fast as possible.

3. Create storytelling from an organized script in scenes, storyboard.
4. Choose a video tool and produce it with the insertion of didactic questions in the same.
5. Add activities from the video: H5p.org can be used.
6. Record a video tutorial executing the experiment, focusing on the learnings derived from it through didactic questions.
7. Consider the principles of Universal Design for Learning (UDL).
8. Reflect on the process of the practice, the video tool, and its applicability in Early Childhood (in the portfolio), and you can tweet the video #InfantilUSC #TIC. Publish the digital product and your reflections in the portfolio (the steps, discoveries, and the video also on Twitter).

To conclude, some examples of the product are offered, where creativity and didactic purpose combine to narrate a scientific story and encourage experimentation in Early

Childhood Education through videos. Thus, specific training in digital literacy is promoted among future early childhood educators.

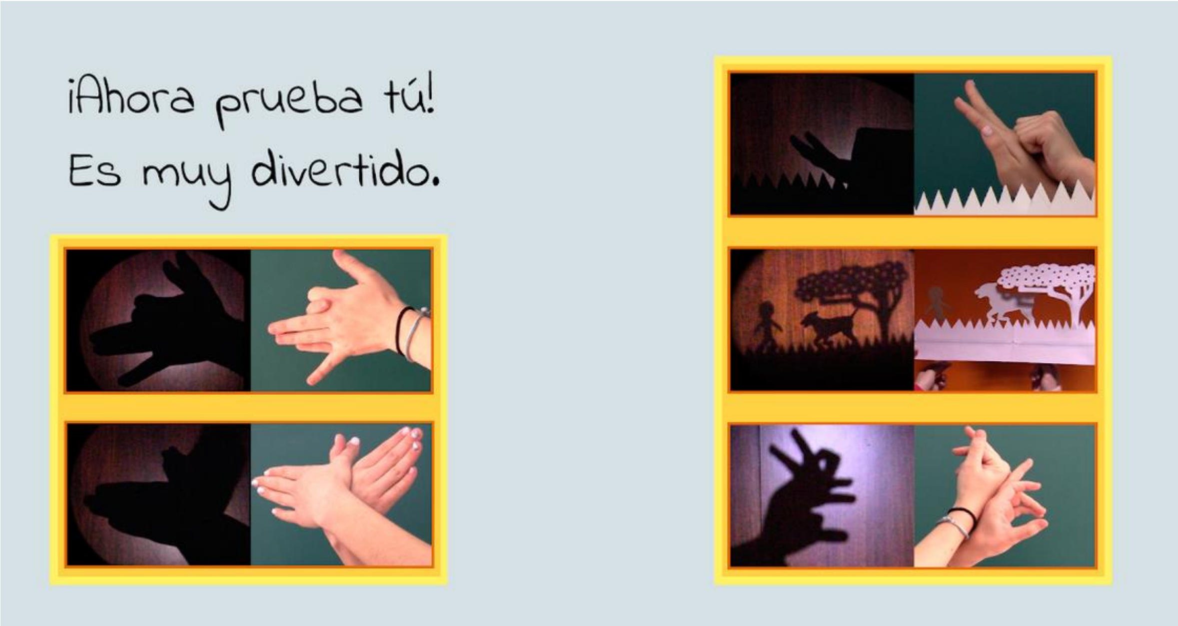

Image 15. Video tutorial on light and shadow. Extracted from here.

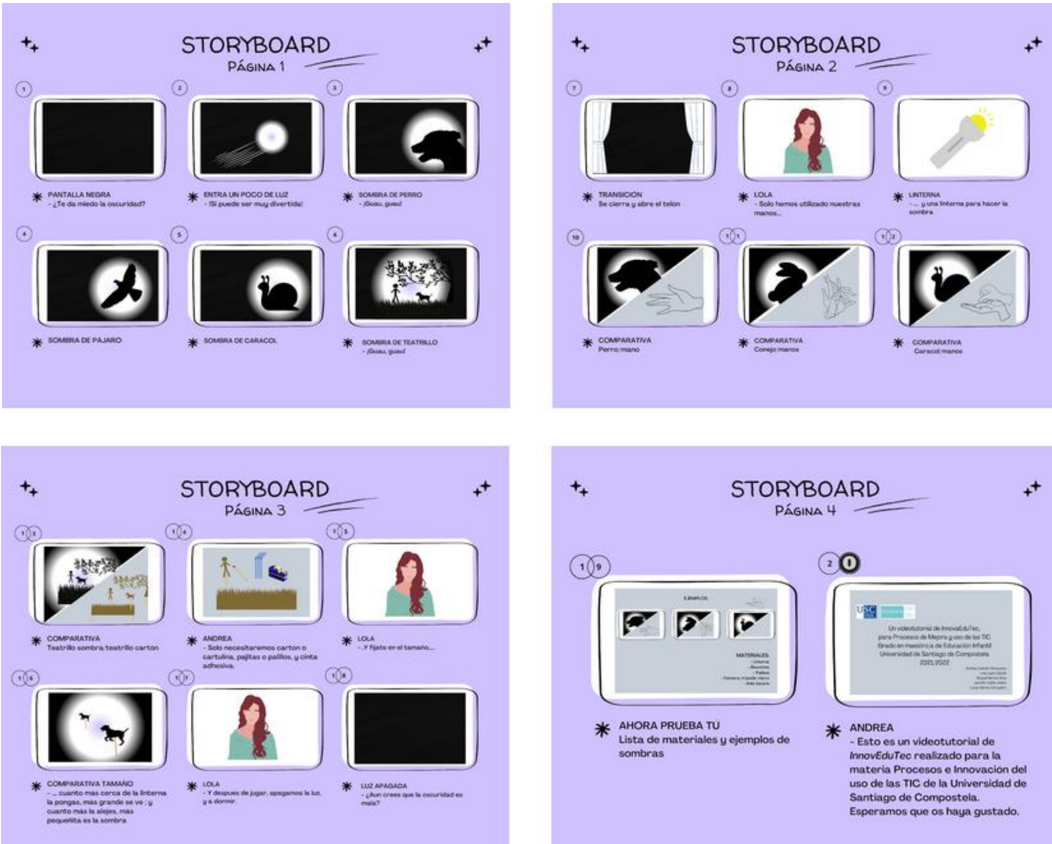

Image 16. Storyboard of the scientific video tutorial. Extracted from here.

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STEAM ing ahead

Fostering critical thinking problem-solving and creativity

9 EDUCATIONAL ROBOTICS

IX. Innovating Pedagogical Practices in Elementary Schools through Educational Robotics

REFEPESEC – an internship teacher training project

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Introduction

The increasing influence of digital technologies in schools, as well as how Digital Natives see them, emphasise the significance of educating children about technology careers while simultaneously emphasising the development of cross-cutting abilities for full citizenship, providing them with opportunities to develop the 21st-century skills needed to thrive in the modern workplace (eMedia. (2019, NYAS, http://www.nyas.org).

Using Educational Robotics in collaborative learning environments, in an interdisciplinary approach, can promote abilities including computational thinking, ICT skills, critical thinking, and social skills like, communication, and collaboration, between others. It also allows the integration of students' knowledge with STEAM subjects (eMedia, 2019, NYAS, www.nyas.org). The integration of Educational Robotics into the teaching and learning process can create a conducive environment for meaningful learning, using the creative, critical, and collaborative abilities of students (Perignat & Katz-Buonincontro, 2019). Additionally, it promotes interdisciplinarity, establishing connections between various STEAM disciplines and students' prior knowledge (Athanasiou et al., 2019; Kuhl et al., 2019).

Participation in Educational Robotics activities also positively influences refuting gender stereotypes, particularly in engineering professions, and contributes to achieving success. Consequently, the teachers, especially the internships, must be trained to incorporate Educational Robotics into their educational practices, making learning more meaningful, and playful, in line with the competence profile preponed in the national regulations, namely the Essential Learnings and Skill Profile of the Students (MEC, 2017; MEC, 2018). In this sense, the Educational Robotics in the Training of Educators and Teachers Project (REFEPESEC), located in the College of Education of the Polytechnic University of Coimbra, has been conceived as a program that pursues to solve this issue while also attempting to democratise the access to these technologies through low-cost Educational Robotics platforms.

Innovating pedagogical practices in elementary school

In this context, different pedagogical projects have been developed in various elementary school classes where future teachers are doing their internships. In this specific case, we would like to highlight a pedagogical experience carried out in a 2nd grade class, made up of 20 students, by a group of three trainees, from the master's degree in preschool education and Primary School Teaching, anchored in the Educational Robotics Project at the Polytechnic Institute of Coimbra.

This activity was designed to achieve the essential learning that had been recommended, and involved linking various curricular areas and promoting multidisciplinary activities within the scope of STEAM activities. The didactic sequence was themed "The Chocolate Cycle" and emerged from the student's interest and curiosity. In addition, this theme served as a centre of interest to address, at first, the professions related to Chocolate production and, later, to introduce other daily professions and their respective social services. This three-week project had as its main objective to provide significant and interdisciplinary learning of the various components of the Primary School curriculum, using Educational Robotics.

This learning was related to location and orientation in space, comparing objects with different magnitudes (mass), in mathematics; vocabulary, understanding written texts, classifying words according to the number of syllables, identifying the characteristics of a narrative text (Portuguese language), observation and identifying different types and constituents of plants (natural sciences) and recognizing institutions and services (social sciences). In addition to these, the aim was to develop reading and writing skills, as well as artistic expression, namely creativity and expression, and physical education.

Objectives and skills to be developed

Throughout the project, it was intended that the students acquire various learnings in the various components of the curriculum, of which we highlight:

- Promote students' autonomy, active participation, and creativity.
- Encourage collaborative work.
- Stimulate students' curiosity and interest.

- Categorise living beings according to observable similarities and differences (plants: root type, stem type, leaf shape, deciduous/persistent leaf, flower color, fruit and seed);
- Identify the constituents of plants.
- Relate institutions and services that contribute to the well-being of populations with their respective activities and functions;
- Develop spatial orientation in students;
- Program the robot to reach a certain position;
- Create low-complexity algorithms to solve specific challenges and problems;
- Understand the concepts of mass and volume;
- Compare the mass of different objects;
- Compare the volume of different objects;
- Promoting the taste for physical activity;
- Encourage moments of oral communication;
- Identify the characteristics of a narrative text;
- Speak clearly and articulate words appropriately;
- Read with correct articulation, intonation, and speed appropriate to the meaning of the texts. (MEC,2018; MEC. 2021).

Interdisciplinary educational practices

Based on the learning recommended in the curricular documents guiding educational practice, this project seeks to achieve integrated practices involving the connection and articulation of the various curricular subjects.

The first day was dedicated to contextualising the project. In this sense, a sensorial activity was promoted, in which the students, with their eyes closed, had to taste food (white chocolate, milk chocolate, or black chocolate) and guess the theme of the new project. Then, the narrative text "What fruit is this?", previously prepared by the trainee teachers, was distributed, to fill gaps in the text, throughout its reading. For a better understanding, an interpretation form was created, with questions about the text and tasks related to the constitution and characteristics of the cacao tree.

Subsequently, the book "The Chocolate Cycle" by Cristina Quental and Mariana Magalhães was read, to know the various stages of the chocolate production line in a factory. In this sense, an activity of plastic expression was promoted, in which the students had to cut and color representative images of the chocolate production process, ordering them according to the story presented.

The second day was dedicated to oral and written interpretation of an excerpt from the book presented. To introduce the professions, an order was received with a chocolate cake, which served as the basis for a big group conversation about the various professions involved in the production and marketing of chocolate, namely the farmer, the carrier, the factory operator, the distributor, the merchant, among others. In addition, the pastry chef who made it, the postman who delivered the cake at the school, and the teacher who received it were introduced. Therefore, it was possible to broaden the student's knowledge, approaching other professions and their respective services, performing tasks proposed in the “Study of the Environment” guidebook.

To reinforce the division’s sense of sharing, the students were asked about the division of the cake, so that all the elements of the class had an equal slice. Then, the class was asked to work on some words from the story, reading and writing their syllables, and, finally, classifying them according to the number of syllables (monosyllable, disyllable, trisyllable, and polysyllable), which were recorded on the board and their daily notebook.

The third day was dedicated to the presentation of texts prepared at home with the families, based on some guiding questions about the profession they would like to play in the future. Subsequently, research was carried out on the computers, to create a concept map about chocolate. Thus, each group was responsible for collecting different information about chocolate, namely about its production, its types of chocolate and ingredients, its nutritional value, and, also, foods from the daily diet that contained chocolate, in the end, each group presented their findings to the class.

Subsequently, a game about the professions was played and, at first, one of the students had to guess a profession presented, through clues given by the class. In a second moment, each student, using mime, had to perform gestures associated with a particular profession, so that the other colleagues could guess it.

On the fourth day, the concept of mass was introduced through the “Hypatiamat Mass" Applet, in a big group dynamic, and then, for a better understanding of the content, the mass of several objects was measured with the assistance of a dish scale.

Based on the foods mentioned in the concept map and its nutritional table, each student had the opportunity to measure the amount of sugar in each food. To reinforce this learning, tasks were carried out in the Math manual and workbook.

Image 17. Measurement the amount of sugar in food.

To integrate Educational Robotics, the trainee teachers made it possible for all the students to have contact with the robot Mind Designer, in groups of five elements, in a game about professions. Therefore, each student should guess the profession related to the clues contained in some cards, programming the robot to reach, initially, the image of the profession and, later, the respective service.

Image 18. Profession game with the robot Mind Designer.

Image 19. Comparison of the mass of various objects

On the fifth day, a playful activity was promoted, to compare the mass of different daily objects. Initially, for every two objects, students had to reflect and fill in a table of estimates, marking: heavier, lighter, or balanced. After their estimate, the objects were placed on the scales, confirming the veracity of their conceptions.

To encourage students to engage in physical activity, the game of the "scarf bar" adapted to the context was promoted, that is, instead of giving numbers to the players, professions were assigned. With this activity was intended for students to associate the profession assigned with the service provided by the trainee teacher, reinforcing the acquired knowledge.

To motivate the students, an activity involving ICT was promoted through a game on the Kahoot platform related to the story of the book "The Chocolate Cycle" and the information collected in the realisation of the concept map.

On the sixth day, the concept of volume was introduced, and an activity was carried out to compare the volume of different containers, filling them with sugar. Thus, for every two numbered containers, students had to fill in a table of estimates, marking: greater volume, lesser volume, or equal volume. After their estimates, the sugar was placed in the numbered containers, confirming the veracity of their conceptions. Given the students' difficulties with this content, it was necessary to carry out tasks in the Math manual and the workbook.

Image 20. Comparison of the volume of different containers

To reinforce the learning about the three fundamental parts of a narrative text, the text "Thomas' father's profession", built by the trainee teachers was distributed, to fill the gaps in the text and also identify the text: the introduction, the development, and the conclusion.

Formative evaluation of learning

Evaluation, from a pedagogical perspective, is fundamental in the teaching and learning process since it is essential in regulating student learning, as well as the professional practice of teachers. In this sense, moments of formative assessment were promoted, with the objective of students and teacher trainees reflecting on the tasks developed and the difficulties experienced, thus regulating their learning and the dynamics of the teaching and learning process. (Fernandes, 2019).

Therefore, students were assessed through direct observation, based on the descriptors provided in the official curriculum documents, namely the Profile of Students Leaving Compulsory School and the Essential Learning. In addition, the students completed an exploration sheet, in which they had the opportunity to identify and reflect on their difficulties in solving the proposed tasks.

Conclusion

After this pedagogical experience, we can consider that the use of robotics in the classroom is a potential tool in terms of awareness and operationalization strategies aimed at the acquisition of new knowledge and skills. In other words, children have contact with technology from an early age, and teachers should see this as an opportunity to innovate their practices.

In the context in which it was applied, Educational Robotics and ICT, as an innovative pedagogical practice, undoubtedly triggered greater interest and motivation in performing the proposed activities and in their dissemination to the class, having enabled the significant, integrated, and socializing learning expected.

Given this reality, it is essential to diversify teaching strategies and methodologies, promoting articulated, interdisciplinary, and innovative practices that enable experimentation and active and autonomous participation of students in the discovery of new knowledge. In this way, students remain truly involved in the tasks, acquiring meaningful, integrated, and socialising learning.

In short, programming and robotics can be fruitful tools, streamlined in an interdisciplinary, meaningful, and socializing, and presented in a gradual and challenging way. Consequently, it develops various skills in students, namely organisation and discipline, the spirit of cooperation, motivation for learning, the spirit of initiative and responsibility, and self-assessment of their performance.

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10

SUPERDOC ROBOT & EXPLORATORY TEACHING MODEL

X. The Exploration of the SuperDoc Robot through an Explanatory Teaching Model

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Introduction

The present work aims primarily to develop: mathematical learnings within the subtopic of Spatial Orientation in the Geometry and Measurement theme; the theme of Data and Probabilities, and the dimensions of Computational Thinking. To this end, a set of tasks was energized that encompasses not only the curricular area of Mathematics but also Portuguese and Environmental Studies. This set of tasks was designed for the 2nd-grade class that the trainee teachers followed within the context of Supervised Practice in Primary Education. In order to respond to the students' interests, they decided to also introduce Educational Robotics (RE), as it is a pedagogical tool that promotes significant learning (Pedro et al., 2017). The tasks are divided into three sessions, each of which was organized according to the four phases of the Exploratory Teaching model (Stein et al., 2008, cited by Canavarro et al., 2013). As it would be the first time the class would engage with this teaching model, and considering that the head teacher does not set a specific time for task completion, they decided it would be important to maintain this dynamic. Additionally, they considered it pertinent that the tasks should be divided into three sessions according to the learning objectives they aimed to develop.

To present a logical and coherent structure, this work is divided into five parts. Firstly, the literature review will be presented, highlighting the importance and contextualizing the evolution of Computational Thinking. The second part will concern the rationale and context, in which the practice implemented by the trainee teachers is contextualized, and they reflect on its importance in promoting mathematical learning. Next, the third part will refer to the description of the educational practice and its implementation, i.e., the practice is framed, and the respective planning is presented. In turn, the fourth part, the evaluation of the implementation of the practice and main results, will consist of a reflection on the results obtained and where some conclusions are drawn. Finally, in the fifth and last part, the main contributions of the educational practice proposal will be presented clearly.

Literature Review

The concept of Computational Thinking (CT) has been around for several decades. It was in 1980 that Papert first argued that children should develop logical reasoning processes, and for this, he created a programming language called LOGO (Grover & Pea, 2013). This programming language allowed the development of problem-solving skills.

In 2006, Jeannette Wing, a researcher at the National Science Foundation (NSF), published the article "Computational Thinking." In it, she stated that CT corresponds to a set of cognitive tools associated with computer science (Wing, 2006). Years later, in 2014, Wing reformulated her conception of CT, defining it as a process involving the formulation of problems and expressing their solutions, comparing humans with computers. In this sense, it was Wing who encouraged and drove the integration of this mathematical ability into the school curriculum (Grover & Pea, 2013).

Over time, Computational Thinking has undergone reforms, making it a concept that is not consensual among the scientific community (Ausiku & Matthee, 2021, as cited in Rodrigues et al., 2022). However, most definitions state that it is a "set of essential skills for problem-solving" (Ausiku & Matthee, 2021, cited by Rodrigues et al., 2022), which include critical thinking and algorithmic thinking of students (Özcan et al., 2021; Voon et al., 2022, cited by Rodrigues et al., 2022).

According to Canavarro et al. (2021), CT fosters the development, in an integrated manner, of practices such as "abstraction, decomposition, pattern recognition, analysis and definition of algorithms, and development of debugging and optimization habits." The "abstraction" dimension corresponds to the ability to select the essential characteristics or information from a given problematic situation (Angeli et al., 2019). The Computational Thinking dimension of "decomposition" allows the student to break down a complex problem into less complex tasks (Albuquerque, 2021). Meanwhile, the "pattern recognition" dimension, when developed, makes students capable of recognizing and identifying common features in the problem-solving process (Canavarro et al., 2021). The "debugging" dimension allows for the correction of errors, testing them, and thereby optimizing a solution (Canavarro et al., 2021). Finally, the "algorithmic" dimension promotes students' ability to develop a step-by-step procedure to address a problematic situation (Canavarro et al., 2021).

In 2021, Computational Thinking emerged for the first time in Portugal as a mathematical capability in the Essential Learning guidelines. This guiding document clarified that Computational Thinking does not have to relate exclusively to Mathematics, but can and should develop in various curricular areas (Moschella & Basso, 2020, cited by Rodrigues, 2022).

Computational Thinking is, according to Wing (2021), "a fundamental ability for everyone, not just for computer engineers" (p.2). It is an ability that includes a set of cognitive tools and allows building knowledge through research.

Integrated practices intentionally combine different curricular areas and are, according to Paixão (2015, cited by Rodrigues et al., 2015), indispensable in the 21st century as they develop in students' essential skills and competencies for their daily life. In an increasingly complex and unpredictable world, it is crucial for schools to be prepared to educate citizens for constant change. In this sense, and since some researchers cited by Sá & Paixão (2013) mention in their studies that schools have not evolved equitably in terms of scientific-technological knowledge and the development of educational policies, it is essential to rethink these policies and the quality of teacher training. According to Ponte (2012), didactic knowledge is divided into four interdependent dimensions. A teacher must have knowledge of Mathematics for learning, to be able to interpret and adapt the way of working with mathematics in the classroom, not limiting themselves to scientific knowledge (Ponte, 2012). On the other hand, the teacher must know the curriculum and know how to manage it according to their context (Ponte, 2012). The teacher must also have knowledge of students and their learning processes to try to respond to their interests, providing more meaningful learning (Ponte, 2012). Finally, the teacher must be able to design tasks, adopt strategies, organize student work, and evaluate to promote meaningful learning, demonstrating knowledge of their Teaching Practice (Ponte, 2012). These dimensions of didactic knowledge are presented in figure 1 below.

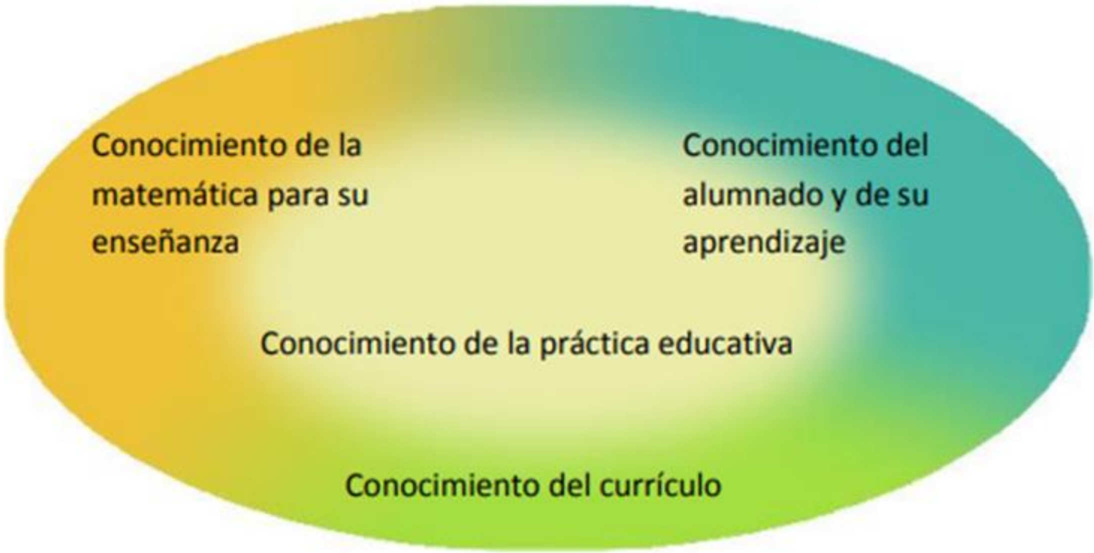


Figure 5. Dimensions of Didactic Knowledge (Ponte, 2012)

Key

- 'Conocimiento de la matemática para su enseñanza' – Knowledge of Mathematics for Teaching
- 'Conocimiento del alumnado y de su aprendizaje' – Knowledge of Students and Their Learning
- 'Conocimiento de la práctica educative'' – Knowledge of Educational Practice
- 'Conocimiento del curriculo' – Knowledge of the Curriculum

Foundations and Context

The Exploratory Teaching Model

The Exploratory Teaching Model was introduced to develop the dimensions of Computational Thinking. In this sense, and based on the interests of the class, proposals were made that involved Educational Robotics at the same time.

Exploratory Teaching is a teaching model organized in four phases (Stein et al., 2008, cited by Canavarro et al., 2013): task introduction, task realization, task discussion, and systematization of learning. In the first phase, the introduction, the goal is for the students to take ownership of the task. For this, the teacher must clarify and familiarize the students with the context of the tasks. In the task realization phase, all students must know how to work in groups to develop reasoning and advance in the tasks. The teacher, to ensure that students develop the tasks with mathematical quality, should circulate around the room and ask guiding questions that help them develop their reasoning. In the third phase, the task discussion, the aim is for one group of students to present their solutions and the others to feel confident to comment, comparing different reasoning. In this phase, the teacher should mediate student interactions and encourage them to compare solutions, developing critical thinking. In the last phase of the class, the systematization of learning, the teacher should systematize the learning acquired throughout the exploration and resolution of tasks through questioning (Canavarro et al., 2013).

This teaching model is distinguished by the roles played by the teacher and the students (Ponte, 2005, cited by Canavarro et al., 2013), throughout the four phases of the class, as previously mentioned. Each teacher is responsible for adapting and defining the learning objectives, taking into account the specificities of their class. For this, the teacher must select the tasks and respective strategies to be developed during the class.

The practice implemented over the three sessions, which will be presented later, is appropriate as we start from Exploratory Teaching to develop the dimensions of Computational Thinking (abstraction, decomposition, algorithmics, debugging, and pattern recognition). The five dimensions were developed through interdisciplinarity and the following tasks:

- "Indicate all the elements you think are important to make a cake." – Abstraction;
- "What is the path you take to collect the ingredients for your cake? Don't forget the cake has to go in the oven." – Algorithmics;
- "What other cake can you make? With what ingredients?" – Decomposition;
- "Do you think you could make other cakes with the ingredients on the mat? If so, which ones?" – Debugging;
- "What ingredients do these cakes have in common?" – Pattern Recognition.

During the weeks of observation, in the context of Supervised Practice in 1st grade CEB, it was noted that students had some difficulties in defining their laterality. In this regard, and in conversation with the cooperating teacher, it was decided to implement tasks within the scope of Educational Robotics, also developing Spatial Orientation.

Educational Robotics

Educational Robotics is a pedagogical tool that promotes significant learning, as the student plays an active role in their own learning (Pedro, A. et al., 2017). One of its contributions to the teaching-learning process is to make the student question, think, and seek solutions, developing problem-solving skills (Ribeiro et al., 2011). The use of Educational Robotics allows students to learn in a playful way, creating a motivating learning environment (Pedro, A. et al., 2017).

According to Benitti (2012), learning is not guaranteed simply by using Educational Robotics in the classroom. There are influencing factors such as the appropriate choice of the robot, the methodology used, the knowledge the teacher has about robotics, and the space available in the classroom for experimentation and movement of the robot (Oliveira, 2013).

Data and Probabilities

The topic Data and Probabilities, initially called Data Organization and Treatment (OTD) as stated in the Basic Education Mathematics Program (2007), emerged with the purpose of enabling students to "read and interpret data organized in the form of tables and graphs, as well as to collect, organize, and represent them to solve problems in various contexts related to their daily lives" (p. 26).

The New Essential Learnings (ME, 2021), in addition to including Computational Thinking as a transversal mathematical ability, renamed OTD to Data and Probabilities, making it a mathematical theme. The aim of Data and Probabilities is to develop in children the ability "to better understand their surroundings, make decisions, ask new questions, and approach uncertainty" (p. 10).

The 2nd grade class with which this work was conducted has been addressing this mathematical theme. In the week prior to this implementation, a table of absolute frequency about favourite fruit had been constructed collectively. From the data in this table, the students created pictograms and point graphs. Therefore, the ability to recognize and analyse an absolute frequency table was identified as prior knowledge. In this sense, session 3 focused on a task intended to develop one of the dimensions of Computational Thinking, so that, through the identified cakes, the students could create an absolute frequency table organizing the collected data.

Formative Assessment Technique

To understand whether the learning objectives were achieved throughout the tasks, the Formative Assessment Technique - Traffic Light Cards was used. Formative assessment is a type of evaluation aimed at "actively contributing to students learning more and better, with understanding and more depth" (Fernandes, 2021, p.4). Being an assessment for and as learning, it encourages active and intentional student participation in the teaching-learning process and the co-construction (teacher-student) of ways to monitor progress (Lopes & Silva, 2020, p.5). This type of assessment fosters responsibility and awareness in students, as they must be able to reflect on and evaluate their work (Lopes & Silva, 2020, p.19).

Description of Educational Practice and Its Implementation

Curricular Framework; Students' Prior Knowledge; Resources Used; Expected Duration; Evaluation

The Supervised Educational Practice of the 1st Cycle of Basic Education takes place at the Basic School of Assafarge with the cooperation of teacher Elisabete Pires. The class where the practice took place is 2nd Grade, consisting of 18 students, 10 being female and 8 being male. Overall, the class is quite interested, curious, and developed in terms of Reasoning and Problem-Solving skills. The students are capable of mobilizing reasoning, presenting logical and diversified problem-solving processes, making discussions more enriching and mathematically quality (ME, 2017, p. 23).

The primary goal of this practice is to promote the development of the dimensions of Computational Thinking through the theme Data and Probabilities, considering the Exploratory Teaching model. In this sense, an interdisciplinary proposal was developed, taking into account mathematical abilities and themes. The proposal emerged following the World Food Day and from a suggestion of the teacher based on the interests of the students. Thus, the trainee teachers proposed introducing a new type of text, the recipe, using Educational Robotics. Through the cake recipe, students were alerted to the necessary ingredients for baking a cake and how they can be substituted with healthier ones. A practical example used was replacing white sugar with brown sugar.

For the proposed tasks, students were expected to be able to: recognize quantities; understand spatial orientation concepts (right, left, front, and back); analyse and interpret an absolute frequency table. The resources needed for the three sessions were: exploration sheet - Resolution (Appendix 1); exploration sheet - Systematization (Appendix 1); writing materials; PowerPoint for systematization (Appendices 2 and 3); four SuperDoc robots; four educational mats; chalk; daily math notebook; ingredients for baking the cake; kitchen utensils (mixer, spatula; mug; spoon); Traffic Light Cards (TAF). The three sessions were planned for two days, corresponding to the context of Supervised Educational Practice. To assess the acquired learning, according to the previously defined learning objectives, the Formative Assessment Technique - Traffic Light Cards was chosen.

Organizational Design of the Learning Environment

The implemented educational practice was carried out over two days, but it is divided into three sessions. On Monday, the first part of the exploration sheet, corresponding to session 1, was completed, totalling 165 minutes. It was also possible to start session 2, the second part of the exploration sheet, totalling 100 minutes. The next day, the second session was concluded, totalling 115 minutes, and the third session was fully completed, resulting in 85 minutes.

During the three sessions, the room was organized into four islands, so four groups of four or five members were formed. Each island consisted of two tables to facilitate group work and the handling of the robot. Only during the third session was a table added at a strategic point so that all groups could observe and assist in the cake-making process.

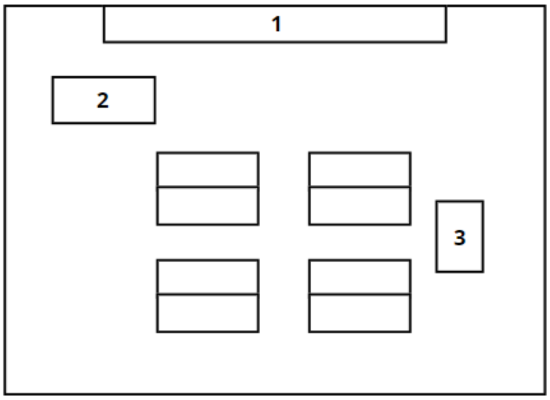


Figure 6. Representative Drawing of the Classroom Layout.

Key

1. Whiteboard
2. Desk of the Cooperating Teacher
3. Baking Table

Description of the Class Development

The set of tasks presented is divided into three sessions. Since the implemented proposal is interdisciplinary, each session initially presents a table containing learning objectives from the mentioned curricular areas.

Session 1

Grade Level	Curricular Area:	Duration
2nd Year	Mathematics	165 minutes

Previous Knowledge	Resources
Recognize quantities.	· Exploration Sheet – Resolution: Part 1 (Appendix 1) · Exploration Sheet – Systematization: Part 1 (Appendix 1) · Writing materials · Systematization PowerPoint (Appendix 2)

Curricular Area	Domain	Contents	Learning Objective	Competence Areas of the Student Profile
Portuguese	Orality	Comprehension	Select relevant information according to the objectives for the task.	A. Languages and Texts B. Information and Communicatio n E. Interpersonal Relationship F. Personal Development and Autonomy I. Scientific and Technical Knowledge.
	Reading and Writing	Reading	Understand the meaning of texts with narrative and descriptive characteristics, associated with different purposes (recreational, aesthetic, informative). Identify explicit information in the text. Identify and refer to the essentials of read texts.	
		Writing	Write short texts for various purposes (narrate, inform, explain).	

Theme		Topic	Subtopic	Learning Objective	Competence Areas of the Student Profile
Mathema tical Themes	Numbers	Numerical Relations	Basic Multiplication Facts	Understandin g the Doubles of Numbers.	D. Critical Thinking E. Interpersonal Relationships F. Personal Development and Autonomy I. Scientific Knowledge.
Mathematical Skills		Computatio nal Thinking	Abstraction	Extracting the Essential Information from a Problem.	

<table>
<tr><th>Phase of the lesson (Time)</th><th colspan="2">Description of the lesson development</th></tr>
<tr><td rowspan="4">Introduction of the task (15 minutes)</td><td colspan="2">Lesson development</td></tr>
<tr><td colspan="2">Organization of students into four groups of four or five members.
Distribution of exploration sheets (Part 1) to each group.
Presentation of tasks to be performed and brief explanation of the work methodology, the Exploratory Teaching model.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>Present the tasks to the class, ensuring understanding by all students:
Familiarize with the context of the task;
Clarify the interpretation of the task.</td><td>Organize the students, taking into account their level of development, forming heterogeneous groups.
Divide the classroom into four islands.
Distribute the exploration sheets.
Explain the working methodology to the whole group.</td></tr>
<tr><td rowspan="4">Task Execution (70 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">Students solve the tasks from Part 1 of the exploration sheet in groups, knowing that all members must participate actively. In each group, it's important to have good communication, knowledge sharing, and reach a consensus to decide on the answer that best suits the question posed.
The trainee teachers circulate around the classroom to observe the different reasoning of the students and to clarify any doubts, in order to select the groups that will present their solutions.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>Ensure that the students solve the tasks.
Ask for justifications for the given answers.
Question the members of each group about the presented solutions.
For Task 1: “What did you extract from the text to affirm that it's a recipe?"
For Task 2: “Why did you order it this way?"
For Task 3: “Where can you find this information?"
For Task 4: “What information do you consider important for solving the problem?"
“How did you think?"
“What led you to think this way?"</td><td>Move around the groups and observe the resolutions.
Question the students, helping them solve the questions.
Provide moments of interaction among the group members.
Remind them that they are expected to work as a group, contributing to the resolution of the problematic situation.
Reinforce the importance of recording their reasoning on the exploration sheet.
Identify and select the various resolutions (different reasoning and difficulties) for later discussion and presentation of the answers.</td></tr>
<tr><td></td><td colspan="2">Development of the Lesson</td></tr>
</table>

Discussion of the task (20 minutes)	In the different questions, different groups are selected, with selection criteria based on errors, difficulties, and reasoning. In addition to the selected group, the others provide comments according to their reasoning. The discussion is mediated by the teachers.	
	Promotion of mathematical learning	***Classroom management***
	– Ask them to clarify and justify their solutions. – Encourage interactions between the presenting group and the other groups. – Question the students about the different reasoning used for the same question. – Encourage students to compare the various solutions presented by the groups.	– Create a conducive environment for presentation and discussion. – Define a presentation order. – Inform that the presenting group should explain their reasoning clearly. – Promote and manage student participation in the discussion.
Mathematical learning systematization (60 minutes)	***Development of the Lesson***	
	Presentation of the teachers' proposed solutions through a PowerPoint. Recording the solutions presented on new exploration sheets, distributed in advance.	
	Promotion of mathematical learning	***Classroom management***
	Systematize the acquired knowledge: Extract the necessary information from a problem (abstraction); Orally question the students about the answers to each task.	– Create a conducive environment for the systematization moment. – Distribute the new exploration sheets. – Project the solutions to the tasks. – Ensure the written recording of the proposed solutions.

Session 2

Grade Level	***Curricular Area:***	***Duration***
2nd Year	Mathematics	215 minutes

Prior Knowledge	***Resources***
Recognize concepts of spatial orientation (right, left, front, and back).	Exploration Sheet – Resolution: Part 2 (Appendix 1) Exploration Sheet – Systematization: Part 2 (Appendix 1) 4 SuperDoc robots + 4 Pedagogical Carpets (Attachment – Figure 2) Writing materials Systematization PowerPoint (Appendix 3)

Curricular Area	***Domain***	***Contents***	***Learning Objective***	***Competence Areas of the Student Profile***
Portuguese	Oral communication	Comprehension	Select relevant information based on the task's objectives.	G. Information and communication

				I. Scientific, technical, and technological knowledge
Study of the Environment	Nature		Reflect on behaviours and attitudes that contribute to individual and collective physical and psychological well-being, whether experienced or observed. Identify situations and behaviours that pose risks to individual and collective health and safety, proposing appropriate preventive and protective measures.	C. Languages and texts D. Information and communication F. Personal development and autonomy I. Scientific and technical knowledge

Theme		***Topic***	***Subtopic***	***Learning Objective***	***Competence Areas of the Student Profile***
Mathematical Topics	Geometry and Measurement	Spatial Orientation	Routes	Create and represent routes using the terms "turn right," "turn left," "up," "down," and "forward" to reach your destination.	C - Reasoning and problem-solving D - Critical and creative thinking E - Interpersonal relationships F - Personal development and autonomy I - Scientific, technical, and technological knowledge J - Awareness and mastery of the body
Mathematical Abilities		Computational Thinking	Abstraction Decomposition Pattern Recognition Algorithmic Thinking Debugging	Extract essential information from a problem. Structure problem-solving into stages of lower complexity to reduce the problem's difficulty. Recognize or identify patterns in the problem-solving process and apply effective ones to solve similar problems. Develop a step-by-step procedure (algorithm) to solve a problem so that it can be implemented in technological resources, even if it is not necessarily implemented. Seek and correct errors, test, refine, and optimize a given solution presented.	

<table>
<tr><th>Phase of the lesson (Time)</th><th colspan="2">Description of the lesson development</th></tr>
<tr><td rowspan="5">Introduction of the task (10 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">Organization of students into four groups of four or five members each;
Discussion about the precautions to take when handling the robots and educational mats;
Distribution of exploration sheets (Part 2) to each group.
Presentation of tasks related to Part 2 of the exploration sheet.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>- Clarify the interpretation of the task.
- Remind students of the precautions to take with the robots and educational mats:
"Do not scratch or dirty the educational mats."
"The materials do not belong to us and were borrowed, so we should return them as we received them."
"The robot is not a toy."
"Pay attention to the instructions you give to the robot to prevent it from falling and breaking."</td><td>- Organize students, taking into account their learning pace, forming heterogeneous groups, considering students with Specific Needs, integrating them into groups with students whose learning pace and reasoning ability are more developed.
- Divide the room into four islands.
- Distribute the exploration sheets.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="4">Task Execution (120 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">Students solve the tasks of Part 2 of the exploration sheet in groups, knowing that all members must participate actively. It is important for each group to have good communication, share knowledge, and reach a consensus to decide on the answer that best fits the question posed.
The trainee teachers circulate around the room to observe the different reasoning processes of the students and clarify any doubts, selecting the groups that will present their solutions.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>- Ensure that students solve the tasks.
- Clarify doubts.
- Question the members of each group about the resolutions presented:
Task 1 "What are you doing?"; "How did you figure this out?"
Task 2 "What path are you going to take?"; "Have you thought about all the steps you need to take? And how will you represent them?"; "Did you follow all the instructions?"; "Did you manage to make the path you had in mind with the robot?"
Task 3 "What other cake did you think of making?"; "What ingredients do you need?"; "Why that cake and not another one?"; "Did you gather all the ingredients for your cake?"
Task 4 "Can you make other cakes?"; "With what ingredients can you make them?"
Task 5 "What does 'in common' mean?"; "What are the common ingredients?"</td><td>- Circulate among the groups and observe the resolutions.
- Question the students, helping them to solve the questions.
- Provide moments of interaction among the group members.
- Remind them to work in groups, contributing to the resolution of the problem situation.
- Emphasize the importance of recording their reasoning on the exploration sheet.
- Identify and select various resolutions (different reasoning and difficulties) for later discussion and presentation of answers.</td></tr>
<tr><td rowspan="2">Discussion of the task (25 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">In different questions, different groups are selected, with selection criteria based on errors, difficulties, and reasoning. In addition to the selected group, the rest comment according to their reasoning.
The discussion is mediated by the teachers.</td></tr>
</table>

<table>
<tr><td rowspan="2"></td><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>- Ask them to clarify and justify their resolutions.
- Encourage interactions between the presenting group and the other groups.
- Question the students about the different reasoning used for the same question:
"Do all groups think this way?".
"Does any group have a different resolution?".
"Did they find more solutions?".
- Encourage students to compare the various solutions presented by the groups.</td><td>- Create a conducive environment for presenting and discussing resolutions.
- Define a presentation order.
- Inform that the presenting group should explain their reasoning clearly.
- Promote and manage student participation in the discussion.</td></tr>
<tr><td rowspan="4">Mathematical learning systematization (60 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">Presentation of the trainee teachers' proposed solutions through a PowerPoint.
Recording of the solutions presented on the new exploration sheets, distributed in advance.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>Systematize the acquired learning:
Clarify the robot's functions (arrows, trash, star, on/off);
Relate spatial orientation to reality (our body) and the robot through concrete examples.
Understand that there are different reasoning processes for solving the same problem.</td><td>- Create a conducive environment for the systematization moment.
- Distribute the new exploration sheets.
- Project the resolutions of the tasks.
- Ensure the written recording of proposed solutions.</td></tr>
</table>

Session 3

Grade Level	***Curricular Area:***	***Duration***
2nd Year	Mathematics	85 minutes

Prior Knowledge	***Resources***
Analyze and interpret an absolute frequency table.	Chalk. Writing materials. Mathematics daily notebook. Ingredients for making the cake. Kitchen utensils (mixer, mug, spoon). Traffic Light Cards (TAF).

Curricular Area	***Domain***	***Contents***	***Learning Objective***	***Competence Areas of the Student Profile***
Portuguese	Reading and Writing	Reading	Understand the meaning of texts with narrative and descriptive characteristics, associated with different purposes (entertainment, aesthetics, informative). Identify and mention the essentials of read texts.	A. Languages and texts B. Information and communication

Theme	***Topic***	***Subtopic***	***Learning Objective***	***Competence Areas of the Student Profile***

Mathematical Topics	Data	Statistical Questions, Data Collection, and Organization	Data collection Table of absolute frequencies	Collect data through a given data collection method. Use a table of absolute frequencies to organize data related to the cake they would like to taste.	A. Languages and texts B. Information and communication C. Reasoning and problem solving I. Scientific knowledge

Assessment of the Lesson
Formative Assessment Technique – Traffic Light Cards, taking into account the following questions: - Did they work well in groups? - Did they understand all the robot's functionalities? - Were they able to program the robot according to the path they had in mind? - Did they enjoy the tasks? - Would they like to work this way again?

<table>
<tr><th>Phase of the lesson (Time)</th><th colspan="2">Description of the lesson development</th></tr>
<tr><td rowspan="4">Introduction of the task
(5 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">Organization of students into four groups of four or five members, maintaining the same groups from the previous session.
Discussion about the different cakes that could have been made using the elements present on the educational mat.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>- Remind students of the elements present on the mat and the answers they provided regarding the recipes that could be made.
"Do you remember the recipes you suggested besides the orange cake?"
"What other cakes can we make?"</td><td>- Inform students that they should remain in the same groups as the previous session.
- Divide the classroom into four islands.</td></tr>
<tr><td rowspan="4">Task Execution
(20 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">The teachers record on the board the different cakes that can be made, as students identify them.
The identified cakes will be used to create a frequency table with the title "The cake I would like to taste...".
Students take turns going to the board to select the cake they would like to taste.
Later, students will count the total number of votes for each cake.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>- Ensure that all students participate in the construction of the frequency table.
- Question students about the organization of data in a frequency table.</td><td>- Question students about their preferences.
- Manage student participation.
- Record on the board the different cakes mentioned by the students.</td></tr>
<tr><td rowspan="4">Discussion of the task
(10 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">The students observe and analyse the table to deduce the votes for each cake, subsequently identifying the most voted cake. This cake will be prepared by all.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>- Ensure that students correctly analyse the data present in the table.
- Question students about which cake they think we will bake.</td><td>- Create a conducive environment for discussion.
- Manage student participation.</td></tr>
<tr><td rowspan="2">Mathematical learning systematization
(50 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">The students record the frequency table "The cake I'd like to taste..." in their daily maths notebook.
The student teachers, guided by the students' indications, prepare the cake.
Implementation of the Formative Assessment Technique - Semaphore Cards.</td></tr>
</table>

	Promotion of mathematical learning	*Classroom management*
	- Encourage student participation. - Ask students orally: "What is the first step in the preparation method?" "After separating the egg whites from the yolks, what comes next?" "How many cups of sugar?" "How do we know when the egg whites are well beaten?" "And now, where are we going to make the cake?"	- Create a conducive atmosphere for the systematization moment. - Ensure the written record of the frequency table. - Manage student interventions.

Student Learning Regulation

To promote mathematical learning in students, various strategies were adopted throughout the four phases of the Exploratory Teaching model. These encompassed clarifications and guiding questions to ensure that students understood, interpreted, solved, and presented their reasoning with mathematical quality.

During the sessions, the introduction phase was characterized by ensuring that students understood the context of the tasks. In the task performance phase, it was intended that all students participated in the development of the task. This development was ensured by the student teachers circulating among the different groups and asking guiding questions such as: "Where can you find that information?"; "How did you think?"; "Did you follow all the instructions?"; "Why that cake and not another one?"; "Can you make other cakes?"; and "What does 'in common' mean?". These maintained the cognitive challenge and the students' autonomy. The task discussion phase involves promoting the mathematical quality of the students' presentations. For this, the groups that were not presenting their solutions commented and compared the different reasonings to clarify the ideas presented or to clarify doubts. Regarding the last phase of the class, the systematization of learning, it aims to systematize the learning acquired throughout the exploration and resolution of tasks. Thus, in a large group, students were orally questioned about the solutions, and as they responded, our solution was presented. This presentation was made through a PowerPoint prepared by the student teachers. Thus, the student teachers could perceive the students' understanding of what was done, having clarified doubts with real situations.

The implementation of this educational practice concluded with the Formative Assessment Technique - Traffic Light Cards. For this TAF, the following questions were considered: "Did you know how to work in a group?"; "Did you understand all the functionalities of the robot?"; "Were you able to program the robot according to the path you thought of?"; "Did you like the activity?"; and "Would you like to work this way again?". The questions were asked in a large group, and each student responded with a red card (no), a yellow card (somewhat), or a green card (yes).

Regarding the evaluation by the student teachers, we based it on the Assessment Grids present in Lopes & Silva (2020). The assessment grid (Appendix 4) aimed to evaluate the students' competencies, with criteria such as participation, cooperation, relationship, reasoning, expressing ideas, arguing, and individual commitment. The assessment scale includes the levels Insufficient, Sufficient, Good, and Very Good (Appendix 5).

Evaluation of the Implementation of the Practice and Main Results

Assessment and Reflection

In planning this educational practice, the student teachers encountered some difficulties. These difficulties were: introducing a new teaching model, both for the student teachers and our students; planning interdisciplinary practices; formulating the questions to be present in the exploration sheet and the strategies to be adopted, with the implementation aiming to develop the dimensions of Computational Thinking.

During the implementation of the educational practice, the student teachers were confronted with challenges, among which stand out: group work, formulating guiding questions, and the students' frustration. Since the class usually did not work in small groups, the student teachers understood the importance of developing "self-confidence, motivation to learn, self-regulation, initiative and making informed decisions" and that they could "recognize, express and manage emotions, build relationships, establish goals." (ME, 2017, pp.25-26). In this sense, the student teachers chose to carry out group tasks providing students with moments of sharing conceptions and reasoning (Oliveira et al., 2013). Thus, one of the difficulties that the student teachers had to overcome was formulating simple guiding questions, maintaining the cognitive challenge, forcing the students to be autonomous and to try to find an appropriate answer (Stein et al., 2008, cited by Oliveira et al., 2013). The fact that the student teachers maintained the cognitive challenge in the work developed by the students in small groups, considering that they were familiar with questions that lead to direct answers, led them to frustration. This frustration was one of the biggest challenges for the student teachers. Thus, the role of the student teachers was crucial to help students understand the benefits of collaborative learning. It is also added that another determinant aspect was the choice of the exploratory teaching model to implement the educational practice.

From the implementation of this practice, the student teachers highlighted that they had to make some adjustments, such as in the systematization of learning phase where they had to change the initially planned strategy. The objective of this phase was to ensure that the students had achieved the defined goals and, for this purpose, the student teachers used oral questioning. Thus, to systematize the learning, it was intended that students would subsequently copy the presented solutions onto the systematization sheets. However, in the first session, the student teachers realized that the students were not participating as expected. For this reason, in the second session, the student teachers asked the students to only copy the solution for some tasks, while the rest were answered orally.

Introducing the Exploratory Teaching model in the 2nd-grade class was indeed a valuable addition, as the students were able to present various reasoning and explain them clearly to the rest of the class. This teaching model allowed not only the development of the dimensions of Computational Thinking but also the competencies of the Students' Profile at the End of Compulsory Schooling. Among the various competencies, emphasis is given to the following: Critical and Creative Thinking; Reasoning and Problem-Solving; Scientific, Technical, and Technological Knowledge; Interpersonal Relationships; Personal Development and Autonomy (ME, 2017).

Presentation of Main Results

The Exploratory Teaching model allowed students to build their own knowledge through sharing ideas within the group (Oliveira et al., 2013). This sharing was promoted by managing and guiding the group so that all members participated, presenting their reasoning clearly. We highlight below the tasks that generated the most doubts and a greater diversity of reasoning.

In the task "Indicate all the elements you think are important to make a cake.", the groups initially showed some difficulty in interpreting what "elements" meant. Through the following dialogue excerpt, we can understand that the students in this group tried to extract the essential information from the problem. In this case, as it was a recipe, they managed to identify the important elements, the ingredients.

Group	*Reasoning*	
Group 4	A Student:	All of them.
	A Student:	Wait! Eggs first, because I always see my mom adding them.
	A Student:	Yes, there must always be eggs.
	A Student:	Eggs, orange... yes, because it's an orange cake.

During the execution of this task, the students developed some of the intended competencies (Martins et al., 2017), such as critical and creative thinking as well as interpersonal relationships, as they debated various ideas to reach the final answer. We highlighted this excerpt because we found it interesting that they mentioned the ingredients in the order as their mothers usually do.

The task "This recipe is for 4 people. If you want to make it for 8 people, what do you have to do?" was the one that caused the most disagreement and therefore provided moments of debate among the members of each group. This task tested the students' ability to share, have a critical spirit, listen, respect, and accept different proposals (ME, 2017), as well as reach a consensus on the answer they would present. We highlight some of the solutions presented to us and the reasoning that led the groups to these conclusions.

Group	Reasoning	
Group 1	Intern Teacher:	So, if you have to make a cake for 8 people...
	A Student:	We have to draw the ingredients!
	Intern Teacher:	What are you doing?
	A Student:	Drawing the eggs.

<table>
<tr><td></td><td>Intern Teacher: But how are you planning it?

A Student: The cake will need 6 eggs, but if it's for 8 people, it will need 12 eggs.

Intern Teacher: Why?

A Student: Because 6 plus 6 is 12.

A Student: And how many cups of sugar will it be?

A Student: It has to be two. It has to be the same number more than before.

Intern Teacher: Why? Did we increase or decrease the number of people?

A Student: Since we increased the number of people, we have to increase the ingredients.

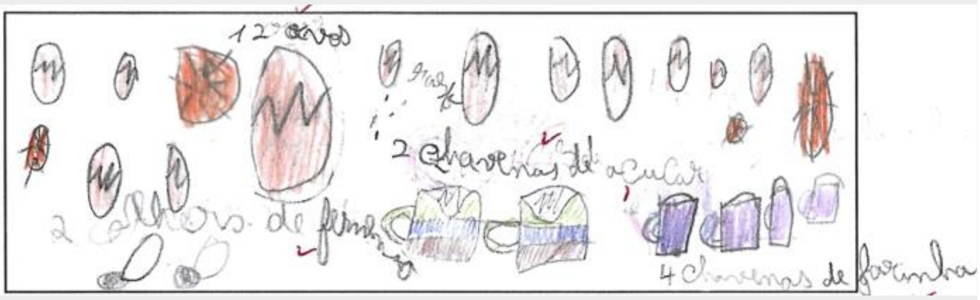
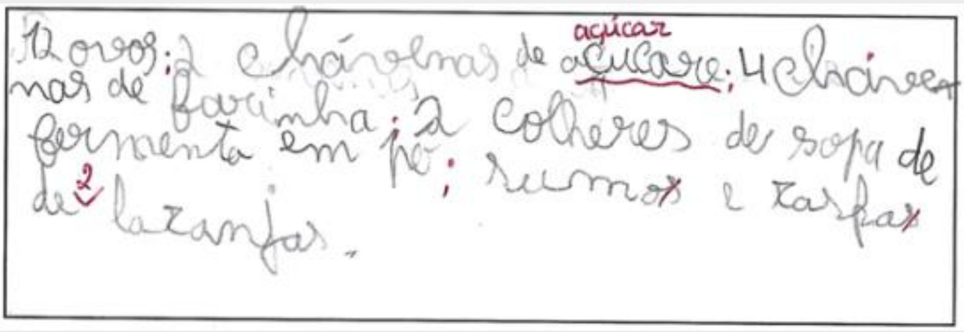


Figure 3. Group 1 Solution.</td></tr>
<tr><td>Group 2</td><td>Intern Teacher: What are you going to do? Explain your reasoning.

A Student: I think for 8 people, it should be one more than it is. Instead of 6, it's 12 eggs.

A Student: I don't think that's right. That would be for 1 extra person.

A Student: If it's for 8 people, let's make it for 4 more. Add 4 more to everything.



A Student: Okay, so instead of 6 eggs, we add another 6. Instead of 1 cup, it's 2...

Figure 4. Group 2 Solution.</td></tr>
<tr><td>Group 4</td><td>A Student: Add baking powder, it will make it rise.</td></tr>
</table>

	A Student: I don't know how to draw baking powder. Intern Teacher: What do you need to do? A Student: Make two cakes. A Student: If one cake serves four people. Another cake will serve eight. A Student: I was going to make one cake, but with double the size. Since not everyone agreed, we decided to make two cakes.

Figure 5. Group 4 Solution.

The last task "What ingredients do these cakes have in common?" raised some questions about the meaning of the term "in common". Once they understood its meaning, they easily resolved the question. However, there were groups that mentioned the oven as an ingredient, as we highlight below.

Group	Reasoning
Group 3	Intern Teacher: What does "in common" mean? A Student: It means having the same thing.
Group 4	A Student: Flour, baking powder, and oven. Intern Teacher: Did you read the question properly? It's about ingredients! A Student: Eggs, white sugar, flour, baking powder, the oven.

In this task, the dimension of Computational Thinking, Pattern Recognition, is evident, as the students recognized and identified the ingredients that are common among the cakes that could be made using the images on the educational mat.

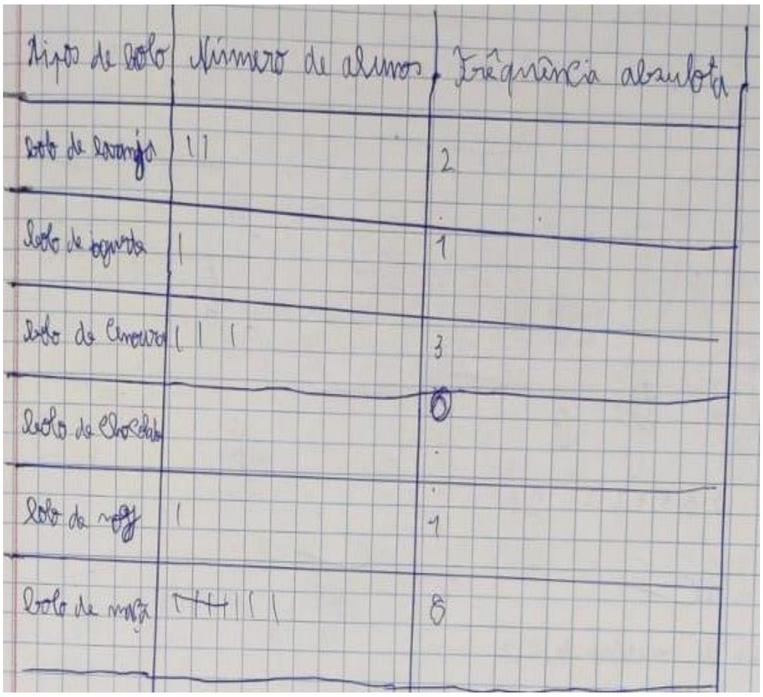
The task "What is the path you take to get the ingredients for your cake? Don't forget the cake has to go in the oven." generated some discussions among the students, both individually and with their peers. A majority of the class initially struggled to understand what was being requested. After some simpler guiding questions, the students deconstructed the task and realized they had to envision the path to make the cake. Some groups first represented the path using arrows on the exploration sheet and then filled in the spaces. Others chose to start by writing in the spaces and then drawing the arrows on the mat represented on the exploration sheet. Subsequently, each group easily carried out the envisioned path, but this time with the robot, and it was at this moment that some realized they were missing steps to make the cake. With this task, the students were able to develop algorithmic thinking by creating an algorithm, although the recipe itself is one, to respond to the task.

The task "What other cake can you make? With what ingredients?" was easy for all groups, as we analysed in the evidence. The groups immediately began identifying various cakes that could be made and their respective ingredients. Then, they discussed and decided on the final answer, developing skills and competencies inherent to group work. Since the students were able to structure what was asked of them into less complex questions, they developed the Decomposition dimension.

Regarding the task "Do you think you could make other cakes with the ingredients on the mat? If so, which ones?" it allowed the students to analyse the reasoning they had in the previous question and to test and optimize the final answer, developing the Debugging dimension.

In session 3, given that the focus was the mathematical theme of Data and Probability, and starting from the previously mentioned task, the students listed the various types of cakes that could be made. As the students identified these cakes, one of the trainee teachers was recording on the board and constructing the table that was intended to organize the data to find out which cake they would like to try. The table was built based on the model used by the class's main teacher, and it was organized into three columns: type of cake, number of students, and absolute frequency. Knowing they had to answer the question "The cake I would like to try...", each student, respecting the classroom rules, went to the board to register that cake with a vertical stroke. Each vertical stroke corresponded to one vote. Then, without much difficulty, they quickly identified the absolute frequency corresponding to each type of cake. To systematize the learning related to this mathematical theme, each student recorded it in their daily notebook (Figure 7). According to the absolute frequency table, the students easily identified the cake with the most votes, which was the apple cake. To conclude the session, and also as a way to systematize the three sessions, the cake was made with the class. Each student, maintaining classroom rules, mentioned the steps following the recipe preparation mode example (Appendix 1– Exploration Sheet: Part 1) so that one of the trainee teachers could make the cake.

Image 21. Filling in the table of absolute frequencies.



Tipo de bolo	Número de alunos	Frequência absoluta
bolo de laranja	II	2
bolo de iogurte	I	1
bolo de cenoura	III	3
bolo de chocolate		0
bolo de noz	I	1
bolo de maçã	[illegible]	[illegible]

Image 22. Written record of the table of absolute frequencies "The cake I'd like to taste...".

During the tasks, as we moved around the groups, we noticed that some students were not collaborating. In this regard, we felt the need to encourage the students to actively participate in solving the tasks and promote true group work where the sharing of ideas and mutual respect prevail. After analysing all the evidence, we realized that the groups were dispersing more often than we had observed.

In the discussion phase of the tasks, the students became aware of different solutions, questioned themselves, and were encouraged to compare with what they had written on their exploration sheet. Thus, the discussions were very enriching not only for the students but also for us, as they positively exceeded our expectations.

Conclusions and Implications

During the training of the trainee teachers, they had not worked with the Exploratory Teaching model. As students in teacher training, they initially found it difficult to understand this teaching model. During their training in the curricular units of Educational Practice II, Mathematics II, and Mathematics Didactics, they came to understand how to plan using the exploratory teaching model as well as the development of Computational Thinking dimensions.

The opportunity they had to engage with the Exploratory Teaching model, as students and trainee teachers, was enriching for their training. Their contributions go beyond the development of the five dimensions of Computational Thinking, as the implementation of this teaching model also allows the development of competencies listed in the Profile of Students at the End of Mandatory Schooling.

In this sense, the introduction of the Exploratory Teaching model in the 2nd-grade class was a positive, enriching, and challenging experience. The trainee teachers have continued to implement this teaching model, and it is evident that the students have been developing competencies and skills such as autonomy; critical and creative thinking; reasoning and problem-solving; expressing and discussing mathematical ideas. To develop the various tasks presented, it was necessary for the trainee teachers to know their internship context, understand the knowledge that the class already mastered with more or less ease, and know their interests. Based on these premises, tasks were developed that were appropriate to the specifics of the class. They understood that it is possible to develop any of the dimensions of Computational Thinking through adaptations to different contexts, considering the internship class and its specifics. Thus, there was a significant evolution in terms of time management in carrying out tasks, interpretation of tasks, cooperation and collaboration in groups, and also the complexity of the reasoning presented.

The teacher, in this teaching model, is just a mediator in knowledge acquisition. Unlike traditional teaching, where the teacher has a transmissive role, in the Exploratory Teaching model, they only accompany students, systematizing at the end what they have discovered. Throughout the process, in which the student engages with the objective of acquiring knowledge, the teacher asks guiding questions to facilitate their reasoning. In addition to the guiding questions, they also provide small debates among the students, allowing them to develop communicative ability and the other competencies already mentioned. The trainee teachers became aware that a teacher should know the curriculum and adapt it to their context, defining concrete and realistic learning objectives and competencies.

In summary, the implementation of this Exploratory Teaching model to develop the dimensions of Computational Thinking allows for the promotion of many more capabilities and competencies than the trainee teachers initially expected. Through this model, and interdisciplinarity, students not only are at the centre of building their knowledge but also develop competencies and capabilities that will accompany them throughout life. The cognitive challenge promoted throughout the four phases of the Exploratory Teaching model makes students curious and leads them to seek answers to consolidate their knowledge.

Acknowledgments

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Appendices

Appendix 1 – Exploration Sheet

<u>Exploration Sheet – "Let's Explore"</u>

For this activity, we will need:

- Six eggs
- One cup of sugar
- Two cups of flour
- One tablespoon of baking powder
- Juice and zest of one orange

Preparation:

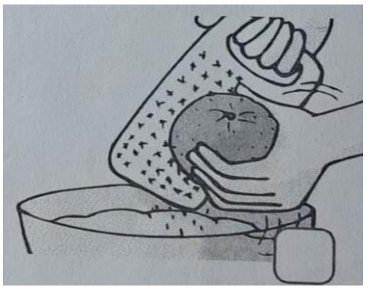
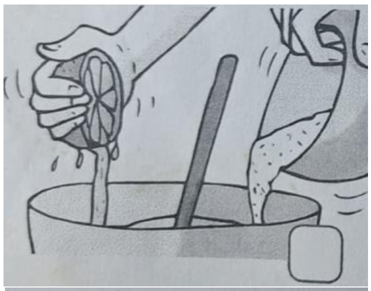
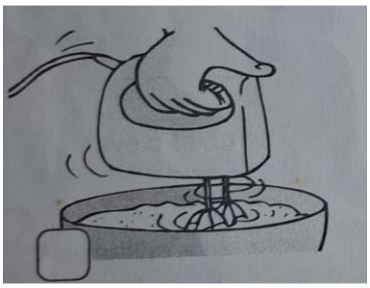
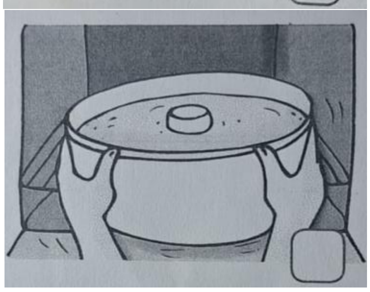
Separate the egg yolks from the egg whites.
Beat the egg yolks with the sugar.
Add the orange juice and flour. Continue to beat.
Add the orange zest and baking powder. Continue to beat.
Beat the egg whites until stiff and fold them into the mixture.
Bake in the oven at 180°C for 40 minutes.

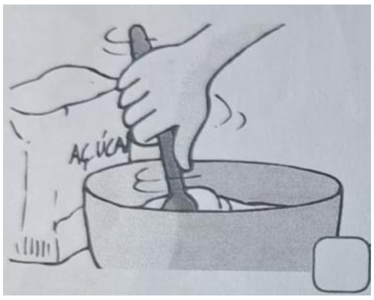
Part 1

1. What type of text does it seem to be?

Answer:
____

2. Observe the images and arrange them in the order of the preparation steps, identifying each image with its respective number.

3. List all the elements you think are important for making a cake.

Answer: ____

4. This recipe is for 4 people. If you want to make it for 8 people, what do you need to do?

Answer: ____

Part 2

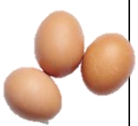
1. What did you discover when exploring the SuperDoc robot?

1st discovery: ____

2nd discovery: ____

3rd discovery: ____

2. What is the path you take to gather the ingredients for your cake? [Apply the number of steps you identify, and do not forget that the cake needs to go into the oven.]

1st step: ____

2nd step: ____

3rd step: ____

4th step: ____

5th step: ____

6th step: ____

7th step: ____

8th step: ____

9th step: ____

10th step: ____

Nth step...: ____

2.1. Now enable the robot to follow the path identified above.

3. What other cake can you make? With what ingredients?

Answer:

____

3.1. Now collect all the ingredients you need to make this cake.

4. Do you think you could make other cakes with the ingredients on the mat? If yes, which ones?

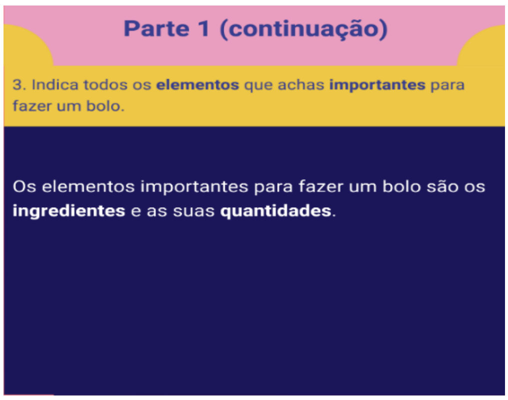
Answer:
____

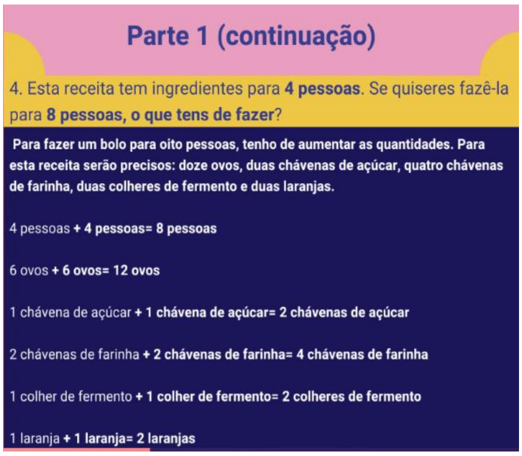
5. What ingredients do those cakes have in common?

Answer:
____

Appendix 2 – Synthesis PowerPoint (Part 1)

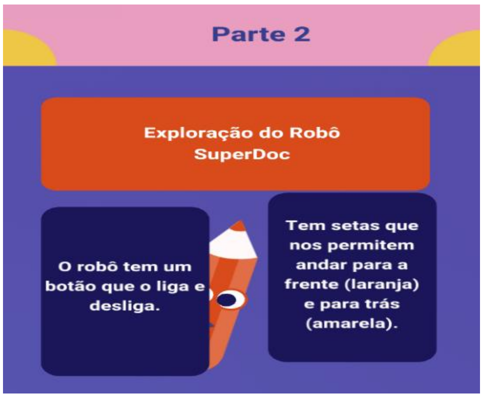
This synthesis (reproduced in the original Portuguese) shows in graphic form the information identified under Part 1 within Appendix 1.

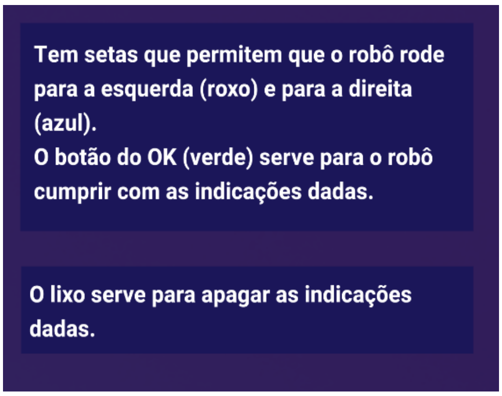


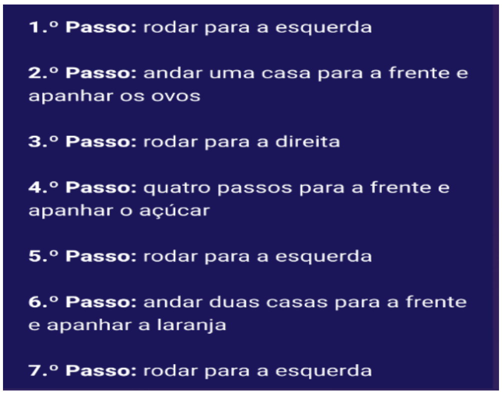


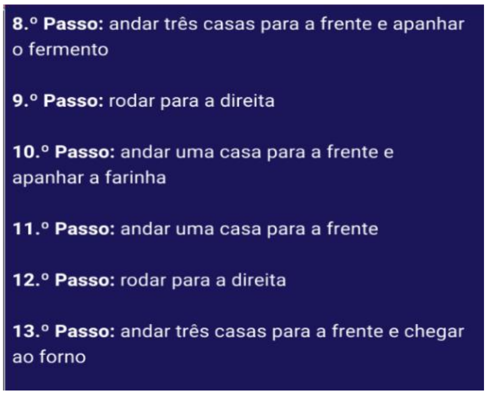
Appendix 3 – Synthesis PowerPoint (Part 2)

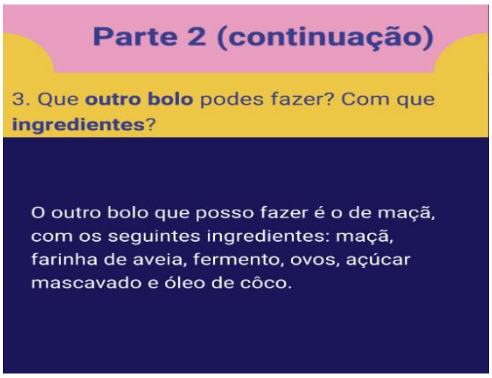
This synthesis (reproduced in the original Portuguese) shows in graphic form the information identified under Part 2 within Appendix 1.

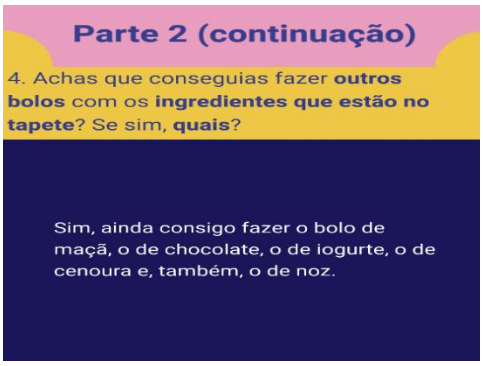


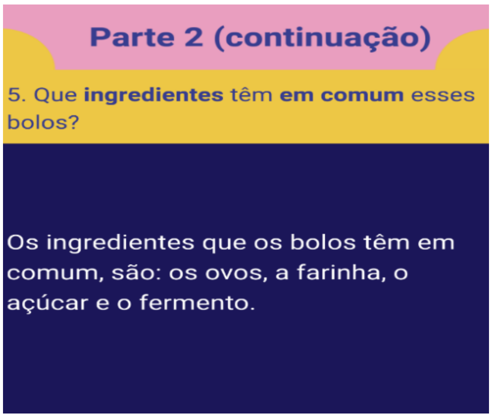












Appendix 4 – Competence Assessment Grid

Student	*Participation*	*Cooperation and Collaboration*	*Relationship*	*Reasoning*	*Expressing Ideas*	*Arguing*	*Individual Effort*
1							
2							

3							
4							
5							
6							
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15							
16							
17							
18							

Appendix 5 – Evaluation Criteria

	Insufficient	***Sufficient***	***Good***	***Very Good***
Participation	Does not participate.	Participates but needs encouragement.	Participates independently.	Participates actively.

Cooperation and Collaboration	Does not cooperate or collaborate with peers.	- Does not cooperate or collaborate with the group unless encouraged. - Works alone.	Cooperates and collaborates with others at some moments during the class.	Cooperates and collaborates effectively.
Relationship	Does not know how to listen, respect, and accept classmates' opinions	Knows how to listen and respect but cannot accept different opinions from their own	Knows how to listen, respect, and accept different opinions sometimes	- Knows how to listen, respect, and accept different opinions. - Can manage the group.
Reasoning,	Does not present logical reasoning.	Presents reasoning with some gaps.	Presents logical reasoning.	Presents logical, coherent, and organized reasoning.
Expressing Ideas	Cannot express their ideas.	Expresses their ideas but does not clarify for peers.	Expresses their ideas.	- Expresses their ideas clearly. - Presents them using different strategies.
Arguing	Cannot argue.	Argues but does not provide a basis.	Argues with a basis but has some gaps.	Argues clearly and with a valid basis.
Individual Effort	Does not make an effort.	Makes an effort when called to attention.	Makes an effort but encounters some difficulties.	Makes an effort independently.

Annexe – Photographic Records

Figure 1. Classroom organization

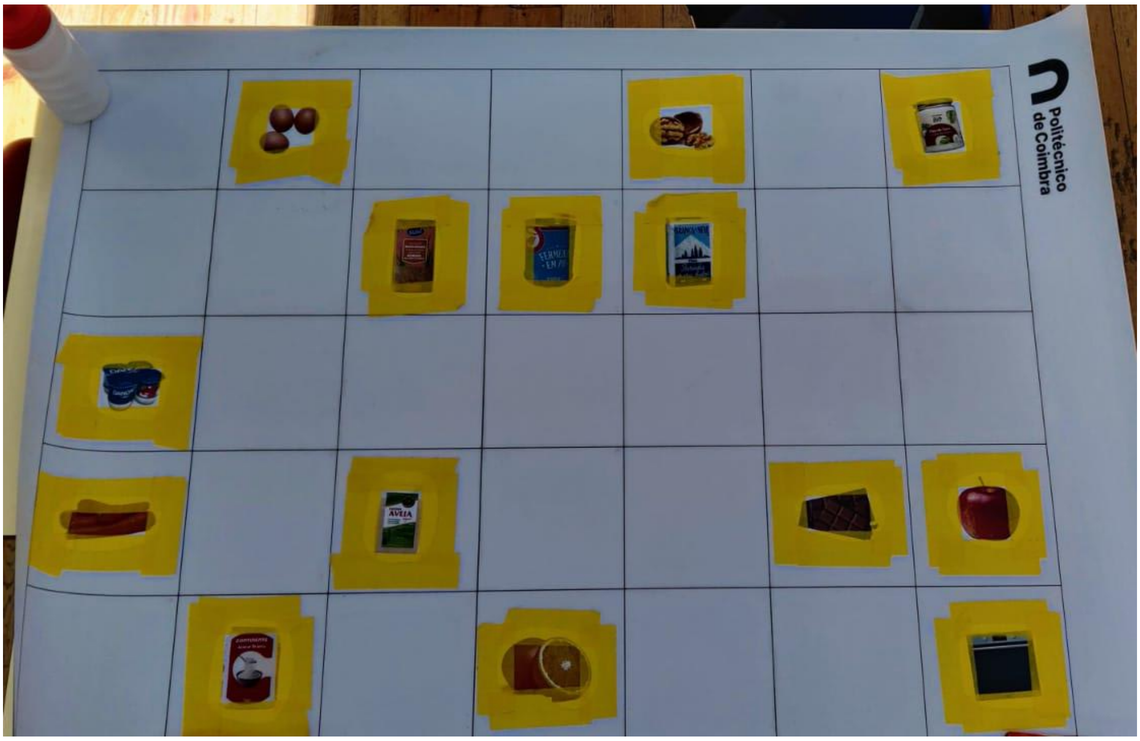

Figure 2. Pedagogical mats

Figure 3. Manipulation of the SuperDoc robot

Figure 4. Baking the cake

Author Biographies

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