International Journal of Instruction *July 2023 ● Vol.16, No.3*
e-ISSN: 1308-1470 ● www.e-iji.net *p-ISSN: 1694-609X*
pp. 465-488

Article submission code: 20220526013042
Received: 26/05/2022
Revision: 12/01/2023
Accepted: 03/02/2023
OnlineFirst: 19/04/2023

Heuristics and Usability Testing of a Project-Based Learning Online Course: A Case Study with Structural Mathematical Concepts

Sara Cruz
Polytechnic Institute of Cávado and Ave & Polytechnic Institute of Porto, Portugal, *scruz@ipca.pt* & *saracruz@ese.ipp.pt*

José Alberto Lencastre
University of Minho, Portugal, jlencastre@ie.uminho.pt

Floriano Viseu
University of Minho, Portugal, *fviseu@ie.uminho.pt*

Usability refers to the system's functionality by the user, allowing the system to be used with ease of learning, efficiency in carrying out tasks and satisfaction. The article presents the design and development of an online course about structural mathematics concepts with a project-based learning approach. With this study, we intend, through the development of an online course, to explore the contribution of project-based learning to approach mathematical structural concepts. The methodological option was development research, fulfilling the following phases of the protocol: (1) preliminary investigation, (2) theoretical embedding, (3) empirical testing and (4) documentation, analysis and reflection on process and outcomes. We started with an exploratory analysis aimed at identifying a group of teachers' knowledge about structural mathematical concepts and the potential of a project-based learning to support students in apprehending these concepts. Based on the data obtained, the design and development of the online course were carried out. Then, heuristic evaluation tests were conducted with experts and usability tests with the target audience to assess the adoption of the online course. The online course was designed to involve teachers in learning mathematics concepts through a project methodology. In the preliminary investigation, all teachers showed interest in knowing the project learning methodology and identified concepts that, from their practice, are usually difficult for their students. In the heuristic evaluation test with the experts, linguistic, structural and course content corrections were made. The results allow us to say that the online course with the project-based learning approach responded to the target audience's needs, arousing their interest in using project learning in teaching mathematics structural concepts.

Keywords: usability, project-based learning, technology-enhanced learning, math structural concepts, learning

Citation: Cruz, S., Lencastre, J. A., & Viseu, F. (2023). Heuristics and usability testing of a project-based learning online course: A case study with structural mathematical concepts. *International Journal of Instruction*, *16*(3), 465-488.

INTRODUCTION

In a society in a constant process of change, the use of technology and the internet have assumed an increasingly important role in teachers' daily routines (Cruz, 2019). This reality leads teachers to resort to artefacts only sometimes integrated into their teaching strategies, such as online communication platforms. Many of these artefacts have reversed the asymmetries previously present in the classroom. Remember that today's students are a generation born in a digital, connected, mobile environment and have never seen the world without the internet (Prensky, 2013; Peters-Burton et al., 2022). Students are used to connecting to the internet to communicate, share information and socialize through mobile devices, which they use daily. The speed with which communication is carried out through these devices is an aspect that highlights its importance nowadays, in which distance communication, for the most varied situations, is done through a click, favouring not only contact in the world as well as at the level of educational establishments themselves.

Furthermore, students live in a network spontaneously and use a language based on emojis to communicate. These factors generate significant challenges for teachers and educational institutions. Teachers are thus faced with the challenges of quickly adapting to a new teaching environment. In addition to these challenges, teachers continue to have to deal with the difficulties of teaching Mathematics threshold concepts that, not being understood by the student, prevent the construction of new knowledge (Cruz, 2019; Harlow et al., 2011; Hofer et al., 2018; Meyer & Land, 2003; 2006). A possible approach can be influenced by digital technologies and active methodologies such as project-based learning around mathematics concepts (Cruz, 2019).

In recent years, the digital world has changed our entire way of living, working, communicating, and interacting. We can access online spaces and work 'at a distance' from anywhere as long as there is an Internet connection. Students work with a vast set of electronic devices full of potential in learning processes, so it is illogical not to use them for pedagogical purposes (Lencastre, 2012). For this innovation to be possible, it is necessary to prepare the teachers with pedagogical and technological skills, which allow them to invest in active and effective methodologies (Cruz, 2019). These assumptions lead us to reflect on the role of the teacher, intending to guide them to do what can be done in a digital environment.

With this study, we intend, through the development of an online course, to explore the contribution of project-based learning to approach mathematical structural concepts. The development process took place over the following phases: (1) preliminary investigation, (2) theoretical embedding, (3) empirical testing and (4) Documentation, analysis and reflection on process and outcomes.

Related Work

The term threshold concept emerged from research conducted in the United Kingdom by Meyer and Land in 2003. According to these authors, a threshold concept is difficult for students to grasp, and they resist overcoming it, sometimes taking refuge in memorisation without sufficient knowledge. This insurmountable barrier to understanding a threshold concept prevents students from progressing in learning this concept and related concepts (Meyer & Land, 2006), often leading them to abandon the study. Understanding the causes of these barriers to understanding a threshold concept helps the teacher to adopt appropriate teaching strategies to support the student in overcoming them. Unfortunately, in their practice with students, it is common for teachers to identify complex concepts for students to understand that does not correspond to the threshold concept already documented in the literature. Cruz (2019), proposed naming structural concepts to these concepts that teachers identify in their practice and that are difficult for students to understand. According to Cruz (2019), understanding a structural concept opens up new perspectives on a topic to the student, allowing a new way of thinking about related concepts. In Cruz (2019) research, many teachers have difficulty understanding students' difficulties when working with structural concepts in Mathematics. Thus, studying these concepts assumes a fundamental role because it allows us to reflect on what the student needs to learn and ways to help him in this process. In addition, they promote discussions around teaching and learning and form the basis for a conceptual framework capable of bringing together curriculum, teaching and learning elements (Barradell & Kennedy-Jones, 2015). Based on the work developed by Cruz (2019), we can say that the structural concepts are presented with the following criteria:

- Identifiable – is identified from teaching practice as problematic for students;
- Transformative – once apprehended, changes the student's perception of a topic;
- Integrator – it can expose previously unknown relationships about something;
- Irreversible – once apprehended, cannot be forgotten;
- Integrator – allow previously unrecognised relationships about a topic;
- Delimiter – may have borders with other concepts from the same or different fields;
- Problematic – can be counterintuitive.

Thus, qualifying the teacher to recognise what, until then, the student could not understand because it seemed to be stuck in an inaccessible context promotes a transformation in the teacher's teaching skills because it allows a broader understanding of the student's difficulties and to the student because it allows a new way of thinking about related concepts.

Online Education

The emergence of multimedia applications, technological devices and virtual learning environments in schools fostered the emergence of differentiated forms of pedagogical work using digital technologies. Khadka et al. (2022) suggest that student-centred instruction best suits students of online courses. Thus, online education has gained importance because of the online teaching practices that allow specific competence and the natural association with continuous and professional training. Salmon (2000) suggested an online education model organized into five levels where at each level, individuals have to have specific skills: (1st level) to facilitate and support access; (2nd level) get to know the online elements and start interacting with them; (3rd level) collaborative exchange of information regarding the contents covered; (4th level) knowledge construction; (5th level) obtaining support information to achieve established goals where online must be integrated with other forms of teaching. Garrison and Anderson (2005) also present a model consisting of three dimensions using asynchronous communication: the social, cognitive, and teacher. This modality is based on a constructivist perspective of the teaching process, where the environment favours the diversity of aspects, the critical sense and development. This is because it is considered that the student can take responsibility for controlling their learning in a collaborative environment. Time-saving and efficiency is another strong point of online learning because students can adjust their learning time to their needs (Lencastre, 2012; Khadka et al., 2022).

Nowadays, many teaching and learning activities result from mobile devices, leading to the debate on mobile learning. Students already have their own mobile devices, and are already regular users of these devices. As students are used to dealing individually and socially with mobile devices, accepting these mobile technologies is essential for them to be a factor of easy inclusion in the teaching and learning processes. Therefore, mobile environments are a fundamental part of students' daily lives, and it seems reasonable to use them to improve student performance (Neto & Fonseca, 2013; Peters-Burton et al., 2022).

The project-based learning process

Active methodologies are teaching approaches in which the student plays an active role in their learning through the interaction between the actors in the process and the valorization of the collective construction of knowledge (Cotta et al., 2012; Torres et al., 2022). According to Glasser's theory (Figure 1), we learn more when we do and when we teach others:

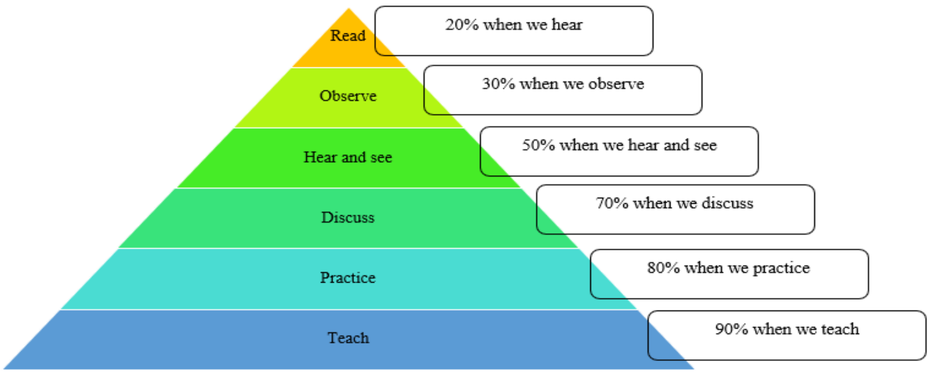

Figure 1
Glasser's pyramid of learning (1999)

Project learning is one of the active methodologies. Students actively explore real-world problems and challenges in the project-based learning methodology and acquire in-depth knowledge of the contents worked. It is an innovative approach to learning that teaches many strategies essential for success in the 21st century (Bell, 2010), promoting education through involvement in projects (Cruz, 2019; Torres et al., 2022). This process often requires interaction between teachers and students and between students in the learning space (Fauziyah et al., 2022). Combining project learning and mathematics teaching can increase teaching effectiveness, generate meaningful learning and influence students' predisposition to the subject (Tseng et al., 2013). Students construct their knowledge through research strategies and collaborative work in project learning (Boss & Krauss, 2022). With project-based learning, greater understanding of a concept or theme, deeper learning and a greater motivation to learn are achieved (Bell, 2010; Torres et al., 2022).

METHOD

The development and evaluation process of the online course presented followed a 'Development Research' methodology (Coutinho, 2013) as a part of a qualitative approach (McMilan & Schumacher, 2014). Development Research has established itself as a methodological reference in empirical research in Education (Coutinho, 2013). Furthermore, development Research allows using theoretical and practical approaches to simultaneously analyse a phenomenon as the construction of a model (Cruz et al., 2020). The structure of the online course entitled to explore the impact of its use in an educational environment (Lencastre, 2012; Khadka et al., 2022), so our methodology is described in the following diagram:

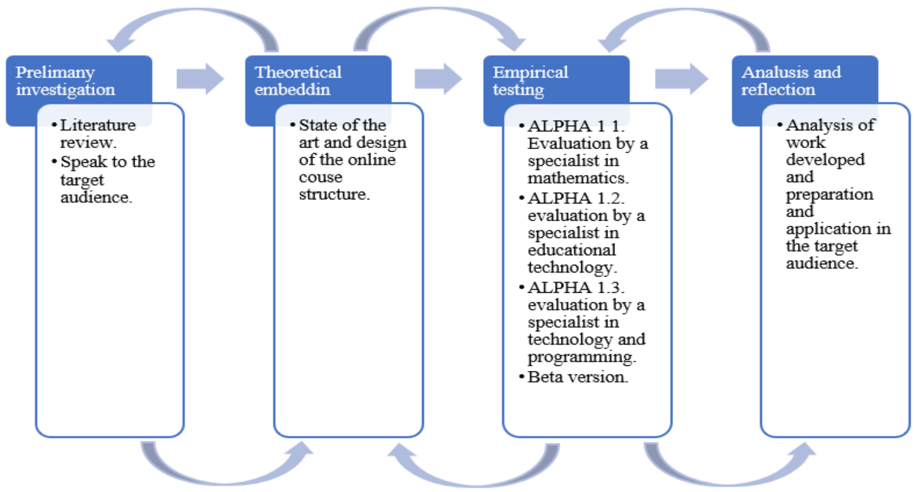

Figure 2
Methodology adopted for develop the online course

Participants

The preliminary investigation included a focus group with six Portuguese teachers, three women and three men. With this focus group, we tried to understand these teachers' perspectives on project-based learning and structural concepts in mathematics. According to Lee and Johnston-Wilder (2013), to understand the perception of our target audience plays a vital role in the continuous improvement of teaching and learning processes. Still, in the preliminary investigation phase, an interview with four Portuguese teachers (three female and one male) belonging to the target group reflected the student's difficulties in understanding structural mathematical concepts. These four teachers are part of the initial group and have volunteered to collaborate in our study and to identify structuring concepts in mathematics.

The empirical testing phase had three moments with different participants.

As our study involved the design and development of an online course, in the empirical testing, two Portuguese teachers (one women and one men) not belonging to the target group but similar to them were involved, essentially in development of the different versions of the course. According to Lencastre (2012), individuals belonging to the target group cannot perform these development tests because they are the final customer who will use the system, so these tests should be performed by individuals with the same characteristics as the target group.

Three experts were also implicated in the Empirical testing the α *(alpha)* version of the course, with distinct expertise in technical usability and/or pedagogical usability: one with knowledge in 'Web Development and Programming', another with a background in 'Educational Technology' and another graduated in 'Mathematics'. After all these tests, we created the β *(beta)* version of the course.

The β version of the course was implemented by eight teachers, four of them from Italy, four from Portugal and two from Greece. All members of the Erasmus+ BeReady project.

Data collection and analysis

The preliminary investigation data was collected through a videotaped focus group (Morgan, 1997), and an interview, and examined through thematic analysis (Braun & Clarke, 2006). Themes emerged through the participants' speeches. To analyse the responses, we designated each of the six teachers involved in the focus group as follows T(teacher)i (i = 1... 6). We then went on to look at the association between these themes and the literature.

In the empirical testing process, two Portuguese teachers think-aloud the protocol (Van Someren et. al, 1994) to collect data in usability testing during our course design and development. Through this method we were able to record the comments verbalized by the experts (Nielsen, 1993).

Still in this empirical testing phase, heuristic and usability tests were carried out.

Development of the online course

This study followed a Development Research methodology (Lencastre, 2012; Coutinho, 2013), a reflective and evaluative process that aims to build an online course. Throughout this reflective process, successive course reformulations were carried out to improve the effectiveness of an online course about structural mathematics concepts with a project-based learning approach.

Throughout this process of building the online course, combining the theoretical and practical components is essential. In this way, it is possible to carry out a reflective practice that allows becoming aware of the whole process and making successive improvements throughout the various stages of construction. Thus, the process develops over four phases (Akker, 1999; Lencastre, 2012): (i) preliminary investigation, (ii) theoretical embedding, (iii) empirical testing and (iv) analysis, reflection on process and outcomes.

Active methodologies are based on the fact that learning is a dynamic process and different students learn differently. Thus, in an active methodology, students learn by doing; hence 'doing' plays a vital role in the learning cycle. Active methodologies can provide students with greater responsibility for their learning. The teacher assumes the role of a facilitator by creating an environment conducive to active learning. This approach fosters several attributes: flexibility, creativity, pro-activeness, appropriate decision-making, and effective communication.

Preliminary investigation

In projects that involve the design of online courses it is necessary to know the audience for whom the product is intended, understand what they expect, what motivates them, and their knowledge and limitations (Lencastre, 2012).

The demands of today's society lead educational institutions to transform their models, leading them to opt for student-centred teaching models (Lopez et. al, 2021; Khadka et. al, 2022). The use of active methodologies brings new challenges to teachers' pedagogical practices. It becomes necessary for the faculty to acquire knowledge and develop skills that allow them to plan and implement pedagogical practices that consider the active construction of knowledge (Guerriero, 2017; Cruz, 2019). Thus, with these teachers, we tried understanding their perspectives on project-based learning, a learner-centered learning model to understand a concept (Sigit et. al, 2022).

The analysis categories of the teachers' responses, we considered the following dimensions: (i) project-based learning, (ii) advantages of project-based learning and (iii) disadvantages of project-based learning. Teacher's report knowing the methodology of gamification "*to carry out the assessment*" (T3), but they "*have no idea what project-based learning is*" (T1). After a brief explanation of the project-based learning methodology, teachers recognize that this method can have advantages because it "*breaks the rhythm of the class*" (T2) and leads "*students to develop other skills in addition to those they would develop in a traditional methodology*" (T5). However, the length of the curriculum they must comply with is a disadvantage of project-based learning because they say that the "*curriculum does not allow it*" (T2) at all times during the class. The following table presents the thematic analysis of the focus group from teachers' speeches.

Table 1
Themes for analysis from teachers' speeches

Theme	Teachers' speeches
Project-based learning (PBL)	"*I confess I have no idea what project-based learning is*" (T1). "*The methodology we used, which was applied in the Gamification training, also to carry out the assessment, it helped a lot at the time to assess remotely"* (T3). "*We have already used discovery problems. Put in exercises, and they are already resolving without knowing it. Formulas work very well because they then have the notion and realize the reason for that formula or the content. Surely there are those weaker students where things do not go so well, and then we have to help and try to explain, but in general, that goes well*" (T5). "*There, the student is highlighted. The teacher is like a bodyguard who guides them to ensure they are on the right path*" (T2). "*The student has to be more autonomous not so passive. When we use the usual method, the student is in his corner and has a more passive role*" (T3). "*Here the student is much more participative and has a much more critical role. We give him much more importance than in those techniques where the teacher talks, talks, talks, talks, and the student just listens. We give him more voice, and we give him more importance; that is my understanding too. We also learn from the students. We learn from what they are thinking and, how they are thinking, why they are thinking the wrong way*" (T1).
Advantages of project-based learning	"*At least it's different, isn't it*" (T3). "*And it breaks the rhythm of the class*" (T2). "*It has advantages at least at the level of mathematical language. At least at that level, at the level of communication and mathematical language*" (T3). "*Yes, students develop other skills in addition to those they would develop in a traditional methodology*" (T5). "*There is more and more need to captivate students. We needed to know a lot more, and the more diversified a strategy is, the more we can captivate them*" (T5). "*Students nowadays have a lot to distract themselves with, and not only that, because there are things much more interesting for them than perhaps learning. They think there are many more exciting things to learn than math. So, we can motivate them a little with project-based learning*" (T3).
Disadvantages of project-based learning	"*We cannot always do this activity because the curriculum does not allow it. So, it is impossible, and becomes a monotonous routine*" (T2). "*However, even then, knowing how to evaluate and how I will make them learn through the project methodology. I have everything very aligned in my head, it has been many years doing the same thing*" (T3).

We also collected from these teachers' elements that they consider essential to be present in an online course: (i) sessions sequentially structured, (ii) the existence of explanatory video tutorials, (iii) presentation of concrete examples.

Four Portuguese teachers participated in the identification of structural concepts. The concepts pinpointed are from mathematics: probability, function, fraction and succession. Together with these four teachers, we also tried to identify reasons that they recognize from their practice as limitations for understanding the structuring concepts. The categories for the analysis used in this stage of the study are - incomplete pre-knowledge, related problems, related intuitive knowledge - were defined from the studies presented by (Cruz et. all 2017) and Cruz (2019) that prioritize categories from the Problem Distiller Tool, a web-based tool designed to help teachers to discover why their students have difficulty understanding threshold concepts (Cruz et. all, 2017). The following table presents the main difficulties identified by teachers in their students have problems with these concepts.

Table 2
Reasons identified by teachers who, in their practice, recognize limitations for understanding the structuring concepts

Concept	probability	function	fraction	succession
Incomplete forecast because...	Understanding of the Scientific method, process and practice.	Understanding of the Scientific method, process and practice. A term refers to several concepts.	Understanding of the Scientific method, process and practice. Support understanding	Understanding of the Scientific method, process and practice.
Problems related to...	Scientific use of everyday language	Scientific use of everyday language	Scientific use of everyday language	Scientific use of everyday language
Intuitive knowledge related to something …	Weak analogies with the human or with the world, imperfect causal reasoning.	Weak analogies with the human or with the world, Imperfect causal reasoning.	imperfect causal reasoning.	Imperfect causal reasoning. Weak analogies with the human or with the world.

Concerning probabilities, teachers report that students have difficulty "*identifying the strategy to use in solving a given situation or problem*" (T1) and "*finding the best counting process to use in each specific situation*" (T3). The difficulty presented by the students is related to the "*difficulty in perceiving the notion of the concept of probability, with what it means and with the lack of knowledge from previous years of notions that allow the recognition of new concepts*" (T2). Therefore, teachers try to overcome the diagnosed difficulties by "*explaining previous concepts, explaining the concept of probability several times and in different ways*" (T3).

Regarding the concept of function, students have difficulty in "*perceiving what a function is and what it does*" (T3), in "*recognizing the type of function*" (T3) and "*in applying the concept of function*" (T1) and in solving "*problematic situations involving the concept of function*" (T2). Regarding the resolution of problems with functions, the main problem of students is related to the difficulty of "*applying a more abstract reasoning necessary to allow a correct interpretation of the problem, combined with the lack of a more methodical working method*" (T1). On the other hand, teachers recognize that "*it is important that the student understands the definition of function and its importance*" (T3). Thus, to help students overcoming these difficulties, teachers present students with "*more concrete examples linked to their daily lives*" (T2) and "*some explanatory videos available on some platforms such as YouTube and the virtual school*" (T3).

Regarding the concept of fractions, students "*do not recognize that the fraction represents a part of the whole*" (T4), mainly "*in the resolution and interpretation of problematic situations*" (T2). To overcome these difficulties, teachers resort to "*diversified ways of exploring the same problem, using instruments from students' real lives, creating activities and tasks where students research*" (T4).

Regarding succession, "*students do not understand the difference between function and succession and do not understand that the domain is the IN set*" (T4). In addition, students have "*difficulties applying more abstract mathematical reasoning when they need to work with sequences*" (T1). The difficulty identified by teachers in the concept of succession is related to the lack of "*capacity for abstraction and difficulties in* *interpreting the problem*" (T1); as students have difficulty understanding the concept of "*function, they also do not understand succession and its difference*" (T4). These teachers refer that they usually try to help students overcoming these comprehension difficulties by presenting them with "*more concrete examples*" (T3) and resorting to "*available explanatory films*" (T1) online.

The exploratory test with the target audience was aimed at identifying the knowledge of a group of teachers about the project-based learning method to understand their difficulties and suggestions. This task was carried out through a focus group. Initially, authorization was requested from these teachers to apply the data mentioned above collection instrument. Then the purpose of this collection was explained, and the fact that the data were treated anonymously. We chose these teachers because they constitute the Portuguese team of teachers participating in the Erasmus+ BeReady project, that this study is a part of. After this first phase, there was a need to change some aspects. Thus, we have (i) structured the course in simple steps with progressively greater complexity and (ii) added video tutorials on digital tools that teachers expressed difficulty with or admitted not knowing. These changes were intended to improve the online course information in the aspects teachers expressed as essential for an online instructional course. The results obtained by this test constitute the basis for collecting data in the literature and creating a version of the course in Google Classroom, which we call ALPHA 1.1. version.

Theoretical embedding

Based on the literature and the insights of a group of four teachers, the first version of the course was developed. In this version, we try to detect errors and identify situations to improve. α version 1.1 was designed to contain four topics: (i) presentation, (ii) Structural concepts and (iii) project-based learning. Each topic was also divided into sub-topics with information, sub-topics with tasks or both.

Empirical testing

The evaluation by experts is an accessible method that seems to predict the problems (Mack & Nielsen, 1994). It is essential to detect mistakes that can be altered and corrected (Lencastre, 2012). Therefore, each expert test was pre-scheduled, and their responses were recorded. Also, the researcher used paper-writing material to make the records. The ALPHA 1.1 version was evaluated only by one mathematic specialist. The male specialist has a PhD in Education, specializing in educational math. With the usability tests, we intend to find difficulties in using the evaluation instrument and problems in understanding the information presented, namely in the tasks requested throughout the course. Therefore, we also looked for recommendations from teachers that allowed us to improve it. Following Lencastre's (2012) guidelines, we carried out this process throughout the design and development of the online course. This assessment based on heuristics allowed us to find aspects to improve which were challenging for the user to understand.

The first heuristic assessment test was with a math education expert, informally through the visualization of the class in the Google Classroom and recording the teachers' observations, complemented by the researcher's self-observation. The first heuristic assessment test was with mathematics teachers informally through the visualization of the class in Google Classroom and recording the teachers' observations, complemented by the researcher's self-observation. We provided the teachers with the link to access the Google Classroom class where we were hosting the course. The option for Google Classroom is because it is the platform chosen to be used in work developed during the Erasmus+ project, where this research work is inserted. The teachers performed a free exploration, choosing their direction to more easily detect susceptible mistakes to correction. The information collected during this heuristic evaluation was used to reformulate the course structure according to the observations made by the teachers, giving rise to the ALPHA 1.2 version of the course.

Specialists in educational technology carried out the second heuristic test. The specialists are male and have a PhD in Education, specializing in Educational Technology. The evaluation test with this educational technology expert added one more topic to the course structure, with a roadmap for the student and a timetable with more explicit information. The expert also made some recommendations regarding the execution of the video tutorials. The data collected during this heuristic evaluation was used to reformulate the tool according to the suggestions made by the expert, originating from the ALPHA 1.3 version of the online course.

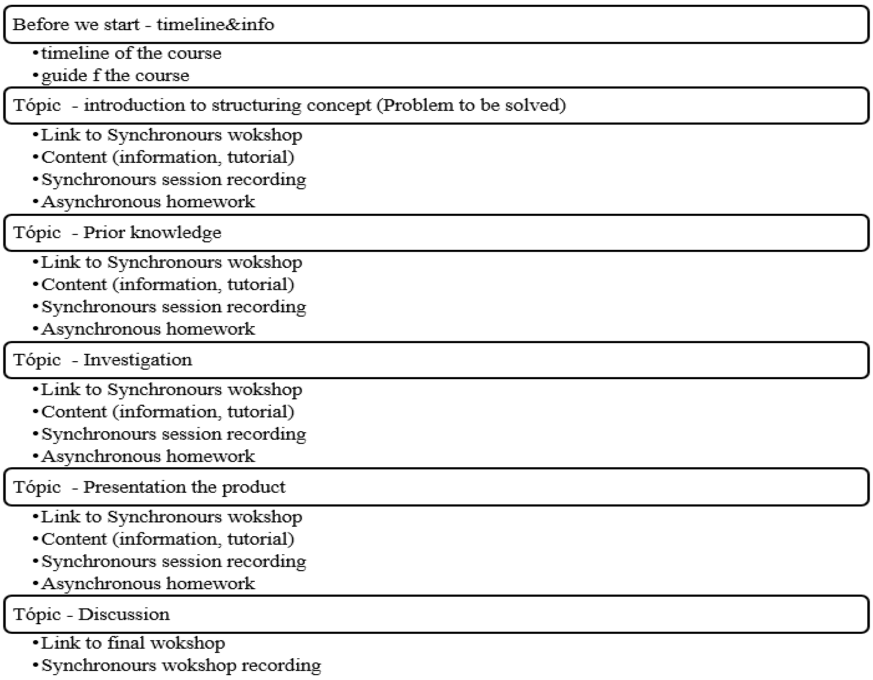

Figure 3
Online course beta version structure

Figure 3 presents the BETA version of the online course we created. The Beta version resulted from the changes made to the ALPHA 1.3 version based on the third heuristic assessment test. A specialist in web development and programming did the third heuristic assessment test. The expert was given access to the course. We also explain the course's objectives and that the course is intended to be organized according to the design methodology. The specialist made several suggestions for changes: (i) the detection of errors in sentences, (ii) changes in the topic structure, (iii) the inclusion of more explicit guidelines and (iii) the sequence in content navigation.

The information collected during this heuristic evaluation was used to reformulate the tool according to the suggestions made by the experts originating the BETA version of the online course. All eight teachers involved in the Erasmus+ BeReady project, participated in the β version test. So, the β version test with the target audience involved four Italian teachers, four Portuguese teachers and two Greek teachers.

Analysis and reflection

The initial course was in Portuguese, but in the final version, the course was entirely in English to be accessible to all collaborators of the Erasmus + project. The final version of the course was implemented in April 2022 to a group of teachers from different countries, chosen for convenience based on their availability and the fact that they are part of the Erasmus+ BeReady project. The work presented was carried out between September 2021 and February 2022. We intend to design and develop an online course according to the project-based learning methodology with this work. Throughout the process of creating and evaluating the course, we based the work on development research. We had as reference the research steps described by Lencastre (2012): (i) preliminary investigation, (ii) theoretical embedding, (iii) empirical testing and (iv) preliminary documentation, analysis and reflection on process and outcomes. Several tests were carried out throughout the development of the online course projected, which proved to be decisive for the final product.

In the empirical testing step, the ALPHA version of the course was evaluated by an expert in mathematics, educational technology, and web development and programming expert.

With the 1st heuristic evaluation test, carried out with a mathematics specialist, we intend to evaluate the clarity of mathematical instructions. With the 2nd heuristic evaluation test, carried out with a specialist in Educational Technology, we want to assess the clarity of the connection between the technology and the content presented in the course. Finally, with the 3rd heuristic evaluation test, carried out with web development and programming specialist, the aim was to evaluate the technical and web usability part of the course.

The Beta version was tested by four Italian teachers, four Portuguese teachers and two Greek teachers, all teachers involved in the Erasmus + Beready Project. During the application of the Beta version, the eight professors were guided through the following stages: (i) choosing a problem for the project, (ii) formulation of partial problems, (iii) project preparation and planning, (iv) research and treatment of the collected information, (v) presentation of the work and (vi) global evaluation of the work carried out.

In the heuristic evaluation with experts following the guidelines of Lencastre (2012), we systematically articulate what the literature refers to as online education, virtual learning environments and project learning (theoretical embedding). The heuristic evaluation with the experts was videotaped. In addition, written records were made of the experts' interaction with the course content. In each evaluation moment with the usability experts, we analyse the results, explore solutions and define the changes to be made.

In the empirical testing phase of the Beta version, we again conducted a focus group with 10 participants other than the first focus group to get feedback on the course we designed.

For data analysis, we designated the responses of each teacher in the focus groups by Ti (i = 1 ...9). The qualitative data analysis was based on recurrent notes in which regularities and differences stood out. We adopt a qualitative approach because we seek to understand the meanings attributed by the participants in the study to his actions (McMilan & Schumacher, 2014). We analysed all the data collected during the various phases of the course's design, development, and evaluation. These data analyses through indirect observation make it possible to draw relevant inferences about the process, which is why it is intended that the interviews and written records carried out are subjected to content analysis (Coutinho, 2013).

FINDINGS

In the preliminary investigation, all teachers showed interest in knowing the project learning methodology and how to apply it to their students. However, only one teacher admitted to knowing the project learning methodology. The remaining teachers admitted to knowing and using "*Gamification that helped a lot in doing the distance assessment*" (T3) associated with "*application of Kahoot*" (T2 & T3) and "*learning through discovery*" (T2, T4 & T5). The teacher's role is redefined when active learning methodologies are used because it becomes "*like a bodyguard who will guide if the student is on the right path*" (T2).

Regarding the role of the student, the teachers recognize that using these methodologies, the student "*has a more active role*" (P3), assumes a "*more participatory activity, has a much more important rol*e" (P5). In this part of our study, teachers also identified some concepts that, from their practice, are usually difficult for their students: the concept of function, the concept of probability, the concept of fraction and the concept of succession. We selected the concept of the variable to be worked on throughout the course. Based on the teachers' perception, we can say that the concept of variable is a structuring concept for students. Relating the teachers' perception with the criteria listed by Meyer and Land (2003) for this concept, we obtain that:

(i) the student's understanding of the concept of a variable can be seen as transformative because it allows him to associate several values to a letter and see this application in real context situations. In addition, a "*correct understanding of the concept of the variable*" (T3) allows the student to establish relationships in everyday situations;

(ii) it is possibly irreversible because once the understanding what a variable is built, "*the student will be able to apply it in a context*" (T5) and "*interpret its meaning*" (T3);

(iii) understanding the concept of variable is "*key in the successful resolution of problem situations*" (T2) which suggests that it is integrative;

(iv) the concept of variable is commonly "*used in disciplines such as physics, chemistry or biology*" (T5), and its understanding enables the "*understanding of the relationship between the concepts*" (T3) of these disciplinary areas, suggesting that the variable concept is bounded.

(v) a misunderstanding of the concept of the variable can lead to "*misinterpretations in a context*" (T4) and "*in the meaning of a solution*" (T2), leading to counter-intuitive relationships about the concept of variable, which suggests that this concept can be troublesome.

In the 1st heuristic evaluation test with the expert in mathematics, the expert was informed that the test consisted of assessing the clarity of the mathematical instructions. The expert ran the course in the desired direction. We noticed that the way the sub-topics were presented could create some entropy by initially appearing hidden. He also suggested the presence of mathematical content in small parts clearly and objectively. We also noticed that some of the topics names were not illustrative of what the user would find.

In the 2nd heuristic evaluation test, the expert in Educational Technology freely navigated the course without difficulty. However, this expert detected some mistakes and suggested adding an initial topic with the course timeline and a guide. He indicated that the guide should have an introduction to the course, a brief explanation of the Google Classroom platform, and the timeline of the various stages of the course. He also alerted to the need to have a final topic with frequently asked questions and their answers to help the user in asynchronous moments.

In the third heuristic evaluation test with an expert in web development and programming, we ask you to report to the technical part of the bear. In this test, the expert noted that the navigation was straightforward, and the first impression showed an appealing virtual learning environment. However, he said that some of the instructions for submitting assignments needed to be clarified. He suggested presenting examples of some technological solutions in the tasks that involved the creation of pedagogical material. He suggested always using the same visual navigation criteria. The specialist also detected some spelling errors that were corrected. He also noticed that some interactions were not working correctly, situations that were corrected in the beta version of the online course. The results obtained in this test led to the next version with six main topics. In the new version, we corrected the information and structure according to the suggestions that the experts made.

The final version of the course, which we call version Beta, was implemented by ten teachers (four Italian, four Portuguese and two Greek), all the teachers involved in Erasmus+ BeReady project. The Beta version of the course is a version where all the information was available in English; we noticed that this was not an obstacle for the teachers. All teachers who tested the Beta version of the course reported that "*the information was presented clearly*" (T2 & T7). In addition, all the teachers involved were able to carry out the various stages of the course successfully. Teachers also report that they could complete the mathematical concepts explained in the course. In addition, they were able to understand the tasks that were requested throughout the course, that "*the information about mathematics concepts*" (T5) presented throughout the course was sufficient and that "*the video tutorials presented helped*" (T2) to understand how to work with suggested digital tools.

The course was divided into five stages, in which each stage took place over a week. In the first week, teachers raised awareness of the topic of learning through the project through video tutorials and a course guide in eBook format. This first step corresponds to the first phase of work in Learning by Project. In this way, we presented to the professors the course's learning objectives, the evaluation mechanism that would be used and possible results. Still at this stage, teachers from different countries started by making an individual presentation on the Padlet.

We promote reflection and questioning in small working groups in the second week. The students reflected on the theme of the work, exchanging information and doubts, as suggested by the project-based learning methodology. Organized into groups, the teachers chose a problem for their project and formulated partial problems from the initial problem identified. Then, as groups of 3 elements, they created a Padlet to function as an e-portfolio of their group work, discussed directions for the project, and researched to develop a solution. The following figure shows the e-portfolio created by one of the groups.

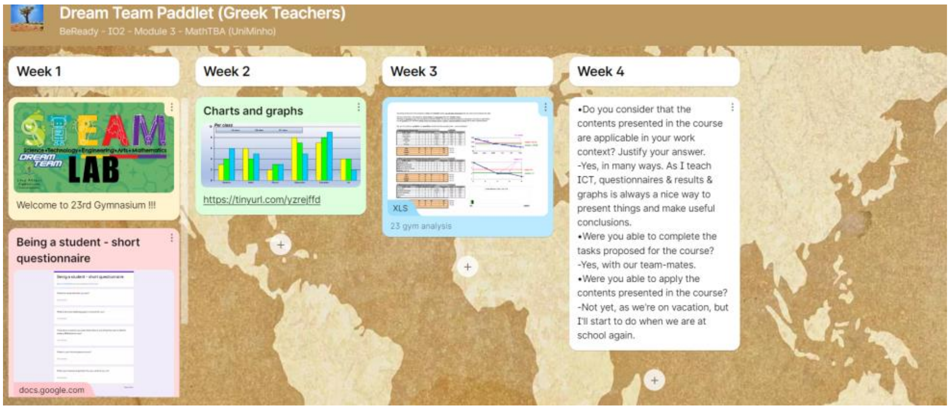

Figure 4
Digital portfolio built by one of the groups

In the week two of the course, we promote research, one of the important stages of learning through projects. Teachers created questions for a quiz, planned and built a quiz in Google Forms and planned its application. In the next stage of the course, the professors learned the basics of descriptive statistics to deal with the information collected through the questionnaires. In module two of the course, teachers began by understanding how to use tables and graphs to organize data. Teachers were taught how to organize data in Google Sheet tables and how to create charts in both Google Sheet and the Canva Platform. In the following image we present the instruction provided on the Platform to teachers. Teachers researched individually and collectively to deepen the theme of their work and unfold it autonomously. Throughout the process, the trainer exchanged ideas with the teachers, guiding them in their learning path.

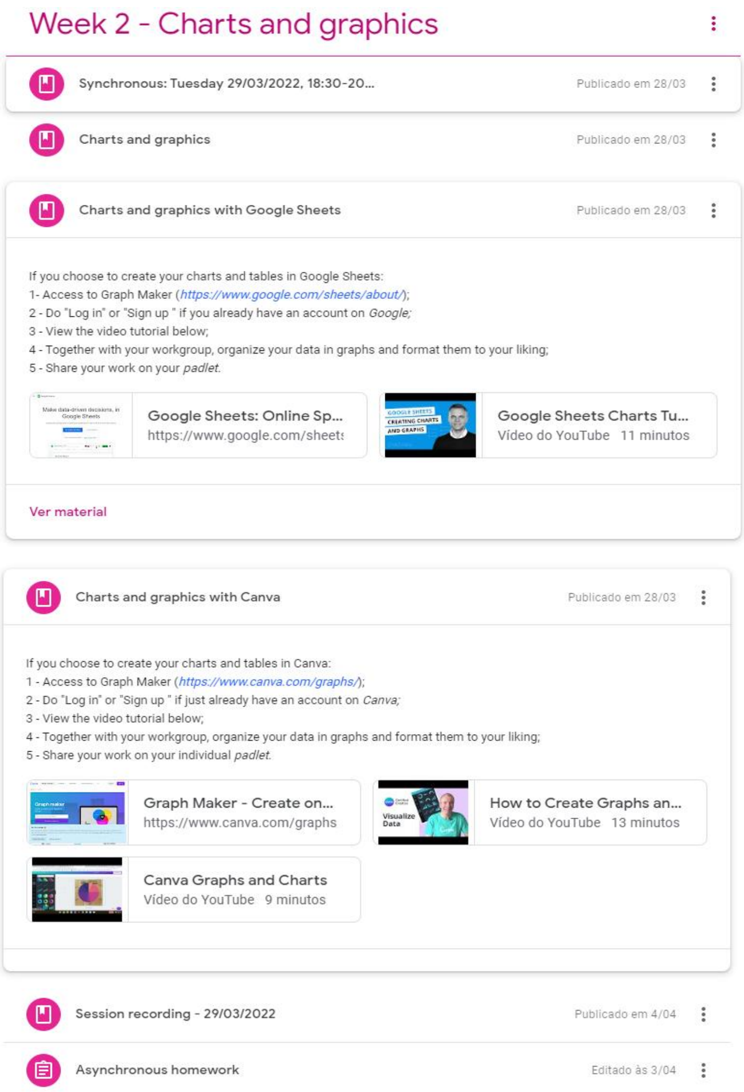

Figure 5
Course charts and tables module

In the next week, we promoted the development of their project with the teachers. Again, teachers put into practice the knowledge and skills acquired in the previous stages. Teachers, for example, learn how to calculate measures of central tendency for a data set and when to use each one in terms of statistical variables. The following image presents part of the instruction provided to teachers. At this project stage, we noted that creativity and empathy among the group members were fundamental for developing the project work.

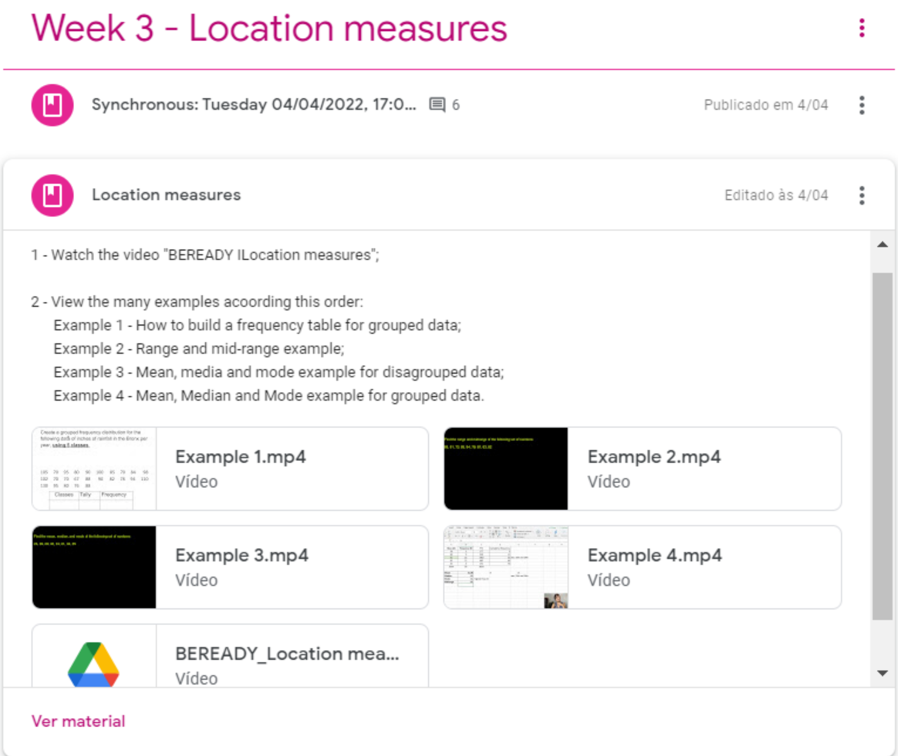

Figure 6
Location measures module

Teachers used the information provided in module three and module four of the course to organize the data in tables and present graphs and the appropriate measures of central tendency for the collected data set. In the next stage of the project, each of the groups presented the work done to the other groups in a synchronous session. A moment of sharing the results of the projects is promoted. In addition to this sharing, in the final workshop (Figure 7) with all the students of the course, the global evaluation of the work was promoted to be developed orally in a large group and individually written. Next, the course structure is presented according to the various moments of the project.

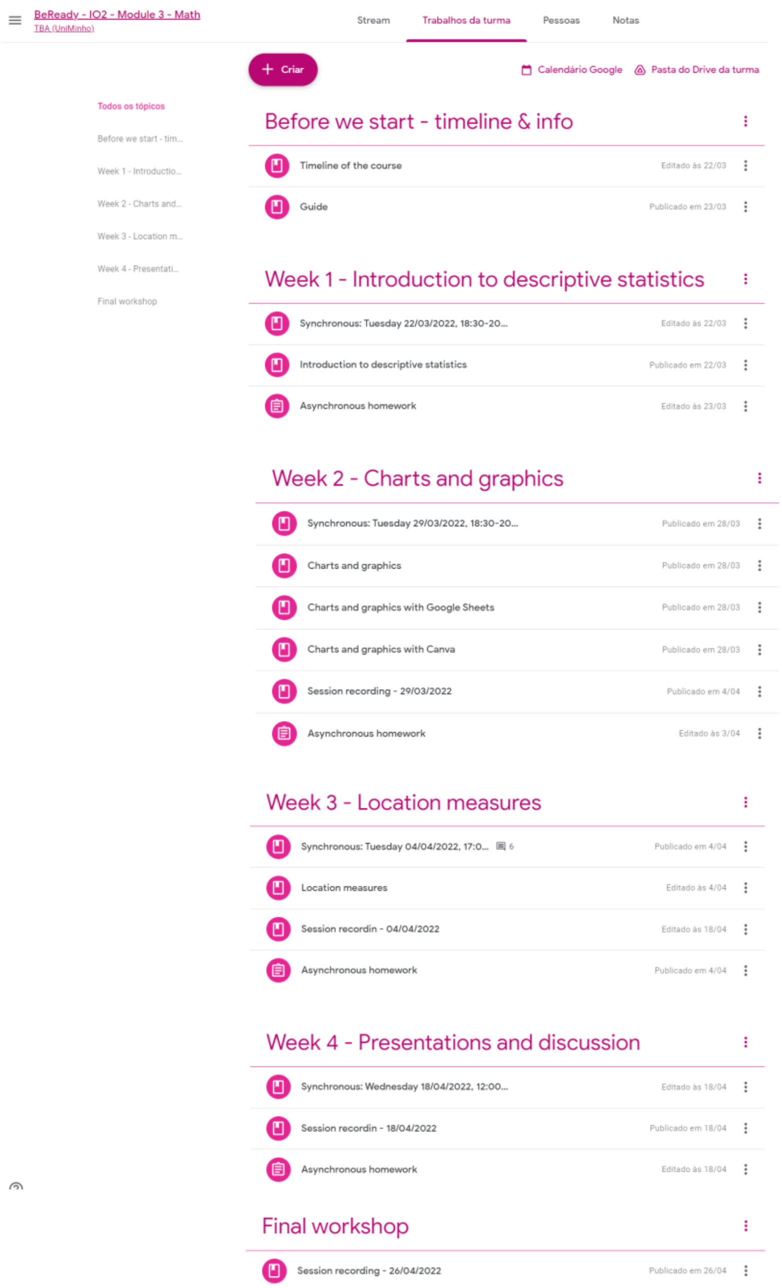

Figure 7
Math online course structure

The course was designed to involve teachers in learning mathematics concepts through a project methodology. On this subject, the teachers mentioned that the various tasks requested in the course "*led us through the execution of the project*" (T3, T6 & T9) and when we realized "*we were already carrying out the final product*" (T2), referring to the final result of the project and which served to evaluate the work of teachers. Starting from a central problem linked to the student's daily lives, the teachers and students of the course investigated, interacted and collectively found a solution to the problem, a product.

DISCUSSION AND CONCLUSION

With this work, we design and build an online course to teach Structural concepts of mathematics according to the design methodology. Teachers were guided along a learning path that involved the design methodology in learning about mathematics concepts. From the preliminary investigation, it can be concluded that only one knew the project learning methodology of the surveyed teachers. Some had already heard about the method but did not know or know how to use it. On the other hand, all professors were interested in taking the course that would allow them to learn how to use the project methodology to promote mathematical knowledge. Matching the answers obtained by the teachers with the criteria of Meyer and Land (2003; 2006) for a concept to be a threshold suggested as a result of this work that the concept of variable is a structuring Structural concept of mathematics.

From theoretical embedding, we concluded that it is common for students to find difficulties in structuring Structural mathematics concepts (Cruz, 2019). The Covid-19 pandemic has changed the way of operating and acting in education. The pandemic brought constant challenges in the teaching of Mathematics and additional difficulties in clarifying structuring Structural concepts in this area of knowledge. Furthermore, the digital world has changed our entire way of living, working, communicating, and interacting in recent years. We can access online spaces and work 'at a distance' from anywhere as long as there is an Internet connection. Today, students work with a vast set of electronic objects full of potential in teaching and learning processes, so it is illogical not to use them for pedagogical purposes (Lencastre, 2012). These assumptions lead us to reflect on the role of the teacher, intending to guide them to do in digital what can be done in a digital environment.

With this work, we designed and built an online course with which we train teachers to make digital pedagogical resources aimed at teaching structuring concepts of Mathematics. These resources are suitable for online teaching and the implementation of the project methodology and use critically and effectively to benefit student learning. The innovative aspect of this article lies in the fact that it presents the design and construction of a course that, instead of simply providing ready-made resources, leads teachers to work on a project to create their pedagogical resources. We followed Nielsen's (1993) guidelines during the course design phases, according to which the course must be appealing, intuitive and be products that can be used with (i) ease of learning, (ii) efficiency in performing tasks and (iii) satisfaction. Through the tests carried out in the empirical testing phase, we sought to know the opinion of experts and the target audience on a varied set of analysis dimensions to develop a course that fulfilled the objectives we set ourselves and corresponded to the needs and target audience expectations.

The suggestions indicated by the experts and lapses detected in each phase were analysed and attended to. It should be noted that there was a positive response and opinion on the part of the target audience during the implementation of the Beta version. The results and reflections raised during this work show that the course was helpful for teachers to understand the Structural concepts involved. Thus, teachers can adapt it to be implemented in the development of competencies around the Structural concepts of mathematics in their students.

The data indicate that teachers need the motivation to learn to work with active methodologies such as project learning but need help to acquire knowledge about them. The learning process in virtual environments involves elements such as the language used, the time and space in which learning takes place, interactivity and ease of access to concepts (Monteiro et al., 2012). All the teachers involved were able to perform the tasks requested throughout the course, organized in increasing order of complexity and with a project-based learning logic. Thus, all teachers involved in the final test with the target audience were able to present the final product expected for the project by each one implemented. Based on the results obtained from the teachers, it can be said that the course responded to what we proposed and engaged the participants in project-based learning.

In a society where students deal side by side with technology, information and communication technologies become an ally and facilitate the construction of content in different formats. Using these technological resources allows both the teacher and the student to reformulate according to the needs and objectives defined. Thus, to increase knowledge about this area, future studies propose to analyse the impact of this type of online course as a reinforcement of students' learning of Structural concepts of mathematics. Thus, it seems pertinent to understand to what extent are teachers aware of the possibility of using online courses as a complement to face-to-face information? The ability to solve problems involving mathematical concepts is usually associated with learning processes that aim, on the one hand, to sharpen reasoning and, on the other hand, to develop logical and systematic reasoning (Fauziyah et al., 2022). Furthermore, does its incorporation into multimedia product bases bring increased usability problems in technical terms?

ACKNOWLEDGMENT

The research leading to these results has been included in the work developed for the Erasmus+ project Supporting the continuation of teaching STEM subjects during the COVID-19 Pandemic through project-based online practices (BeReady). Project number: 2020-1-PL01-KA226- SCH-095959. This work is also funded by CIEd – Research Centre on Education, projects UIDB/01661/2020 and UIDP/01661/2020, Institute of Education, University of Minho, through national funds of FCT/MCTES-PT. We would like to thank to the teachers involved in BeReady Project who collaborated in the tests. We also would like to thank the experts for their contributions in improving the course.

LIMITATIONS AND IMPLICATION

There were obstacles during the implementation of the study. The teachers and students of the course needed to learn how to use the Google Classroom platform, and it was necessary to make an introduction to the platform using video tutorials that explained its main features. The interaction between teachers and students as learning was conducted online using Google Meet. It was necessary to contextualise teachers on aspects such as screen sharing, raising your hand and removing sound or image during a video call.

REFERENCES

Baeta, P., & Pedro, N. (2018). Salas de Aula do Futuro: análise das atividades educativas desenvolvidas por professores e alunos. *Revista Indagatio Didactica,* 10(3), 81-95. https://doi.org/10.34624/id.v10i3.11259.

Barradell, S., & Kennedy-Jones, M. (2015). Threshold concepts, student learning and curriculum: making connections between theory and practice. *Innovations in Education and Teaching International*, *52*(5), 536-545. https://doi.org/10.1080/14703297.2013.866592.

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The clearing house*, *83*(2), 39-43. https://doi.org/10.1080/00098650903505415.

Boss, S., & Krauss, J. (2022). *Reinventing project-based learning: Your field guide to real-world projects in the digital age*. International Society for Technology in Education. Available online: https://www.readpbn.com/pdf/Reinventing-Project-Based-Learning-Your-Field-Guide-To-Real-World-Projects-InThe-Digital-Age-Sample-Pages.pdf

Cotta, R. M. M., Silva, L. S. D., Lopes, L. L., Gomes, K. D. O., Cotta, F. M., Lugarinho, R., & Mitre, S. M. (2012). The construction of collective portfolios in traditional curriculums: an innovative approach in teaching-learning. *Ciência & Saúde Coletiva*, *17*(3), p.787-796. https://doi.org/10.1590/S1413-81232012000300026.

Coutinho, C. P. (2013). *Metodologia de Investigação em Ciências Sociais e Humanas*: Teoria e Prática (2ª Ed.). Coimbra: Almedina.

Crompton, H. (2014). Research windows: ISTE standards in the research. *Learning & Leading through Technology*, *41*(6).

Cruz, S. (2019). A edição criativa de vídeo como estratégia pedagógica na compreensão de threshold concepts na disciplina de matemática. [Tese de Doutoramento, Instituto de Educação da Universidade do Minho].

Cruz, S., Lencastre, J. A., Coutinho, C., Clough, G., & Adams, A. (2017). The Problem Distiller Tool: supporting teachers in uncovering why their students have problems understanding Threshold Concepts. In Gennaro Costagliola, James Uhomoibhi, Susan Zvacek and Bruce M. McLaren (Eds.), *Computers Supported Education*, vol 739 (pp. 380–401). Cham: Springer.

Cruz, S., Coutinho, C., & Lencastre, J. A. (2020). Heuristics and usability of a video assessment evaluation tool for teachers. In H. Lane, Susan Zvacek and J. Uhomoibhi (Ed.), *Proceedings of the 12th International Conference on Computer Supported Education* (CSEDU2020), Volume 2 (pp. 445-454). SCITEPRESS – Science and Technology Publications.

Fauziyah, N., Budayasa, I. K., & Juniati, D. (2022). Cognition processes of ASD students: Recommendations for mathematics teaching and learning process. *International Journal of Instruction*, *15*(3), 805-830. https://doi.org/10.29333/iji.2022.15344a.

Garrison, D. R., & Anderson, T. (2005). El e-learning en el siglo XXI: Investigación y práctica. *Barcelona. Octaedro*. ISBN: 848063748X 9788480637480

Guerriero, S. (Ed.) (2017). *Pedagogical Knowledge and the Changing Nature of the Teaching Profession*. Paris: OECD Publishing.

Harlow, A., Scott, J., Peter, M., & Cowie, B. (2011). 'Getting stuck'in analogue electronics: threshold concepts as an explanatory model. *European Journal of Engineering Education*, *36*(5), 435-447. https://doi.org/10.1080/03043797.2011.606500.

Hofer, M., & Swan, K. O. (2008). Technological pedagogical content knowledge in action: A case study of a middle school digital documentary project. *Journal of Research on Technology in Education*, *41*(2), 179-200. https://doi.org/10.1080/15391523.2008.10782528.

Khadka, J., Joshi, D. R., Adhikari, K. P., & Khanal, B. (2022). Learner-centered instruction: Teachers' practice in online class of mathematics During Covid-19 pandemic in Nepal. *International Journal of Instruction*, *15*(3), 831-852. https://doi.org/10.29333/iji.2022.15345a.

Lencastre, J. A. (2012). Metodologia para o desenvolvimento de ambientes virtuais de aprendizagem: development research. In A. Monteiro, J. A. Moreira & A. C. Almeida (Orgs.), *Educação Online: Pedagogia e aprendizagem em plataformas digitais* (pp. 45-54). DeFacto Editores.

Lopez, L. F., Ferrandis, E. M., Castillo, A. G., & Palomino, S. V. (2021). Problem-and project-based learning in conservation-restoration training programs. *In ICERI2021 Proceedings* (pp. 969-976). IATED.

McMillan, J., & Schumacher, S. (2014). *Research in Education: evidence-based in inquiry*. Pearson.

Meyer, J., & Land, R. (2003) Threshold concepts and troublesome knowledge: linkages to ways of thinking and practising within the disciplines. In Rust, C. (Ed.) *Improving student Learning - Theory and Practice Ten Years on*. Oxford, Oxford Centre for Staff and Learning Development (OCSLD), pp.412-424.

Meyer, J., & Land, R. (2006) Overcoming barriers to student understanding: Threshold concepts and Troublesome Knowledge. In J. Meyer, & R. Land (Eds.), *Overcoming Barriers to Student Understanding: Threshold concepts and tToublesome Knowledge* (pp- 19-32). Routledge.

Morgan, D. L. (1997). *Focus Groups as Qualitative Research* (2nd ed.). Thousand Oaks: SAGE Publications.

Monteiro, A., Moreira, J. A., & Almeida, A. C. (2012). *Educação online: Pedagogia e aprendizagem em plataformas digitais*. DeFacto Editores.

Neto, J. F. B., & da Fonseca, F. D. S. (2013). Jogos educativos em dispositivos móveis como auxílio ao ensino da matemática. *RENOTE – Revista Novas Tecnologias na Educação*, 11(1). https://www.seer.ufrgs.br/renote/article/viewFile/41623/26403.

Nielsen, J. (1993). *Usability Engineering. New Jersey*: Academic Press.

Prensky, M. (2003). Digital game-based learning. *Computers in Entertainment (CIE)*, *1*(1), 21-21. https://doi.org/10.1145/950566.950596.

Peters-Burton, E., Rich, P. J., Kitsantas, A., Laclede, L., & Stehle, S. M. (2022). High School Science Teacher Use of Planning Tools to Integrate Computational Thinking. *Journal of Science Teacher Education*, *33*(6), 598-620.https://doi.org/10.1080/1046560X.2021.1970088.

Salmon, G. (2003). *E-moderating: The key to teaching and learning online*. Psychology Press.

Sigit, D. V., Ristanto, R. H., & Mufida, S. N. (2022). Integration of project-based e-learning with STEAM: An innovative solution to learn ecological concept. *International Journal of Instruction*, *15*(3), 23-40. https://doi.org/10.29333/iji.2022.1532a.

Tseng, K. H., Chang, C. C., Lou, S. J., & Chen, W. P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal of Technology and Design Education*, *23*(1), 87-102. https://doi.org/ 10.1007/s10798-011-9160-x.

Torres, A., Hu, J., Sriraman, V., Martínez-Ortiz, A. M., & Membrillo-Hernández, J. (2022). Assessing the effectiveness of problem-based learning across two concrete construction courses. *International Journal of Instruction*, *15*(4), 473-496. https://doi.org/10.29333/iji.2022.15426a.

Van Someren, M., Barnard, Y., & Sandberg. (1994). The Think Aloud Method: *A practical guide to modeling cognitive processes*. London: Academic Press.

Van Den Akker, J. (1999). Principles and methods of development research. In J. van den Akker, R. M. Branch, K. Gustafson, N. Nieveen, & T. Plomp (Eds.), *Design approaches and tools in education and training* (pp. 1–14). Netherlands: Kluwer Academic Publishers.