The VideoM@T Project
Engaging Students on Learning Tricky Topics in Mathematics Through Creative Skills

Sara Cruz, José Alberto Lencastre and Clara Coutinho
Institute of Education, University of Minho, Campus de Gualtar, 4710-057, Braga, Portugal

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Abstract: This article presents the VideoM@t project, designed to enhance students' understanding of mathematical concepts through creative video editing. VideoM@t was founded on the JuxtaLearn process, an eight-stage pedagogical framework that uses an online platform to assist the students in planning, editing, and sharing knowledge about threshold concepts in a flipped classroom model. The project involved 52 students from 9th grade and three teachers of mathematics. Qualitative and quantitative data were collected to understand students' level of comprehension on tricky topics in mathematics. The results show that students were able to overcome their difficulties during the creative video editing process. The comparison between the first and the final quiz radar charts suggest that students have developed understandable knowledge on tricky topics in mathematics.

1 INTRODUCTION

VideoM@t was one of the winning projects of the contest "*Ideias com Mérito*" [Ideas with Merit] promoted by the Portuguese Ministry of Education to encourage schools to develop innovative projects that use information and knowledge to support the school curriculum. The prize was used to buy tablets that students used throughout the project implementation. In the VideoM@t project, we seek to stimulate students' understanding of mathematical threshold concepts through the production of creative videos. Threshold concepts are reported in the literature as complex concepts that students have difficulty in understanding, sometimes taking refuge in the memorisation of the concept without really understanding it (Meyer and Land, 2003). For students, threshold concepts are troublesome because they are conceptually difficult to comprehend (Perkins, 2006). An abstract concept describes something general, but concrete representations and real-world examples always describe something specific and are very important when connecting concrete and abstract mathematical contexts (Rystedt, Helenius and Kilhamn, 2016).

VideoM@t project was founded on the JuxtaLearn learning process. The JuxtaLearn process uses creative video editing by students to get them to a deeper understanding of a threshold concept or a tricky topic (Adams, Rogers, Coughlan, Van-der-Linden, Clough, Martin, and Collins, 2013). In the JuxtaLearn process, the terminology 'tricky topic' is used to refer to issues identified by teachers as difficult for their students (Adams and Clough, 2015), even though these difficulties are not the same as those reported in the literature as core threshold concepts. In the JuxtaLearn process, to understand the tricky topic, students have to surpass some stumbling blocks that are outstripped first during storyboarding and then in video editing. During the whole process, CLIPIT coordinates all user interaction and data such as documents, storyboards, quizzes and videos.

This article is structured in five sections: in Section 2, we introduce VideoM@t and the JuxtaLearn learning process, while Section 3 presents the methods for data collection, then Section 4 presents our main results and reflections. We conclude in Section 5 with a synthesis and proposals for future work.

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2 BACKGROUND

2.1 VideoM@t Project

The search for solutions that foster academic success in mathematical subjects for a group of students and our willingness to implement the JuxtaLearn learning process led to the elaboration of the VideoM@t project. VideoM@t is centred on a taxonomy developed by the JuxtaLearn project that helps teachers to promote students' interest in threshold concepts through the creation of original explanatory videos. With VideoM@t, our primary goals were to implement methodological alternatives in which students construct their knowledge through actions where they develop mathematical literacy to understand complex math concepts. The project was funded and the money was used to buy tablets. The use of tablets, due to their portability, allows higher efficacy in accessing digital contents (Lencastre, Bento, and Magalhães, 2016). With this project, we promote the sharing and involvement of students in the production of videos that explore the mathematics curricula. We developed in students a creative inspiration, as well as an improvement in their conceptual understanding and their knowledge.

2.2 The JuxtaLearn Learning Process

The JuxtaLearn learning process is founded on a specific pedagogic framework that aims to identify and promote knowledge in threshold concepts in STEM areas (Science, Technology, Engineering, and Mathematics) through creative video editing. The JuxtaLearn process involves the students in eight steps, and is user-centred (Martín, Gértrudix, Urquiza-Fuentes, Haya, Hernán-Losada and Castellanos, 2014); i.e., the student is the protagonist in the learning process, and the teacher is a facilitator between the student and the knowledge (Lencastre and Coutinho, 2015).

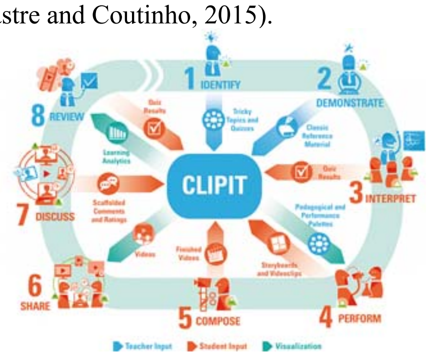

Figure 1: The JuxtaLearn Process.

Step 1 (Identify) – The teacher identifies the tricky topics based on their previous experience. Each tricky topic can be divided into smaller stumbling blocks.

Step 2 (Demonstrate) – The teacher creates one or more Standard Teaching Activities (STA) around the stumbling blocks.

Step 3 (Interpret) – Students perform a diagnostic quiz to determine their level of understanding about the tricky topic.

Step 4 (Perform) – Students create a storyboard to explain the tricky topic.

Step 5 (Compose) – In groups, the students make a video explaining the tricky topic.

Step 6 (Share) – Videos are shared with the class via CLIPIT.

Step 7 (Discuss) – Debate among students is promoted, allowing the social construction of knowledge while promoting the consolidation of the concept.

Step 8 (Review) – Students return to the quiz from Step 3 to re-assess their understanding of the tricky topic.

The entire process is tracked online on the CLIPIT platform (see Figure 1). CLIPIT is a web space that allows collaboration, peer assessment, and analysis of the learning progression in a flipped classroom model. The productive failure-based flipped classroom pedagogical design, allows students to have more time for thinking and discovering, and may help to improve students' problem-solving skills (Song and Kapur, 2017). CLIPIT was developed to support the JuxtaLearn learning process by allowing comments and analysis of the results (Adams and Clough, 2015). CLIPIT has a database of tricky topics, and their related stumbling blocks, examples of student's problems, quizzes and teaching material. To learn more about CLIPIT, see the article from Cruz, Lencastre, Coutinho, Clough, and Adams (2016) - *Threshold Concepts Vs. Tricky Topics - Exploring the Causes of Student's Misunderstandings with the Problem Distiller Tool,* reported in the references.

3 METHOD

VideoM@t was strongly anchored on JuxtaLearn learning steps. The study included the identification of tricky topics in mathematics with three teachers and the application of the entire process with 52 students. The teachers collaborated voluntarily, involving three of her own classes.

Diverse methods were used to collect the data: (i) interviews with the teachers; (ii) system logs on the platform, (iii) a diary to gather direct observations, (iv) a final focus group with the students to understand their perceptions about the whole process.

3.1 Identifying the Tricky Topics

The first step was to identify the threshold concepts with the teachers. The three teachers assembled in a group, reflected on the difficulties of their students and identified threshold concepts that, from their teaching experience, are tricky topics. Thus, based on their knowledge, teachers identified the following tricky topics: solving equations with denominators, literal equations, solving 1st-order equations, and solving equations with parentheses. Then, with the guidance of the Problem Distiller tool, they divided each tricky topic into stumbling blocks, and wrote a brief description of the specific problems. The Problem Distiller tool displays a set of tabbed panes prompting teachers to reflect on and select possible reasons why their students might be having a particular problem, connecting all the information entered to the appropriate tricky topic and stumbling block or blocks (Adams and Clough, 2015). The gathered tricky topics were then used by the students to develop their videos.

3.2 Creative Video Editing

The creative video editing process involved six tasks for each group of students: (1) diagnostic test (initial quiz available on CLIPIT); (2) create a storyboard; (3) edit the video, (4) watch the video and discuss it with peers, (5) post-knowledge test (final quiz available on CLIPIT) and (6) reflect on the results.

Initially (Identify) with the help of the Tricky Topic Tool, we identified tricky topics and mathematical topics that teachers considered difficult for their students. The data collection was done through system logs on the platform and a diary to collect direct observations.

Next, (Demonstrate step) the teachers made CLIPIT available through students' activities (videos, PDFs, links) with relevant information about the identified tricky topics. The students accessed the information, clarified doubts and then completed a diagnostic quiz to determine their level of understanding about the tricky topic. A diagnostic quiz is the starting-point for students participating in the JuxtaLearn Process (Adams and Clough, 2015). Figure 2 shows a student verifying the result obtained in the questionnaire.

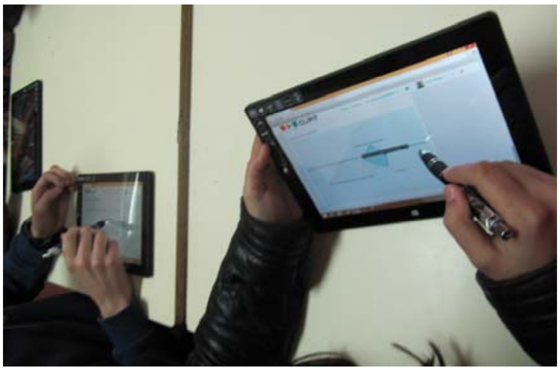

Figure 2: Students checking the quiz radar charts.

Based on the results obtained in the diagnostic quiz, the teachers established work groups comprising two students. The group was set so that a student with more difficulty in a certain topic would work with a student who presented less difficulty. So, in pairs, students drew storyboards to explain one of the tricky topics or the initially identified stumbling blocks (Perform step). The storyboards were scientifically and pedagogically validated by the teachers and the students created explanatory videos based on these storyboards (Compose step).

The videos were shared in the class (Share step) and a discussion was organised around the work done (Discuss step). Then, the students performed a final quiz (with the same questions as the diagnostic quiz) to be able to compare results and see their evolution.

In the end, with students, we performed a focus-group to understand their perception of the JuxtaLearn learning process. After transcribing the material from the focus-group, a content analysis was done following the guidelines of Bardin (2013). A set of dimensions and categories emerged from data, which are as follows: (i) Students' perception of the storyboard design process, (ii) Students' perception of the value of video editing, and (iii) reflection about the process.

3.3 Participants

Three math teachers (T1, T2, and T3) working in a public school, all being women aged between 42–50 years old. 52 students (Si, com i∈{1, …, 52}) from the 9th grade, 31 girls and 21 boys, ages from 13–15 years old. Each teacher was responsible for developing the JuxtaLearn process in her own class.

4 RESULTS

The Problem Distiller Tool helps teachers reflect on the causes of student problems they had identified (Cruz, Lencastre, Coutinho, Clough, and Adams, 2016). So, based on their teaching practice, teachers identified the tricky topics in mathematics that are problematic for their students, and checked if the tricky topics were already listed in the Tricky Topic Tool and the database of CLIPIT.

Studies consider that concepts poorly understood in arithmetic constitutes an obstacle to a student's understanding of algebra (Guimarães, Arcavi, Gómez, Ponte, and Silva, 2006). There is a mathematical connection between algebra and arithmetic as each is normally taught using abstraction and generalisation processes. The teachers identified arithmetical difficulties in understanding and apprehending the algebraic process for solving equations. So, teachers identified the following tricky topics: (i) solving 1st-order equations, (ii) solving equations with denominators, (iii) solving equations with parentheses, and (iv) literal equations.

Then teachers reflected on the difficulties they usually encounter with their students and tried to identify stumbling blocks and comprehension gaps in tricky topics (Table 1). When teachers expressed problems explaining why their students had difficulty understanding the tricky topic, they were guided by the Problem Distiller Tool.

Table 1: Tricky Topics and their stumbling blocks.

Tricky Topic	Stumbling Blocks
Solving 1st-order equations	Translation of statements of current language for symbolic language
	Simplification of algebraic expressions
	Principles of equivalence
	Verification of solution
	Notion of unknown and notion of solution of an equation
Solving equations with denominators	Distributive property of multiplication
	Priority of elementary operations,
	Equivalence principles of equations, notion of equation
	Notion of solution
	Simplification of algebraic expressions and simplification of fractions
Tricky Topic	**Stumbling Blocks**
Solving equations with parentheses	Distributive property of multiplication
	Distributive property of multiplication
	Property of elementary operations
	Principles of equivalence of equations
	Use of rules to solve 1st degree Equations with a non-denominator unknown
	Notion of unknown
	Current language translation to symbolic language
	Simplification of algebraic expressions and rational numbers
Literal equations	Principles of equivalence of algebraic equations
	Simplification of algebraic expressions
	Solve a literal equation in order to an unknown
	Notion of solution and notion of equation

The Problem Distiller tool lists a set of problems that typically challenge students, helping the teacher to think and reflect on their experience working with students. Through this reflection, the teacher is able to identify the gaps in an understanding of the tricky topic and associate their own students' difficulties to the comprehension problems listed in the Problem Distiller tool. As they made selections from the Problem Distiller tool, teachers were identifying problems that students typically encounter in understanding tricky topics. At the same time, teachers were also able to reflect on why these problems occur and how they can be solved.

Figure 3: Problem Distiller to a 1st grade equation.

For example, on the tricky topic 1st-Grade equation (Figure 3), the teachers reported that students do not know the principles of equivalence and have considerable difficulty in simplifying algebraic expressions, which makes it difficult to work with equations. Teachers also reported that their students sometimes cannot verify whether a number is a solution to a given equation because they cannot recognise the meaning of unknown. On the Problem Distiller Tool, teachers also associate possible causes for difficulties on the tricky topic 1st-Grade equation. They said that the causes for the difficulties may arise from the students' incomplete knowledge of concepts that they should already know, or a misunderstanding of the method for solving equations.

The tricky topics identified in Step 1 of the JuxtaLearn process have been revised. Then, teachers shared material available in CLIPIT for students to review the mathematical contents (Step 2 of the JuxtaLearn process). All students had an initial quiz (Step 3 of the JuxtaLearn process), previously prepared by the teachers on the Quiz Tool in CLIPIT. We used the Radar Chart to help students diagnose their own comprehension problems in a tricky topic and to help teachers reflect on ways of aiding the student to overcome these stumbling blocks. The visualisation by students of their own radar chart helps them to identify and to diagnose the stumbling blocks they encounter when trying to understand the tricky topic (Hartnett and Adams, 2016); this can assist them to focus on overcoming these difficulties. The reflection on one's mistakes is relevant (Cherepinsky, 2011) to overcoming gaps in understanding and overcoming difficulties in learning mathematics. Based on the results obtained in the initial quiz, each group of two students created a storyboard (Step 4 of the JuxtaLearn process) on a mathematical subject in which they had difficulty. Then, based on the storyboard created, the students edited a video (Phase 5 of the JuxtaLearn process) on the following topics: (i) solving a literal equation in order to an unknown, (ii) the distributive property, (iii) principles of equivalence between equations, (iv) check if a value is a solution to an equation, (v) notion of solving an equation, (vi) notion of unknown of an equation, (vii) check if an ordered pair is a solution, notion of unknown, (viii) simplification of algebraic expressions, and (ix) properties of the elementary operations. A storyboard is a set of drawings as a representation of a film in sequences, and these drawings can contain elements such as dialogues, pictures, sketches (Hartnett, Malzahn and Goldsmith, 2014). At the end of this phase, 25 storyboards and their videos were created. Storyboards and video scripts are potential objects that allow the transfer of knowledge between different students through the creation of a movie. The creation of storyboards constitutes a creative step on which students collaborate, share knowledge and reflect in order to identify and clarify differences (Hartnett et al., 2014). The collaborative construction of videos favours motivation for tasks (Cruz, Lencastre and Coutinho, 2015). The videos created were shared (Step 6 of the JuxtaLearn process) in class and a discussion (Step 7 of the JuxtaLearn process) was promoted around the results achieved. In the end, students completed a final quiz (Step 8 of the JuxtaLearn process) to compare performances. The visualization of their quiz results as a radar chart helps students to diagnose their own progress. In the following image, we present an example of a radar chart of the initial and final quizzes by one of the students involved – S4

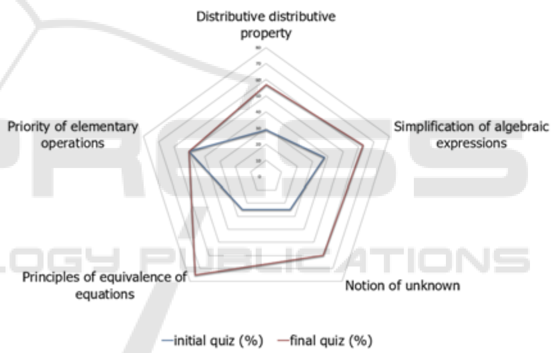

Figure 4: Radar chart with initial and final quizzes.

Comparing the chart radar observations for the initial and final quizzes, we found that the student improved in overcoming some stumbling blocks. We observed that the student increased the number of correct answers to questions that involve having the notion of unknown, knowing the equivalence principles of equations, knowing the distributive property of multiplication and knowing how to simplify algebraic expressions. The student kept the same number of correct answers to questions that involved knowing the priority of elementary operations.

Comparing the results obtained on the radar of the initial quiz with the ones obtained on the final quiz (Table 2), in all three classes it was found that most students improved their scores.

Table 2: Comparison between the initial and final quiz.

Class	Teacher	Variation of the final to the initial quiz		
		Positive variation	There was no variation	Negative variation
A	T1	≈87%	≈13%	0%
B	T2	50%	≈28%	≈22%
C	T3	≈69%	≈12%	≈19%
Total		≈67%	≈18%	≈ 14%

Song and Kapur (2017) in their quasi-experimental study comparing the “traditional flipped classroom” pedagogical design to the “productive failure” pedagogical design in the flipped classroom for a curriculum in a Secondary school found something similar. In this study, authors worked in two Grade 7 classes, one of them with “traditional flipped classroom” and the other class with the “productive failure-based flipped classroom”, with students who had more difficulty.

The content analysis was developed according to the phases suggested by Bardin (2013), so Table 3 presents students’ voices according to the three categories considered.

Table 3: Category of analysis.

Tricky topic	N.º	Stumbling Blocks
Students' perception of the storyboard design process	5	"The most difficult thing is to have the idea for the storyboard" (S2). "Because we had to find a way to explain an equation and it was complicated" (S24). "It is as if we were to teach" (S32). "Was the one who gave more work, to have ideas" (S41). "Was the one that gave more work, to have ideas" (S41).
Students' perception of the value of video editing	3	"I enjoyed recording the video" (S13). "The one I liked the most was making the video" (S11). "We did the same job, but on the computer, so it's more appealing" (S32).
Reflection about the process	2	"The first problem is that we had to know the matter, then we had the problem of perceiving how we are going to explain that. The third problem was getting it to the paper, which was in our head. The fourth problem was to convey to reality "(S4). "This work has clarified some misunderstandings, almost all of them" (S51).

Interpreting Table 3, we verified that during reflection at the end of the cycle, the students considered that "storyboard phase" (S4) was the stage of the process they felt to be the most difficult as they had to "get the idea for the storyboard" (S2). Finding "a way to explain an equation and it was complicated" (S24), worked "as if we were teaching" (S32), so this step "was what worked the most" (S41).

According to the opinion of the students, the most enjoyable step in the process was to "record the video" (C4A13), or "make the video" (C4A11). They enjoyed doing creative video-editing work and having the opportunity to work out more exercises using this method, because "on the computer, then it's more appealing" (S32). These results are similar to those obtained by Kearney and Schuck (2006); in a study with a group of students who had to choose the content for a video, they wrote their own scripts and storyboards and proceeded to the creative edition of the video. During this work, creative video production has motivated, enveloped, and enthused students in learning and working with mathematical concepts. All the students admit that the process helped them to think differently, "because it clarified some doubts, almost all of them" (C4A51). Students need to feel that they can create and choose their own path in learning through clear guidelines in order to improve their understanding and creative performance (Adams et al., 2013).

In general, students consider that thinking about and planning the videos helped them to overcome the stumbling blocks that were obstacles to learning. However, they admit that they had difficulties in doing the work: "The first problem is that they had to know the matter, then they had the problem of realising how they were going to explain it. The third problem was getting what was in the head on to paper. The fourth problem was to convey the reality" (S4). By awakening students' curiosity in concepts, the JuxtaLearn learning process is intended to support students in a deeper understanding of a specific concept through a creative process of video editing that is based on a stimulating and flexible approach (Adams et al., 2013).

5 CONCLUSIONS

In this article, we described the VideoM@t project based on the JuxtaLearn learning process. During the study, we identified and discussed ways in which the process helped the students to overcome misunderstandings on mathematical concepts.

Teachers identified the tricky topics that their students have, and we uploaded them into the Tricky Topic Tool. Then, with the help of the Problem Distiller Tool, teachers were led to reflect about misunderstandings that they usually find among their students. Teachers were able to put into practice the whole JuxtaLearn process with their students, by guiding them in the production of storyboards and instructional videos in a collaborative way. Students created 25 explanatory videos about concepts they had difficulty in. They considered that producing videos helped them – “work has clarified some misunderstandings, almost all of them" (S51). In this phase, they admit to having experienced increased difficulty, because they "had to find a way to explain an equation and it was complicated" (S24). In general, all students enjoyed doing the work, mainly "recording the video" (S13), because the process involved students by making them an active part in their own learning. The results of Rystedt, Helenius and Kilhamn (2016) in a case study investigates how a group of 12-year-old pupils contextualise a task formulated as an equation expressed in a word problem, showing the importance of giving pupils opportunities to realise the position of symbolic mathematical representations when dealing with mathematical concepts. In line with Rystedt et al. (2016), our analysis indicates that engaging students in concrete activities that involve them helps to improve their skills.

Data analysis showed that the VideoM@t involved the majority of the students. All of them completed the JuxtaLearn learning process and most improved the results in the post-knowledge test. According to the results obtained by Rystedt et al., 2016), the concrete representations (such as real-world situations) are conceptually different from abstract mathematical concepts. Pirhonen and Rasib (2017), in a study about the learning method in which students produce instructional videos about the content matter of their learning process, realised that producing a video combined with the content approach can be an efficient and motivating way of learning. A didactical implication of this case study is that it is difficult to incorporate the rich meaning of an abstract concept. However, the video creation involve the students in recreational activities that allowed them to develop skills around these concepts. It also seems appropriate to analyse in future research if the level of reflection achieved with the use of the Problem Distiller Tool contributes to changing the teachers' professional practice.

The radar chart works as a digital tool for evaluation and visualisation of the results by students and teachers. The students’ view of the radar chart, however, should be regarded as a significant means to support reflection alone. Although the role of the teacher is also important, it is a teacher's task to manage the students’ reflection in order to promote deeper thinking. In line with Cruz, Lencastre, Coutinho, Clough and Adams (2016), findings suggest that students are receptive to making videos and can improve their mathematical knowledge around complex concepts. These results are important to foster curiosity around mathematical topics, but further research is needed to study the pedagogical relevance of this.

In today's innovation society, mathematical knowledge becomes ever more relevant in the development of the next generation of creative thinkers and innovators. This VideoM@t project was set out to solve problems in the understanding of mathematical concepts, through creative video editing. The ease with which students deal with video, mobile technology, and digital resources should be used in the learning process for educational purposes (Lencastre et al., 2016). Do teachers conceive the idea of being able to work remotely, to create digital resources to help the student and guide a student-centred work in a non-presentational way? Global connectivity and new forms of communication are some of the drivers that reshape the way we think, which influences how we learn and develop skills. Are schools taking advantage of the potential of digital technologies, including the possibility of having personalised information and open content? Do teachers use the interactivity that this type of material make possible? To improve the teaching of mathematics, it is necessary to establish a new vision for learning. It would be beneficial if students could learn with study tools that adapt to their capabilities. CLIPIT helped students to assess their own knowledge about a mathematical topic. Students are positively reinforced during their individual learning processes. In future research, it would be interesting to create some courses in a similar way to create the storyboard and video in the same application, aiming for a more immediate support to students’ work by the teacher and at the same time broadening the possibility of online co-production, breaking away from the traditional way of teaching and learning.

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