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From task implementation to task reorganization through technology: A case study with an in-service mathematics teacher

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Abstract: Studies on technology represent a fertile field of research in mathematics education. Discussions cover both competencies and dispositions to integrate technology and involve human and contextual factors. In this work, we present the results of a study of an in-service mathematics teacher that investigated the different uses of technologies that he could recognize in his students, and how this allowed him to reorganize a modeling task. Through an intrinsic case study, we analyze documents and interviews with this teacher. The results show that the teacher paid special attention to the students' actions and paths to solve a mathematical modeling task, which allowed him to incorporate new actions and uses of digital technologies for task reorganization. This study provides evidence of the role of the analysis of one's own experience and the recognition of the functionalities of technology in modeling task reorganization.

Keywords: Technology, mathematical modeling, modeling task, reorganization.

1. Introduction

Mathematical modeling, models and applications have come to constitute a major research domain in mathematics education [1]. In recent research, it is possible to identify a growing interest in the development of interdisciplinary relationships and STEM education [2,3], and teacher education [4]. In some of this research, technology takes diverse roles in researching and designing tasks and other educational resources [5,6]. For example, Molina-Toro et al. [7] differentiated two roles of technology in mathematical modeling. First, it can serve as a reorganizer of modeling processes, including the development of new phases of modeling cycles and contributions to mathematical understanding and the development of modeling sub-competencies. Second, technology can serve as a reorganizer of the understanding of modeling itself, which is in correspondence with the opportunities that new technologies offer in the consolidation of environments for learning mathematics.

Based on the above, Villa-Ochoa and Suárez-Téllez [8] identified that the bulk of research on modeling incorporates an understanding of it as a process/cycle, and predominantly uses calculators, Dynamic Geometry Software (DGS), and Computer Algebra Systems (CAS). These authors highlighted the need for more research that recognizes alternative understandings of modeling in correspondence with other internet-based technologies, including mobile technologies, platforms, and videoconferencing systems, among others. Considering these works, we understand that different technologies and understandings of modeling could be combined with human actors (students and teachers) and their contexts (social and institutional) to generate different uses of technologies. Therefore, we developed a study in which we offer an answer to the question: What are the uses of technologies that a teacher recognizes in a mathematical modeling task and how does the use of technology allow him to reorganize it?

2. Theoretical Background

Studies in modeling provide evidence to argue that technology transforms visions and ways of acting in school mathematics [5,7,9]. For example, some studies have shown how mathematics class participants can use sensors [10] or program electronic devices [11] to produce mathematical knowledge in alternative ways to those traditionally imposed in school. Different studies recognize that the use of technologies in modeling depends on the teacher's thinking about mathematics, technologies, and their integration into teaching [5,12]. Thus, humans are not the only actors in the production of mathematical knowledge. In the Humans-with-Media perspective [13], technologies are also key actors in the process. In this framework, Soares and Borba [14] described how participants can interact with Modellus software to study mathematical models that relate to malaria transmission. In this work, the role of this technology was transcendental since it allowed students to analyze graphs and the changes they show when various conditions in the phenomenon vary. Students in Molina-Toro et al.'s [15] study worked with software simulations of the movement of a clock to analyze the mathematics in the movement of its hands. The software led the group of students to elaborate other ideas around the study of the sine trigonometric function and, in addition, led them to generate conjectures that originated in the arguments that arose from the study of the graphs. In a study by Borba, Villarreal, and Soares [16], students participated in a modeling process; with technology, they had the possibility of choosing, based on their needs or interests, a phenomenon to approach their study. The students who took part in the experience were able to analyze data in GeoGebra software and estimate how the phenomenon's results would develop in the future.

Collectively, these studies not only show the opportunities offered by the articulation of modeling and technologies, but also contribute to the discussion on how the role of the student in the classroom can be transformed and in what ways mathematical knowledge can be built with them. These experiences are also inputs to consolidate reflections around which new designs of school environments can be proposed. This includes designs in which the student does not approach mathematics by the imposition of the curriculum in the school itself, but by conscious and detailed analysis of the context that surrounds them, of the multiple social needs that accompany them, and of the interests that they have as a subject.

Although several experiences have been developed from analysis along these lines, the present study discusses work done with a single in-service mathematics teacher. This analysis is part of a broader body of work that seeks to have other voices that, based on their experiences, promote discussions on the use of technologies in mathematics classes.

3. Methodology

The empirical phase of this research was conducted with Carlos (pseudonym), who is a middle and high school mathematics teacher in an urban school in Medellín, Colombia. This section presents the details of the context and the participant, the empirical data, and, finally, the data analysis procedures.

3.1. Context and Participants

This research was conducted during the first semester of 2022 following the guidelines of an intrinsic case study [17]. The case corresponds to Carlos, a mathematics teacher who has been interested in the integration of modeling in his classes; this teacher participates in networks and research groups in mathematics education and has postgraduate training in research in mathematics education. Carlos voluntarily accepted the invitation to participate in our study.

At the beginning of his postgraduate training (first semester of 2018), Carlos planned a class (54 minutes) to solve a problem through mathematical modeling. Carlos designed a three-part class. In the first part (15 minutes) the teacher presented the objective of the class, introduced the situation, and prompted questions to see if the task was understood. In the second part (26 minutes), students were distributed in teams of 4 or 5 people to work on the task, they made decisions regarding the ways that were emerging to find their solution and developed a proposal. At the end of the class (13 minutes), some strategies that were used to solve the task were presented.

For Carlos, the literature on modeling offers opportunities to design new class-room environments, which is why he found inspiration for the design of the task in the works of German researchers [18]. For Carlos, tasks based on existing monuments in public cultural spaces can become problems for the mathematics class and allow the development of mathematical modeling skills. Based on the cultural characteristics of Medellín, Carlos designed the following task: "In the Plaza Botero sculpture park in the city of Medellín, Colombia, there is a bust of a man's face. Could we calculate how tall the sculpture would be if it were necessary to add what is missing from his body?" Figure 1 shows the sculpture that served as a reference to approach this task with the students in mathematics class. Complementary to the statement, Carlos provided the students with a video in which he promotes the city for its different museums and art expressions. The goal of the video was to engage his students in a scenario in which creativity, culture, and regional traditions would enter into the discussions between teacher and students — the task would incorporate the meaning of Medellín having a plaza with works by the painter and sculptor Fernando Botero into the mathematical task, that is, to estimate the size of the sculpture with the size of the bust and an image as reference.

After presenting the image to the students, the teacher indicated to his students that the reference measurement for the height of the sculpture was approximately 3 meters.

This measurement would be a parameter that all participants would consider solving the task, since it was not possible to get a group visit to the park.

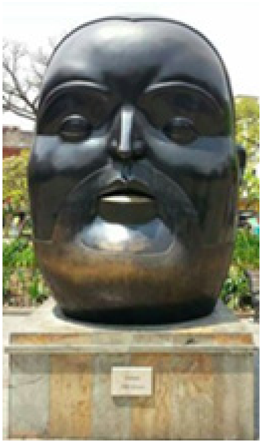

Figura 1 – Sculpture of the Plaza Botero in Medellín.

3.2. Data and its analyses

The data collection and its respective analysis were divided into two phases. The first one was carried out once Carlos finished his postgraduate studies (second semester of 2021); at that time, we invited him to analyze the videos of his class. For this, first, we accessed the video and asked him to identify the uses of technology that he evidenced in the development of his class; then, Carlos presented the research team with a document in which he described the three paths that, according to him, the students used to develop the task, the technologies involved and the uses that his students made of those technologies.

To analyze this document, we considered the guidelines of Villa-Ochoa et al. [19], who understand that the notion of 'use' transcends the 'presence' of technology in a specific place and context. For the authors, this notion focuses on identifying how this technology can offer possibilities to achieve the subject's objectives and satisfy his or her explicit needs. Based on this notion, we identified the technologies used in the class by the teacher, those used by the students when solving the task, and then looked for evidence to answer the following questions: What were they used for? What potential actions did the teacher consider that he could promote in the students? How were they articulated with other technologies during the class? In what student actions was the use of these technologies evidenced? For each of these questions, we used specific codes. Two of the researchers coded the data, and then discussions were generated among the entire team to discuss the interpretations and reach a consensus. The results of this first phase of the analysis are presented in section 4.1.

Subsequently, we conducted a semi-structured interview with Carlos in which we asked for his reflections on the use of the technology present in his class, the relevance of the task and the design of the environment, and the changes he would make to the design of his class. This interview was saved in audio and was analyzed following the principles of H-w-M [13] to identify those fragments of the interview that revealed “new” uses of technology, the conditions he would consider and the reasons why he would introduce those new uses. The results of this section are presented in Section 4.2.

4. Results

4.1. Technology as a resource for developing a modeling experience

To answer the question of our study, Carlos analyzed his own video and identified actions and ways in which students solved the task. The teacher identified actions such as: exploration, measurement, and experimentation; although he did not recognize the use of digital technologies in all of them, he did recognize the use of non-digital technologies as means or tools for the development of the task. Likewise, he recognized three ways of solving the task, namely: (i) using proportionality from the ratio between the measurements of the head and the body of a classmate; (ii) estimating the size of the statue’s body from the measurements of the photos; (iii) estimating from the number of students that should be grouped to obtain the size of the bust. In the research team, we analyzed these actions and ways of resolution and discussed to identify the digital and non-digital technologies used. In the following, we describe each of these ways.

1. In the first way of resolution, some working groups chose a partner to measure the length of his head and construct a relationship between this measurement and the height measurement of the partner.

Figura 2 – Students measuring the height of a classmate

The following excerpt shows the decisions made by Carlos and Nelson when they were questioned by the teacher:

- Teacher: Well, what are you going to measure?
- Carlos: we are going to measure Nelson, how much did he measure?
- Nelson: 1.70 m
- Carlos: The face measured 21 cm, then we are going to look at how many times the measurement is [points to Nelson's face and the rest of his body] to multiply or divide it

[Video 05/13/2017]

The mathematical work in various groups focused on developing a proportional model that would provide information on how tall the sculpture was if they had information on the length of the head and body. This simplified model is of the form $\frac{a}{b}=\frac{c}{?}$, where a and b correspond to the measurement of the head and total body height in centimeters respectively and c is the measurement of the bust height that was presented to the students. With the measurements, they found using the tape measure and the calculator they estimated a value for the height of the sculpture.

2. Other groups decided to use a notebook to measure the length of the image projected on the board and estimate, with the length of one of their own faces, how many times the head measurement can fit into one's own height: "I want to see how many times the head is in the body and compare [student placing a notebook as a reference of the measurement of his face]" [Video 13/05/2017]. This process led students to determine that a person can have a height (a) of 8 times the length of their face (c) which mathematically is represented as a ratio of the form a=8c. This ratio was the main input to determine the height that the entire sculpture could be. The tape measure was a resource with which the students, in addition to obtaining measurements, were able to validate some numerical results that they found when using calculators. These results offer evidence, on the one hand of how the students reduced the operative load with numbers from numerical domains that they had not worked on in math class and, on the other hand, how they used multiplicative and counting strategies to establish a solid and explanatory argument to obtain the solution to their task since, in the curricular plan, the topic of proportionality had not yet been worked on.
3. In the third form of solution, students grouped together to find the number of classmates needed to ensure that the sum of the length of their heads was 300 centimeters (the length of the statue), and subsequently, add each of their heights together to find a final numerical value: "we need 15 people that measure 20 the face [referring to a measurement of 20 cm] then we take the height" [Video 05/13/2017]. The measurements found by all groups were in the range of 21 m to 23.7 m and corresponded to relationships they could find between each of the group members, some with greater height than others.

Overall, in these three paths, we recognized digital and non-digital technologies. Each was used by students for specific purposes to solve the task; for example, some students focused on measurement, where they used conventional and non-conventional instruments to take measurements. They also employed the technologies to estimate and substantiate their results with the use of the mathematical content of proportionality. Given this scenario, we interviewed the teacher to understand his views on the use of these technologies and on how the task could be reorganized. In the following section, we will present the results of this part of the study.

4.2. Digital and non-digital technologies for reorganizing a modeling task

Once the previous task and class were analyzed, Carlos recognized the conditions he had considered for the class. According to the teacher "the class was on a fixed schedule of one hour; the class was to involve students in solving mathematical problems; for the class, students were not connected to the internet or to the use of other technologies." According to our conceptual framework [13], this comment allows us to recognize that the development of mathematical activity and the use of technologies is conditioned by specific factors, according to the context and to the subjects who develop it. To go deeper into this aspect, we questioned Carlos regarding the way he would develop his class in different conditions. In this regard, he answered:

"Having technologies, what I could do with GeoGebra is to take more photos of the students, and so work with those measurements that they first find with a tape measure, which I could do for several students and with the measuring tools of the software, we could scale those measurements and measure the bust and get an approximate measurement — the height of the bust in correspondence with the height of one of the students". Later he added *"this class would be different from the other because with GeoGebra we would have access to measure several students and make use of other mathematical tools, e.g., height promises, or other statistical measures. Although the way of solving is similar, with GeoGebra it would be different in that we would have more data to have a more standard measurement"*. In these excerpts, Carlos recognizes that GeoGebra can be used for developing the task. In this case, based on the use notion [19], GeoGebra is not only introduced into the task, but also, roles and actions-with-students were projected; for instance, it could provide a substitute for the tape measure, but also for the analysis and exploring, and processing of a larger amount of data.

"If we had access to the internet, we could validate this task; in the first task [class video], we "validated" in some way because all the teams found approximate answers in a range of values; but we could not do a trace to see if indeed, those values [obtained by the students] are in accordance with what some pattern estimates; then on the internet, we could look for anthropometric measurements, and with them, rethink some calculations". In this excerpt, Carlos reports the possibilities that the internet would offer him for access to data, but also to develop other ways of validating the results in the modeling process.

Additionally, Carlos recognized two aspects for a reorganization of the class. The first of these was access to more specific information about the sculptor, materials, styles, and other data that would help to deepen understanding of his work. The second was the possibility that some measurement applications of smartphones would have; however, he recognized that he would still need to better understand the functionalities of these devices to think about the class.

5. Discussion and conclusion

International literature reports that teachers are important agents in the integration of technologies in the mathematics classroom [2,20]. Therefore, inquiring about their knowledge, practices, and needs is a key aspect of educational research [5,20]. A large part of the literature suggests that teachers should develop capabilities to create diverse learning environments and transcend rigid curricula; however, this is not always possible to achieve. Therefore, teachers should prepare themselves to make the best use of their classes in the contextual and subjective conditions of their schools. In this sense, this study offers evidence of the potential of collective reflection and discussion of one's own experience to identify uses of technologies and promote new ways of integrating them for the reorganization of a task in mathematical class.

According to Geiger et al. [21], task design and task implementation can be seen as different sides of the same coin; this case study informs about this complementarity in the other direction, in this case, from task implementation to task reorganization (task redesign). Through task implementation, the teacher recognized several ways a student can solve the task, but with (digital and non-digital) technologies, the teacher could create "new" ways to solve the task based on opportunities offered by technologies. These results concur with Geiger et al. [21] on "teachers' intimate knowledge of key factors, such as local curriculum requirements and students' previous experience in mathematics, [being] essential if tasks [are] to be successfully implemented in classrooms" (p. 318). In addition, this case study informs about knowledge of school context and uses of technologies as opportunities for task reorganization.

In addition to the reflection on the practice itself, in this study we observe that there are cases in which the integration of technologies must consider the type of resource, the functionalities of the technology and the way to fit or enable the development of actions that the teacher considers key in the class. However, consistent with Molina-Toro et al. [19] the notion of modeling is still articulated to a process that students go through to solve the (same) situation. Therefore, in this study, we see that technologies were projected to feed those actions; in particular, to offer an experiential environment in data taking and analysis [6,16].

Finally, we highlight two important results. On the one hand, in the analysis of the task implementation itself, the recognition of the school and contextual conditions allowed Carlos to identify how his students can solve the task, but also allowed him to recognize that technology could dynamize some of the actions that students performed and promote new opportunities for learning to model. Another important result of this study is the possibility offered by technology to reorganize existing tasks. Although research on these tasks has shown the opportunities they offer for the development of mathematical competencies and knowledge in the classroom, it is possible to recognize that these same tasks can be reorganized with technology and still respond to the curricular conditions and institutional context. We join the call of Guerrero-Ortiz and Camacho-Machín [5] who suggest the importance of investigating the role of modeling tasks with technology in the learning of mathematics.

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