THE TEACHING PROFESSIONAL KNOWLEDGE FORMATION BY AN INSTRUMENTAL META-ORCHESTRATION

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This investigation explores the combination of Instrumental Meta-Orchestration (IMO) and the Lesson Study methodology (LS) in teacher training. Under the Theory of Instrumental Orchestration (IO) and the knowledge domains of Ball and colleagues, and of Koehler and Mishra, the knowledge mobilized by mathematics undergraduates from a Brazilian public university was analyzed following a research-action-training design. The results indicate the relevance of combining the IMO and the LS to foster both future teachers' development on mathematics topics and their knowledge on preparing and implementing an IO.

Keywords: Instrumental meta-orchestration; Lesson Study; Professional teaching knowledge; Reflexive investigation

La formación del conocimiento profesional docente mediante una Meta-Orquestación Instrumental

Esta investigación explora la combinación de la Meta-Orquestación Instrumental (MOI) con la Metodología de Estudio de Lecciones (EL) en formación del profesorado. Bajo el marco de la Teoría de la Orquestación Instrumental y los dominios de conocimiento de Ball y colaboradores, y de Koehler y Mishra, se analizó el conocimiento movilizado por estudiantes del grado de matemáticas de una universidad pública brasileña siguiendo un diseño de tipo investigación-acción-formación. Los resultados indican la importancia de combinar la MOI y la EL para potenciar tanto el desarrollo matemático de los futuros docentes como sus conocimientos sobre la preparación e implementación de una OI.

Términos clave: Conocimiento profesional del docente; Investigación reflexiva; Lesson study; Meta-orquestación instrumental

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A formação do conhecimento profissional docente mediante uma Meta-Orquestração Instrumental

Esta pesquisa explora a combinação da Meta-Orquestração Instrumental (MOI) com a Metodologia de Estudo de Aula (EL) na formação de professores. Sob o referencial da Teoria da Orquestração Instrumental e dos domínios de conhecimento de Ball e colaboradores, e de Koehler e Mishra, o conhecimento mobilizado por estudantes do curso de matemática de uma universidade pública brasileira foi analisado seguindo um desenho do tipo pesquisa-ação. Os resultados indicam a importância de combinar o MOI e o EL para melhorar tanto o desenvolvimento matemático dos futuros professores de formação inicial como o seu conhecimento sobre a preparação e implementação de uma OI.

Palavras-chave: Conhecimento profissional docente; Investigação reflexiva; Lesson Study; Meta-orquestração instrumental

Teacher training, whether pre-service or in-service, has been the object of study in the area of teacher training supported by authors such as Shulman (1986), Nóvoa (2017) and Perrenoud (2018). Studies by Ball et al. (2008) stand out when considering specifically the mathematics educational demands, while Koehler and Mishra (2009) focus on integrating Technologies of Information and Communication into the teaching practice.

The results and proposals of these studies are in line with the Brazilian National Curriculum Guidelines for the Initial Training of Teachers of Elementary Education, which establishes the National Common Base for the Initial Training of Teachers of Elementary Education (BNC-Training) defined by Resolução CNE/CP Nº 2, de 20 de dezembro de 2019. It classifies general teaching skills and respective specific skills into three key dimensions, which, interdependently and without hierarchy, integrate and complement one another in the teaching action, namely, professional knowledge, professional practice, and professional engagement.

Concerning the curricular organization of courses targeted at the Initial Training of Teachers for Elementary Education, in line with the learning processes provided by the BNCC for Elementary Education, Resolução CNE/CP Nº 2, de 20 de dezembro de 2019 establishes, among others, as guiding principles the strengthening of responsibility, leadership, and autonomy of undergraduates along with their professional development and the integration between theory and practice, both regarding the pedagogical and didactical knowledge and the specific knowledge of the field or curricular component to be taught.

Regarding the pedagogical grounds, the courses targeting the Initial Training of Teachers for Elementary Education should invest in innovative methodologies aimed at the development of autonomy, the exercise of the collective, in addition to the pedagogical use of innovations and digital languages as a resource for development, in in tune with the BNCC and the contemporary world (Resolução CNE/CP Nº 2, de 20 de dezembro de 2019).

This resolution is another attempt by Brazil to face the challenge of teacher training. However, when establishing an overview of teacher training for elementary education in Brazil, the general picture is not very encouraging (Gatti et al., 2011; Libâneo, 2010).

In Brazil, the training of higher education teachers has historically developed and accumulated bottlenecks and problems that need to be faced. In the case of basic courses, this confrontation does not only take place at the level of regulations and norms, which is also important, but it is a process that must also be carried out in the daily life of the university. That is why you need to know how to get rid of ingrained concepts and mundane habits and innovate (Gatti, 2014).

This research introduces the theoretical model of Instrumental Meta-Orchestration associated with the Lesson Study methodology aiming to contribute to the initial training of mathematics teachers and potentially enlarge the relations between knowledge about and for education involved in such a training phase.

The conceptions of training often restrict to enlarging and deepening knowledge, sometimes of specific areas and sometimes of the didactical or pedagogical fields. In mathematics education, especially in the scope of the Documental Approach to Didactics—DAD (Trouche et al., 2018), teacher training seeks to encompass the key elements in the professional perspective of the classroom know-how, which implies a learning know-how.

It is worth noting that currently processes such as instrumentation and instrumentalization, products of the Documental Approach to Didactics (DAD) inherited of instrumental approach (Rabardel, 1995), are inborn processes to the development of the teaching profession. This is because the need to teach with the support of technology, that is, with the support of digital resources, sharply emerged during the COVID-19 pandemics and will certainly linger on, thus becoming relevant in the professional teacher training. Teachers have been led to use such resources imperatively, and the action of an Instrumental Orchestration can compensate for this role according to the methods implemented by teachers concerning resources in general. Such a training method may contribute to an educational improvement in mathematics and other knowledge fields, at all educational levels.

That is the purpose that led us to conduct this investigation aiming to answer the following question: How can the combination of the Instrumental Meta-orchestration Model and the Lesson Study methodology influence the mastering of the Instrumental Orchestration model and the theoretical-practical training of undergraduates?

Thereby, our goal is to analyze the knowledge mobilized/developed by undergraduates during an experience of online Instrumental Meta-Orchestration whose execution method is guided by the Lesson Study methodology.

THEORETICAL BACKGROUND

The method of Instrumental Meta-Orchestration (IMO) was introduced by Lucena (2018) for trainee teachers to master the theoretical model of Instrumental Orchestration (IO) (Trouche, 2004) by structuring and implementing an IO in their professional activity. We begin by introducing the basic principles of the theoretical models of IO and IMO. Furthermore, since the activities involved in this study occurred remotely, we also refer to the concept of Online IO (Gitirana & Lucena, 2021) and introduce the concept of Online IMO.

Instrumental Orchestration and Online Instrumental Orchestration

The IO is a metaphor for a classroom as an orchestra, the teacher as a conductor, the resources as music scores, and the rehearsals as the position of the musicians in front of the music scores (Trouche, 2004). Trouche (2005) defines:

> *An instrumental orchestration is the systematic and intentional arrangement of the elements (artifacts and human beings) of an environment, performed by an agent (teacher) to effect a given situation and, in general, guide the apprentices in their instrumental genesis and the evolution and balance of their instrumental systems* (p. 126).

In our view, an instrumental orchestration consists of three elements: a didactical configuration, an execution method, and a didactical performance. The didactic configuration consists of the arrangement of artifacts in the teaching environment. These artifacts can be technological tools, concrete materials, textbooks, and the tasks students work on. The way of exploring a didactic configuration is the way in which the teacher decides to explore it for the benefit of his didactic intentions. This includes decisions about how the task is presented and approached, what roles the artifacts play, and what designs and techniques students develop and create. Didactic performance involves decisions made during the exploration of the chosen didactic configuration, such as what question to raise and how to deal with unexpected aspects of the mathematical task or technological tools (Drijvers et al., 2010).

Concerning the instrument involved in the instrumental orchestrations, Trouche and Drijvers (2014) support the idea that the role of the orchestration is to help students develop their own instrument system. The idea of instrumental orchestration proposed by Trouche (2004, 2005) in mathematics education aims to define the time and space management of a learning environment, considering the different stages of the task to be performed (Trouche & Drijvers, 2014).

In the pandemic context of emergency-remote education demands, Gitirana and Lucena (2021), inspired by Trouche's IO, introduce the concept of Online Instrumental Orchestration as an adaptation to the IO model with new perspectives for the online educational future.

> *An Online Instrumental Orchestration (Online IO) is the systematic and intentional arrangement of the elements (artifacts, humans, and time) of an environment made up of different spaces, geographical and virtual, all connected, performed by agents (teacher(s) and monitor(s)) to effect a given situation and, in general, to remotely guide, synchronously and/or asynchronously, its learners in their instrumental genesis and the evolution and balance of their instrument systems* (Gitirana & Lucena, 2021, p. 376).

According to Gitirana and Lucena (2021), an online IO can be performed either online or offline aiming at synchronous and asynchronous lessons and distinct research modes that can be executed by the participants involved.

A reflection on the orchestrations reveals the diversity of variables that teachers must account for, such as the didactic, «artifacts», and organization variables. It also emphasizes the knowledge that teachers must develop to control such variables. Analyzing the knowledge of the teacher is a complex task relating to a set of individual, social, and institutional dimensions. The instrumental approach is interested in the processes of mathematics conceptualization by the students. In a similar perspective, we propose to approach the concerning processes of professional development of the mathematics teachers.

Instrumental Meta-Orchestration and Online Instrumental Meta-Orchestration

Lucena's doctoral dissertation (Lucena, 2018) introduces the Method of Instrumental Meta-Orchestration (IMO) defined as the systematic and intentional management by an agent (trainer (s)) of artifacts and subjects (teachers and future teachers) facing a meta-situation to master the concept of Instrumental Orchestration. The term 'meta' is used in a cognitive perspective, that is, referring to the ability to understand and reflect on one's particular understanding.

For Lucena (2018), since IMO is a training model for appropriating IO, the situations that are proposed in the training model are not only of a mathematical nature, but of theoretical foundation, theoretical-practical discussion, etc. In this way, the researcher brings the notion of Metasituation, which can be understood "as a complex situation that can be analyzed as a combination of situations of their own nature and difficulty" (Lucena, 2018, p. 125). It is worth mentioning that Lucena (2018) takes the notion attributed by Vergnaud (1996) as a situation.

Just like the IO model has a didactical configuration, execution method, and didactical performance that structure and favor the analysis of the orchestration conceived and executed, Lucena (2018) perceives it as relevant to define such steps in the IMO context: the didactic metaconfiguration; execution metamethod and didactic metaperformance.

The didactic metaconfiguration consists of the architecture of subjects (students), artifacts, didactic choices and situations. This architecture, defined by the conductor (teacher/trainer), presupposes the organization, articulation and management of the instrumental orchestrations that will compose the IMO. The didactic execution metamethod consists of different ways for the conductor to execute the architecture of each instrumental orchestration of the didactic metaconfiguration.

The performance achieved by Instrumental Meta-Orchestration is called didactic metaperformance and considers the viability of the architecture created with a view to appropriating the theoretical model of Instrumental Orchestration. It is about identifying unforeseen situations, ad hoc decisions and reactions that are relevant to determine the success of the executed orchestrations, considering the organization, articulation and management of the orchestration set and its execution.

The Meta-Orchestration described herein was conducted remotely since the university involved had remote lessons as a safety measure due to the pandemic context. Therefore, inspired by Lucena's (2018) instrumental meta-orchestration, we introduce the concept of online instrumental meta-orchestration as an adaptation of the model of instrumental meta-orchestration to the hybrid educational context.

Therefore, we proposed the following definition: online instrumental meta-orchestration is the systematic and intentional management, by agents (trainer(s) and monitor(s)), of artifacts, subjects (teachers and future teachers), and time, in an environment formed by different spaces, whether geographic or virtual, all connected, confronted with a meta-situation for the subjects to seize the concept of Instrumental Orchestration so that they develop the skill to execute educational situations and, in general, guide their students at either on-site or remote lessons (synchronous and/or asynchronous) from their instrumental genesis to the evolution and balance of their instrument systems.

Based on the concept assigned by Vergnaud (2009), Gitirana and Lucena (2021) understand a meta-situation as a complex situation that can be analyzed as a combination of situations of particular nature and difficulty.

Lucena (2018) assertively proposes that teachers must integrate digital resources into their practice, however, it can only occur by overcoming challenges, among many other actions. In this context, the author states that this is why we should think about training mathematics teachers in the sense that in their mathematics classes various digital devices are known and tested, which require more than special knowledge from the teacher. Some mathematical situations require knowledge of digital technology and its integration. A fact that only occurs with the instrumentation and instrumentation of this professional in relation to such devices.

Lucena's reflections corroborate the need for teachers, whether future or practicing the profession, to enjoy experiences that may favor their professional evolution during training. This justifies research that reinforces the theoretical potential for initial or continuous training of teachers with the characteristics of IMO.

This is the goal of this research, the professional development of mathematics undergraduates, that is, future mathematics teachers. The choice of the instrumental meta-orchestration as the method was based on its potential. In addition to observing how the composition of the resource system of the parties developed and investigating how the undergraduates modified such a system, this research/training sought to identify changes in the aspects of the undergraduates' teaching knowledge.

Teaching Professional Knowledge

Discussions on the teaching professional knowledge have been increasingly frequent in the training scope of mathematics teachers and are the target of many studies that largely refer to Shulman's theoretical assumptions (Shulman, 1986, 1987).

Herein, we focus on the domains that compose the mathematical knowledge for teaching (Mathematical Knowledge for Teaching—MKT) by Ball et al. (2008), as well as on the knowledge and skills to integrate the Technologies of Information and Communication into the teaching practice based on the TPCK model—Technological Pedagogical Content Knowledge by Mishra and Koehler (2006).

Ball et al. (2008) share, enlarge and deepen the understanding of the professional knowledge of mathematics teachers in a similar way as in Shulman's research. The scheme proposed by Ball et al. (2008) for the mathematical knowledge for teaching combines a series of theoretical notions seeking to contribute to teachers' knowledge that is considered relevant and/or required to teach mathematics.

This scheme encompasses two sets of knowledge: Specific Content Knowledge (essentially referring to the mathematical content to be taught) and Pedagogical Content Knowledge (concerning the method as the content to be taught, ranging the curriculum, students, and particular relations between these and the mathematical content). Pazuch et al. (2018) synthetize such a scenario as follows: Common Content Knowledge (mathematical knowledge used in contexts other than teaching), Specialized Content Knowledge (mathematical knowledge tied solely to the craft of teaching mathematics), Content and Student Knowledge (encompasses knowledge about students and about knowing mathematics), Content and Teaching Knowledge (combines knowledge about teaching and mathematics), Content and Curriculum Knowledge (is a subdomain of pedagogical content knowledge) and Horizon Content Knowledge (is the mathematical knowledge that enables the teacher to know how mathematical topics are constructed conceptually across the curriculum).

It is worth highlighting that both sets, as pointed out by Ball et al. (2008), establish a dialogue with each other, and the six classifications described should be seen as ways of organizing knowledge that surround the processes of teaching and learning mathematics.

Developing the knowledge and skills required for the teaching practice demands mobilizing knowledge and specific skills of several knowledge fields, including the integration of the Technologies of Information and Communication. Thereby, we considered studies on the TPCK model—Technological Pedagogical Knowledge Content, or in Portuguese—concerning the Technological Pedagogical Content Knowledge presented by Matthew Koehler and Punya Mishra. Also, in addition to the sets of knowledge by Ball et al. (2008), we consider an unfolding of Shulman's proposal.

For Mishra and Koehler (2006), one should not understand the technological knowledge as isolated from the pedagogical and content knowledge, and what distinguishes such an approach is the specificity of articulating content, pedagogy, and technology, whereas Mishra and Koehler (2006) address seven types of knowledge.

The content knowledge refers to the content to be learned or taught, the pedagogical knowledge, is in-depth knowledge of educational processes and practices or learning methods and processes, and pedagogical content knowledge, which contains information about whether pedagogical approaches are compatible with content and how content elements can be organized for best teaching practice.

The technology knowledge involves the skills necessary to operate from basic technologies such as books, chalk and blackboard, to more advanced technologies such as the internet, applications and educational platforms. The technological content knowledge deals with how technology and content are mutually related and consists of mastering both the subject to be taught and the ways in which it can be modified by the technology that. The technological pedagogical knowledge consists of an understanding of how teaching and learning can change when specific technologies are used in specific ways, as well as a deeper understanding of the limitations and possibilities of technologies and the disciplinary contexts within which they function. Finally, the technology, pedagogy, and content knowledge are an emerging form of knowledge that is different and goes beyond the three "core" components (content, pedagogy, and technology). This knowledge is an understanding that emerges from the interactions between content, pedagogy, and technological knowledge.

These categories of knowledge by Ball et al. (2008), and Mishra and Koehler (2006) support our investigation of the knowledge mobilized/developed by undergraduates during the implementation of an Instrumental Meta-Orchestration proposal.

Lesson Study

The decision of relying on the Lesson Study—LS methodology is based on how it relates to the orchestration for involving future teachers in the lesson study as part of its pre-service training for them to continue with the practice throughout their careers. It is an educational and learning methodology for the educational community started in Japan over 100 years ago. For Dudley (2014):

> *LS involves groups of teachers collaboratively planning, teaching, observing, and analyzing learning and teaching in research lessons. They record their findings. Over a cycle of research lessons, they may innovate or refine a pedagogical approach that will improve pupils' learning, and which will be shared with others both through public research lessons and through the publication of a paper outlining their work* (p. 1).

Many are the benefits of the LS methodology, for example, it helps teachers change their teaching practice to better support the learning process as result, perceive the students' learning process more thoroughly than usually possible, understand the gap between what is assumed to happen when students learn and what indeed happens, and plan the learning process that best fits the students' needs as result. Not only that but accomplishing it all in a context of a community of support to the teaching and learning process that is strongly dedicated to helping students learn and to the professional learning process of the members of the group (Dudley, 2013).

The LS differs from any other training process that involves observing lessons but focuses especially on teachers' actions due to its reflexive and collaborative nature (Fernández et al., 2003) focusing on the students' learning processes and not on the teachers' work. Participation in an LS gives teachers the opportunity to learn about important topics related to what they teach, curriculum guidelines, student thinking processes and tasks, and the dynamics of the classroom itself. At LS, learning takes place in a collaborative environment, allowing participants to form close relationships, share ideas and support each other. In this way, they provide a context not only for reflection, but also for promoting self-confidence, essential for their professional development (Ponte et al, 2016).

The LS, which usually starts by identifying a relevant issue about the students' learning process (Ponte et al., 2014), is regarded as a very particular dynamics of development, structured into the following well-defined steps: formulating goals for the investigation, planning, materialization/execution, reflection and, if desirable, repetition of the lesson (Lewis, 2002).

Formulating goals for the learning process and students' development involves selecting a topic or theme from the curriculum to be addressed in the investigation lesson. This moment should engage great concern with the needs and difficulties of students regarding the learning process for the curricular topic chosen.

With the goals defined, the planning process starts based on careful collaborative research that seeks to predict the students' thinking methods, their strategies of resolution of tasks, difficulties, what they are likely to say during the activities, as well as possible interventions by the teacher to be strategically used to build and develop the lesson. Such planning must be carried out so that the student is the central agent of the learning process actively participating in the lesson.

During execution, one of the members of the group teaches a lesson planned to a class of students, and the other members, including the team that coordinates the process, observe, and carefully register all actions by the teacher and students and their relationships, without intervening. Coelho et al. (2014) recommend that the lesson is filmed since "the exhibition of the images may work, in the next step, as a kind of test run in case of doubts or when some member of the team wishes to discuss some specific section more deeply" (p.5).

In the step of reflection, the group discusses and reflects on the recorded video content and observed by the other members, also contributing to professional self-criticism. At this moment, the team focuses on the student, and the learning process, and seeks to improve the lesson plan. Considering the content brought by the team in terms of adaptations required, the plan may be altered. Coelho et al. (2014) presented the dynamics to be used in this step of the Lesson Study:

> *The teacher, who implemented the lesson plan, is the one who initiates the discussion, exposing feelings and sensations, explaining why certain attitudes were the way they were, especially when they deviated from what was planned, and what they would do differently if there were another opportunity. Next, it is time for the observers to present their records* (p. 5).

In the fifth moment, the group collaboratively resumes the investigation lesson by modifying aspects that were not considered adequate by the group or questions that require a different approach. It is desirable that the plan rebuilt based on the observers' criticism is implemented to another class, thus starting another cycle (Ponte et al., 2014).

Even though the LS methodology focuses on raising the students' interest and on the quality of their learning, it can also provide professional gains for the teacher. This point of view is the focus of our research since we aim to identify the potential contributions of such a methodology to the future teacher when implemented combined with the model of Instrumental Meta-Orchestration.

Methodology

This research has a qualitative approach, descriptive in terms of objectives and action research in terms of procedures. The methodology is based on the five principles of reflective investigation (Trouche et al. 2018): (1) a broad collection of the material resources used and produced by the teacher; (2) a long-term follow-up; (3) a follow-up inside and outside the classroom; (4) a reflective follow-up of the teacher's documentation work, and (5) a permanent confrontation of the teacher's opinions about their documentation work with the materiality of this work.

For this purpose: (1) we made an extensive record of the resources used and produced by the participants; (2) we followed the work of the participants during a semester; (3) we monitored, remotely, before, during and after the planning and execution of classes; (4) we encourage, during class studies, a reflective follow-up and (5) a permanent confrontation of the participants' opinions about their documentation work. All these principles stem from DAD's holistic view of a teacher's work, considering their interactions with all the resources that feed into their teaching.

Such principles are in line with Schön’s reflexive practice (Schön, 2009) and Zeichner’s reflexive teaching. For Ziechener (2008):

> *A lot has happened that has led to a shift in focus in teacher education: from a view of training teachers to perform certain types of behavior to a broader one in which teachers should understand the reasons and rationales associated with different practices and which develops in teachers the ability to make wise decisions about what to do based on educational goals carefully set by them within the context in which they work and considering the learning needs of their students* (p. 536).

Since our study involves groups of teachers at initial training who collaboratively work in the planning, teaching, observation, and analysis of instrumental orchestrations, we decided to introduce the concept of Instrumental Orchestrations Study. Along the cycle of research instrumental orchestrations and supported by a didactical performance, the undergraduates can innovate or improve both the didactical configuration and the execution method aiming at a better learning process that will be shared with others.

Table 1
Structure of data collection

Technique	Instrument	Data produced
Observation	Logbook	Cursive record from the notes
Filming	Record function on Google Meet	Video of the subjects’ presentations
Form (Electronic)	Google Drive	Files of planned and executed orchestrations

The data collection method used herein involves conducting each situation in each corresponding orchestration. It is executing the situation in the orchestra that produces the data and, at the same time, allows their collection. Table 1 explains the data collection techniques and the collection instruments.

Bellemain and Trouche (2016) emphasize the difficulty of researchers, whether for short or long periods, to gather and structure the data collected. To enable such structuring, we used the Google Drive application as a documental device (Pepin et al., 2015) to store the data collected by the researchers on the undergraduates' documental research.

As for the methodological procedures, we used the particular structure of the conception of an instrumental meta-orchestration (didactical meta-configuration and execution method) added with essential elements of the Lesson Study methodology aiming to answer the research question.

Didactical meta-configuration

The Metasituation in question deals with the theoretical foundation and theoretical-practical discussion of the planning, execution and study of online instrumental orchestrations.

Sixteen undergraduate students of an undergraduate mathematics course participated in the orchestra, the curricular component of educational instrumentation of Mathematics II had been attended remotely in the second semester of 2021.

In addition to the students, the researchers were also actors in the orchestration, being a teacher of the curricular component and one graduate student, whose thesis will introduce the results of the complete study. The teacher should coordinate the synchronous meetings and prepare the electronic forms. In addition to participating in the meetings, the graduate student should also monitor the conduction and delivery of activities in each group.

The students could also form their groups freely provided that they did not exceed four members. Four groups were formed, and the meta-orchestration was implemented to two groups at a time. Herein, we present the data obtained from the group identified as A1, composed of four students, identified as Student 1—D1, Student 2—D2, Student 3—D3, and Student 4—D4.

The time destined for this step of meta-orchestration with the group of undergraduates ranged 6 (six) weeks. During such a period, three cycles of six orchestrations each were performed. Figure 1 presents the sequence of orchestrations per IMO cycle.

Figure 1. The sequence of orchestrations per IMO cycle

The mathematics contents were defined by the researcher-teacher: (Cycle 1) Polyhedral or round bodies with their plans or views; (Cycle 2) Total field and/or volume of pyramids; (Cycle 3) Linear system. The synchronous meetings occurred remotely on the Google Meet implementation with two classes of elementary education students who were invited to watch the orchestrations. Each step had a duration of two hours.

Figure 1 brings up situations of different natures (planning, execution, reflection) that are not only of a mathematical nature, but of theoretical foundation, theoretical-practical discussion that make up the Metasituation.

Execution method

As seen in Figure 1, the orchestrations constituting the instrumental meta-orchestration implemented herein are classified into 5 (five) types: Planning, Implementation, Study (2x), Replanning, and Reimplementation. Subsequently, we describe the execution method of each type. It is worth noting that the IMO occurred online on the Google Meet.

In the IO of planning, the team shared the screen of their computers/cell phones and introduced the electronic form containing the initial planning of the Instrumental Orchestration. The teacher/researcher stimulated the discussions and proposed questions to cause the students to discuss and reflect on the planning. We were careful to interfere as little as possible with the undergraduates' ideas for the planning to become, indeed, the result of the students' collective work. By the end, 2 (two) students were chosen by their colleagues to conduct the first implementation of the IO planned.

High school students from public schools were invited to participate in the IO implementation. Two classes of 15 students on average were formed and a WhatsApp group was created for the undergraduates to communicate with the high school students and relay information, materials, and tasks related to the IO. It was a remote implementation on Google Meet scheduled for Saturdays from 9 am to 11 am. As the chosen pair implemented the IO, the other members of the team observed and took notes. By the end, the pair that executed the IO and those who had observed filled a logbook, a peer review, both in an electronic form and stored on Google Drive.

The study IO followed each (re)implementation. In this orchestration, the students who implemented the plan IO started the discussion by reporting their sensations and feelings and explaining the reason for certain attitudes, especially when those went off the planned, and what they would have done differently if provided with another opportunity. Subsequently, the observers presented their records and opened the discussion and replanning of the IO.

For the IO reimplementation, the pairs exchanged functions: the students who had been observing in the first implementation took over as executors and the other two who had implemented the IO became observers. Such a reimplementation was performed in a different class of students from the first implementation. Finally, the IO was studied once again for evaluating the reimplementation, thus ending the cycle.

RESULTS AND DISCUSSIONS

As previously highlighted, this paper introduces the results and discussions relating to the case of one of the groups of students from a total of four groups that participated in the study. The group was chosen due to the fact that it was the group that participated in all activities and produced the most data for the study. Aiming to guide the undergraduates in the planning of the Instrumental Orchestrations, we created and made available an electronic form containing the main elements of the didactical configuration of an IO. Furthermore, it contained a black space for the description of the execution method.

Data analysis will take place in the following order: analysis of the didactic configuration of each (re)planned IO; analysis of the execution mode of each (re)planned IO; analysis of the reflections made by the undergraduates about their practice recorded in a logbook.

We begin our discussion on the didactical configuration of each (re)planned IO by analyzing the undergraduates' interaction with the resources. After defining the object of knowledge to be the focus of the orchestration, the undergraduates were instructed to refer to the National Common Curricular Base—BNCC or the Reference Matrices of the Evaluation System of Elementary Education—SAEB or the National High School Exam—ENEM to consult the general educational goal of the objects of knowledge, according to the official documents that constitute curricular resources (Remillard, 2005), thus providing the mobilization/development of the content and curriculum knowledge (Ball et al., 2008).

By analyzing the resources used by the undergraduates during the planning and replanning of the orchestrations in the three execution cycles, we found that the undergraduates demonstrated an understanding of the technologies and how technology and content are reciprocally related based on the use of the Geogebra, thus characterizing the mobilization/development of technological knowledge and technological content knowledge (Mishra & Koehler, 2006). Furthermore, in all cycles, the number of resources used during the replanning was always higher than that used during the initial planning. This shows an evolution in the system of resources (Bellemain & Trouche, 2016) used by the undergraduates after the moment of study in each orchestration.

By observing how the undergraduates structured the cultural resource time (Adler, 2000) of each orchestration, we were struck by how the time during the planning of the Cycle I IO and the replanning of the Cycle 3 IO was managed. In the former situation, we noticed a structure of a "classic" lesson where the teacher presents the content and then assigns activities to the students. However, in the latter situation, the undergraduates resort to an educational methodology based on the steps of the Theory of Didactical Situations by Guy Brousseau (Brousseau, 2002). Such a scenario reveals an evolution of the pedagogical content knowledge since the undergraduates demonstrate to know different strategies to make the teaching process more fruitful, rearranging the specific content into different ways of understanding. We also notice the mobilization/development of content and educational knowledge (Ball et al., 2008) due to their ability to identify the different methods and procedures that allow for instruction.

From the replanning of the Cycle 1 IO, the undergraduates started to dedicate some time to solving potential students' doubts, which means that they showed concern with what the students could think or consider confusing, thus indicating the mobilization/development of content and students' knowledge (Ball et al., 2008). We also found that the undergraduates structured the time in the moments of replanning of the orchestrations more thoroughly than initially planned, which reveals the influence of the analyses and reflections during the moments of study of each IO.

We analyzed the execution method described by the undergraduates on the electronic form during planning and replanning in the three cycles of IMO implementation. Initial analysis shows how the execution method evolved towards planning and replanning. All steps (planning and replanning) will be analyzed for each cycle.

The planning of the Cycle 1 IO reveals the intention of the undergraduates to establish an articulation between the use of manipulable didactical materials and the use of educational digital resources, since it was an online IO, corroborating the idea that those two types of resources are not in opposition, on the contrary, they are complementary (Souza, 2018).

By analyzing the replanning of the Cycle 1 IO, we noticed a significant evolution of the execution method initially designed by the undergraduates since its structure was based on three moments: pre-lesson, lesson, and post-lesson. This demonstrates the ability to evaluate the instructional advantages and disadvantages of the representations used to teach a specific idea and identify the different methods and procedures that allow for instruction, highlighting the mobilization/development of the content and educational knowledge (Ball et al., 2008).

The pre-lesson step provides for the submission of support materials (short planning videos) and an introduction of the content on the WhatsApp group with the students, highlighting the technological pedagogical content knowledge (Mishra & Koehler, 2006). At the moment of the lesson, the undergraduates planned to start with an introductory talk to stimulate the students to participate by discussing the material of the pre-lesson, which was used to introduce the lesson and establish some link to the content addressed in the previous lesson concerning the planning step, thus referring to the horizontal content knowledge (Ball et al., 2008). Once the whole content was explained, the undergraduates sought to start to resolve the exercises of increasing levels of difficulty, thus highlighting the mobilization/development of the content and educational knowledge (Ball et al., 2008), since they chose both introductory and further examples for the students to deepen the contents.

While planning the Cycle 2 IO, the undergraduates presented no further details on the execution method. It is worth highlighting the reference to the Geogebra Software, which had not been provided previously, thus revealing the technological content knowledge (Mishra & Koehler, 2006). During the replanning, the undergraduates once again use the structure of pre-lesson, lesson, and post-lesson. Like in the Cycle I IO, it is clear the undergraduates' concern with providing the students with a more active attitude in the learning process.

For the start of Cycle 3, the undergraduates planned to contextualize the content (counting problems) based on the dialogue between two characters from the internet involving an issue of clothing combination. This demonstrates both the technological knowledge and the technological pedagogical knowledge (Mishra & Koehler, 2006). Once again in the replanning of the OI, there is a significant evolution in the execution method proposed by the undergraduates. The orchestration was guided by the Theory of Didactical Situations by Guy Brousseau working with the students' inductive logical reasoning in the resolution of counting problems. This highlights both the content and educational knowledge (Ball et al., 2008).

It is also part of the execution method of an IO attempting to forecast potential difficulties in the process. Based on the undergraduates' answers on the electronic form, we ranked the difficulties into two types: technical and pedagogical. The most mentioned problems potential in the former category were the lack of internet access and computer failure. Seeking to overcome such issues, both the undergraduates responsible for the execution were aware of all steps of the IO so that if one of them experienced any problem, whether of connection or computer failure, the other one would be able to proceed with the lesson.

In contrast, the problems of pedagogical nature that were most often pointed out by the undergraduates referred to the absence of students in the lesson, lack of previous knowledge, and lack of more active participation of the students during the meeting. To encourage the presence of the students, the undergraduates created a Whatsapp group for daily communication that increased as the days of the lessons approached. To overcome the lack of previous knowledge, the undergraduates sent PDF materials and video lessons during a week for the students to watch and prepare for the lessons. Making the students participate more actively in the lessons was the greatest challenge for the undergraduates, since it led them to seek, at every IO, to choose particular examples and predict what the students would find interesting and encouraging, thus highlighting the mobilization/development of both the content and the students' knowledge (Ball et al., 2008).

From the above, it can be seen that, the Google Meet feature guided the activities of the undergraduates, since the execution of the planned IO's should be remotely, due to the context of the pandemic, thus characterizing the Instrumentation process. On the other hand, the appropriation, adaptation, and modifications of resources such as software, messaging applications and even concrete material, carried out by the undergraduates, evidenced the instrumentalization process.

Logbook and peer review

By the end of the execution of each IO, the undergraduates who had performed the lesson individually filled an electronic form containing four questions and a blank space for a logbook, while those who had been observed filled another form establishing a peer review. Our goal was to make it easier to record the activities allowing the undergraduates to reflect on their own practice and their pairs'.

According to Porlán and Martín (2000), a logbook is a methodological tool of teaching research that is almost indispensable in both the initial and continuous training for providing reflection, autonomy, and development of new practices, thus opening a wide range of knowledge and didactic-pedagogical actions.

Concerning the resources used by the undergraduates to execute the orchestrations, the percentage of those who agreed that those resources were used to their full potential dropped from 50% in Cycle 1 to 33% in Cycle 2. This reveals a critical reflection of the undergraduates about their practice since they believe that the resources could have been further explored. In contrast, the percentage of those who classified the skill of the team to manage the resources used to execute the orchestration as excellent increased from 50% in Cycle 1 to 66.7% in Cycle 3, thus highlighting, in the undergraduates' perception, gains in both the technological knowledge and technological content knowledge (Mishra & Koehler, 2006).

Seeking alternatives to make the students participate more actively in the lessons was a constant concern of the undergraduates. Thereby, we explore how often situations aimed at developing initiative, creativity, and ability to speak in public were proposed, and how often the undergraduates showed concern with how well the students understood the content. For both situations, the percentage increased from 75% in Cycle 1 to 100% in Cycle 3.

A recurrent issue in the logbook was the undergraduates' internet connection failure, leading their pairs to often take their parts in the lessons. In general, in the undergraduates' view, the orchestrations developed as planned. We highlight the undergraduates' report concerning the Cycle 3 orchestration, based in the dialectics of the Theory of Didactical Situations. According to the undergraduates, such a methodology causes the students to participate more actively in the lesson.

Concerning the resources used by the team to execute the orchestration, the percentage of observers who agreed that the resources were used to their full potential decreased from 50% in Cycle 1 to 33.3% in Cycle 3. In contrast, the observers' perception improved concerning the ability of the performer pair to manage the resources used in the orchestration execution. How often the performers proposed situations aimed at developing initiative, creativity, the ability to speak in public, and concern with how the students understood the content increased from 50% in Cycle 1 to 66.7% in Cycle 3.

As for the peer review, we highlight the observers' perception of the complexity imposed by remote teaching. Situations such as problems with an internet connection, little experience of the undergraduates in using online resources, side conversations, and students who turned on the audio disrupting the class are some of the numerous obstacles faced by teachers in the context of this educational modality.

CONCLUSION

Herein, we sought to answer the following question: How can the combination of the instrumental meta-orchestration model and the Lesson Study methodology influence the mastering of the IO model in the professional teaching formation?

Thereby, we established the need to analyze the knowledge mobilized/developed by mathematics undergraduates during the experience of an online instrumental meta-orchestration whose execution method was guided by the Lesson Study methodology.

The evolution of teaching knowledge was evidenced by the evolution of didactic configurations and the respective modes of execution of the IO's planned and executed by the undergraduates. With regard to didactic performance, the evolution was presented in the diagnosis of the undergraduates in relation to the need to treat previous knowledge and search for means to obtain a more active participation of the students during the meetings, by seeking alternatives, such as the use of messaging applications and sending study materials in advance. We observed that the collaborative and reflective work of the Lesson Study methodology was particularly important for this evolution.

That said, the analyses and reflections of the study moments of each IO contributed to the evolution of the instrumental orchestrations proposed by the undergraduates. We also identified an evolution in their respective system of resources, which, among other initiatives, sought to combine the use of manipulable didactical materials with educational digital resources, corroborating the idea that these two types of resources can be complementary.

Regarding the mobilization/development of knowledge for teaching by the undergraduates, the data analysis revealed numerous evidence. For example, the use of the BNCC demonstrating the mobilization/development of content and curriculum knowledge, the use of software, such as GeoGebra, and the fact that the amount of resources used in the replanning is always greater than those used in the initial planning, evidencing the mobilization/development of technological knowledge and technological content knowledge, the use of a methodology based on the dialectics of the Theory of Didactic Situations, and the ability to identify different methods and procedures demonstrating an evolution in pedagogical content knowledge and knowledge of content and teaching, respectively.

Therefore, the combination of the Instrumental Meta-Orchestration model with the Lesson Study methodology showed evidence that it can contribute to the mobilization of knowledge required to teach mathematics and, therefore, benefit the initial training of mathematics teachers.

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