

# Training intervention as a means for the implementation of mobile learning\*<sup>1</sup>

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## Abstract

In this research, tools of the Ontosemiotic Approach (OSA) were used to analyse the formative experience of two teachers in Primary Education service, guided towards the design and implementation of tasks for mobile learning, based on the meaning of the natural number and the use of Kahoot. The experience was developed during a workshop on the design of interactive lessons, where teachers were trained on the use of Kahoot for the design of mathematical content and its implementation in a real class context. Didactic engineering in the general sense of OSA was used as a methodological element. Specifically, the case of the design and implementation of an interactive lesson on the meaning of number sequence was analysed, where some results of the retrospective analysis of the formative experience indicated that: 1) the reference meaning of the natural number is a tool that allows to guide the design of tasks towards the partial meanings, the identification of primary objects, and the Ontosemiotic analysis of them; 2) the use of mobile devices and Kahoot together motivated the teachers. With these results, two training actions are proposed, aimed at teachers: 1) the design of mobile content from the reference meaning of the natural number, and 2) the assessment of the didactic suitability of teaching experiences mediated by mobile devices.

## Keywords

Training intervention – Mobile learning – Didactic engineering – Primary Education – Natural number – COVID-19 pandemic.

\* English version by Myriam López. The authors take full responsibility for the translation of the text, including titles of books/articles and the quotations originally published in Portuguese.

**1-** The dataset supporting the results of this study is not publicly available because it is not in a repository. The request for access to the data can be made directly to the following email: [imgarcia@uagro.mx](mailto:imgarcia@uagro.mx)

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## Introduction

The COVID-19 pandemic worldwide changed the context regarding the teaching-learning of Mathematics, making most teachers move to a totally virtual field, where technological resources were the means of communication during the instruction process. In Mexico, the Ministry of Public Education (SEP) implemented the *Learn at home* program, which used television to broadcast preschool, primary, secondary, and high school education content, based on the official Curricula and Programs of Study (MEXICO, 2011; 2017). Likewise, through the Classroom and Teams platforms, teaching staff were trained during the period of isolation (MEXICO, 2020).

On the other hand, with COVID-19, research where technology, in addition to being a resource, is the means of communication has gained importance (FONT; SALA, 2020) and with it, teaching methods have been reported to be applied during the pandemic (e.g. CERVANTES-BARRAZA, 2021), and resources available online for the teaching of mathematical concepts (e.g. BARRIGA; BELTRÁN-PELLICER, 2021; PINCHEIRA; VASQUEZ, 2021; VALENZUELA; BATANERO; BEGUÉ, 2021). The above, as a response to support and face the challenge of teaching classes in virtuality (e.g., BAPTISTA *et al.*, 2020).

In general, there are different trends about the introduction of technology in the teaching-learning process of Mathematics. This research is framed in *mobile learning* (CROMPTON, 2013a, 2013b; CROMPTON; BURKE, 2015, 2020) and the notion of Training Intervention of the Ontosemiotic Approach (GODINO *et al.*, 2017; POSADAS; GODINO, 2017) and has as a research question: Which OSA tools can be used in a training intervention to achieve the implementation of mobile learning? For this reason, the objective is to: use OSA tools to analyse a training experience of two teachers in Primary Education service, guided towards the design and implementation of tasks for mobile learning.

### Mobile learning in mathematics education

Over the past decade, interest in mobile technologies as emerging and innovative tools has grown (BENALI; ALLY, 2020). Mobile learning broadly involves the integration of mobile devices into teaching and learning (GRANT, 2019). There are different stances on the definition of mobile learning (e.g., BRAZUELO; GALLEGO, 2014; UNESCO, 2013) and mobile device (AGUILAR; PUGA, 2015; CROMPTON, 2013a; UNESCO, 2013) becoming a topic of discussion among the research community.

Properly in this research, mobile learning is “[...] learning through multiple contexts, through social and content interactions, using personal electronic devices” (CROMPTON, 2013b, p. 4). This definition includes three important aspects of the term, on the one hand, it involves the diversity of contexts where learning can take place, for example, at home, school, or outdoors, as well as the interactions that can be achieved between students or between the student and the mathematical content. It also refers to the use of personal electronic devices, understanding a mobile device as any personal and portable technological device that could be used in the mathematics classroom, including devices such as laptops, smartphones, and tablets (AGUILAR; PUGA, 2015).

Particularly, the use of mobile devices in the teaching-learning of Mathematics is gaining interest among researchers and education professionals (BORBA *et al.*, 2016), and in Primary Education three main results can be highlighted:

- Mobile learning has a positive impact on motivation, attitude, emotions, and interest in students and teachers (*e.g.*, FABIAN; TOPPING; BARRON, 2018; MALIK *et al.*, 2020).
- Mobile applications have the potential to support the learning of mathematical concepts (*e.g.*, CROMPTON, 2015; TUCKER; JOHNSON, 2020).
- Teachers generally have a positive outlook on the use of mobile applications in the school context (*e.g.*, HANDAL *et al.*, 2015; INGRAM; WILLIAMSON-LEADLEY; PRATT, 2015).

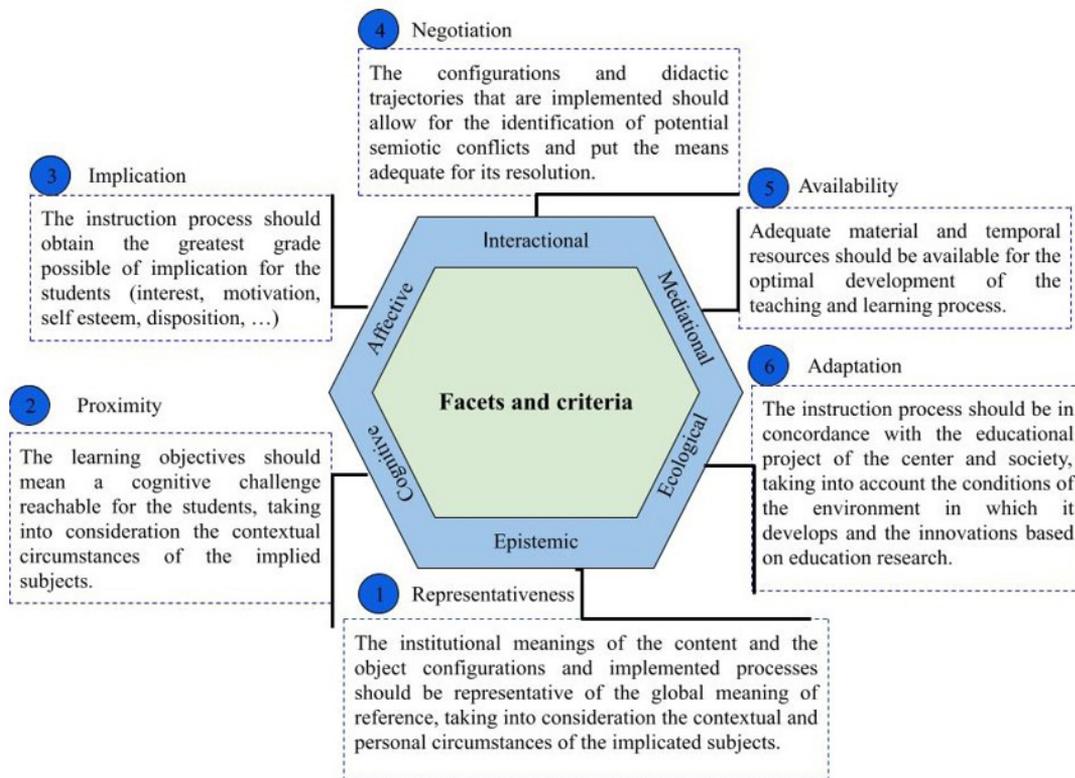
However, research that reports on uses or potentialities that could be the basis for the implementation of mobile devices is limited in Mathematics Education (BORBA *et al.*, 2016; SUNG; CHANG; LIU, 2016); in addition, in most researches, a specific mathematical concept is not identified (CROMPTON; BURKE, 2015). In this regard, Brazuelo and Gallego (2014) raised the need to promote the design of mobile educational content and prepare teachers as a key element for the real integration of mobile technologies for educational purposes. Therefore, it is important to guide teachers on the design and implementation of mobile content for the teaching of Mathematics.

### Training intervention

This research was based on the Ontosemiotic Approach (OSA) which is understood as a modular and inclusive theoretical system for Mathematics Education, consisting of principles and methodological tools to address aspects related to the teaching and learning processes of mathematics (GODINO *et al.*, 2021). It is considered that OSA can add elements that contribute to the previous problem, specifically there is research that reports training interventions related to “[...] the analysis of the didactic suitability of teaching experiences lived by the teachers themselves” (GODINO *et al.*, 2017, p. 103). In general terms, in these interventions “[...] it is about the teacher reflecting on the design, implementation, and evaluation of a teaching experience of a specific topic in a fixed educational context” (p. 107).

The above, through the facets and criteria of didactic suitability (GODINO, 2013, 2021), understood as the degree to which an instruction process or part of it meets characteristics that allow it to be qualified as optimal or adequate to achieve adaptation between personal meanings achieved (learning) and the meanings intended or implemented (teaching), taking into account the circumstances and resources available (GODINO *et al.*, 2021). Figure 1 presents the facets and criteria of didactic suitability.

**Figure 1-** Facets and criteria of didactic suitability



Source: Created by the authors based on Godino (2021).

This type of training action has been widely reported in research carried out by the OSA. For example, Morales, García, and Durán (2019) designed and implemented a training proposal for the development of the mathematical knowledge and competence profile of teachers, where they identified incidents or recurrences of each component of the didactic suitability. Pochulu, Font, and Rodríguez (2016) carried out a training cycle aimed at teacher trainers of mathematics, guided towards the design of tasks for the development of the didactic analysis competence, where the suitability criteria were used in the planning of the task sequences. Giacomone, Godino, and Beltrán-Pellicer (2018) analysed and evaluated the implementation of a training design for the development of the competence of analysis of didactic suitability. Meanwhile, Aké and other authors (2014) analysed a training experience of teachers, guided towards the development of knowledge to discriminate algebraic objects and levels of algebraization of mathematical activity.

In this case, the analysis of a training experience guided towards the design and implementation of tasks for mobile learning is presented, based on the experience lived by two in-service teachers, with the teaching of the meaning of numerical sequence and

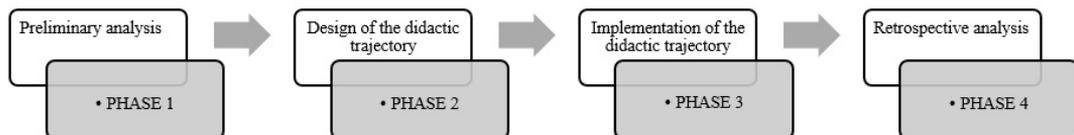
the use of Kahoot. To this end, didactic suitability, and other theoretical tools of the OSA were used, which are presented in the following section.

## Methodological elements

Given the nature of the objective, this research is qualitative; it was framed in an exploratory-descriptive approach (HERNÁNDEZ; FERNANDEZ; BAPTISTA, 2014) and a design research methodology was applied, based on the use of OSA tools (POCHULU; FONT; RODRÍGUEZ, 2016) in a real classroom context. In line with the above, this study involved the design/planning, implementation, and retrospective analysis of a training experience (GIACOMONE; GODINO; BELTRÁN-PELLICER, 2018) aimed at in-service teachers of Primary Education, which was organised in five stages: 1) previous instruction for the management of Kahoot, which is an educational platform to design content on mobile devices; 2) instruction on the diversity of meanings associated with the concept of study, in this case, natural number; 3) design of interactive lessons in Kahoot on the meaning of natural number; 4) planning a class to introduce an interactive lesson in a real classroom context; and 5) implementation and validation of the interactive lesson.

The development of the formative experience was based on didactic engineering understood from the expanded perspective of the OSA (GODINO *et al.*, 2014) considering its potentiality as a methodological element that guides the design, implementation, and evaluation, as well as the orchestration of the theoretical tools used during the training experience. The goal in the use of engineering is to show how some OSA tools can be used in the design and implementation of mobile content for the teaching of the natural number. Figure 2 shows the phases of this didactic engineering.

**Figure 2-** Phases of didactic engineering



Source: Created by the authors based on Godino and other authors (2014).

The phases and the theoretical tools used in each case are described below.

- *Preliminary analysis.* This phase is guided by the notion of reference meaning of the mathematical object, which is focused on the systematic analysis of the literature for the identification of the various meanings of the objects and their articulation in a global meaning, “[...] this global meaning is considered as the reference population (of situation-problems) from which samples appropriate to the particular circumstances of the processes to be designed will be selected” (GODINO *et al.*, 2017, p. 94). For this reason, in this phase, the reference meaning of the natural number was established, according to the literature review.

- *Design of the didactic trajectory.* Among other aspects, it consists of the selection of situation-problems, sequencing, and *a priori* analysis of them (GODINO *et al.*, 2014). This phase focused on the design of tasks (problem-situations) in Kahoot, their sequencing, and a priori analysis. Also, the planning of a class was requested to achieve the implementation of some tasks. In accordance with the above, the theoretical notions of epistemic trajectory were used, understood as the distribution of primary objects (situation-problems, language, procedures, concepts, propositions, and arguments) in an instruction process (GODINO; CONTRERAS; FONT, 2006), for this, ontosemiotic analysis was used (MORALES-GARCIA; DÍAZ-LEVICOY, 2022; MORALES-GARCIA; NAVARRO; DÍAZ-LEVICOY, 2021) and epistemic configuration (FONT; GODINO, 2006), as well as the teaching trajectory, understood as the actions of the teacher in the planning of the instruction process (GODINO; CONTRERAS; FONT, 2006).
- *Implementation of the didactic trajectory.* Focused, among other aspects, on the observation of interactions between people and resources (GODINO *et al.*, 2014), in this case, the interactions between people and the technological resource used in the design of tasks. Consequently, two implementation cycles were carried out, in order to validate and refine the tasks. In each cycle, Significant Didactic Facts (SDF) were identified, understood as any event that has a place and a time in the evolution of a process of mathematical instruction (WILHELMI; FONT; GODINO, 2005).
- *Retrospective analysis.* It focuses on reflection on the *didactic suitability* of the instructional process (GODINO *et al.*, 2014). In this phase, the indicators of didactic suitability (GODINO, 2013, 2021) were taken to reflect on the suitability of the design and implementation of tasks measured by mobile devices.

## Design of the training process

### Participants and context

Two in-service Primary Education teachers participated in the training experience, whose information is shown in Table 1.

**Table 1-** Personal data of participants

Participant	Age	Academic background	Teaching experience (years)
Teacher <sub>1</sub>	28	Bachelor of Science in Mathematics	4
Teacher <sub>2</sub>	28	Bachelor's Degree in Primary Education	3

Source: Own creation.

Teacher<sub>1</sub> was a teacher in a private school, where they taught Mathematics to two 3<sup>rd</sup> grade groups, 3A (22 students) and 3B (24 students). At the time of the investigation, the health emergency due to COVID-19 occurred worldwide, and in accordance with the

guidelines of the Ministry of Public Education, classes were taught virtually. Particularly, Teacher<sub>1</sub> used Zoom to teach classes by video call, synchronously using a computer, a tablet, and a smartphone. On the other hand, Teacher<sub>2</sub> taught in a public school, to the sole 3rd-grade group (21 students) virtually in an asynchronous format, using a smartphone and WhatsApp messaging.

### Technological resource

For the design of tasks, Kahoot (<https://kahoot.com/schools-u>) was used, a technological resource that allows teachers to design interactive activities (tasks) that can be seen on a smartphone, tablet, and computer. This resource is interactive and intuitive and allows you to design tasks without the need for advanced knowledge about programming, the latter being the reason why it was selected.

In the premium version of Kahoot, the following tasks can be designed: a) quiz (Figure 3a); b) true or false (Figure 3b); c) write the answer (Figure 3c); d) puzzles (Figure 3d); and e) survey (Figure 3e). In addition, in the resource, each task is assigned a time limit to respond, which ranges anywhere from 5 seconds to 4 minutes.

**Figure 3-** Types of tasks in Kahoot

 <p><b>Examen</b> Dar a los jugadores varias alternativas de respuesta para elegir.</p>	 <p><b>Verdadero o falso</b> Deje que los jugadores decidan si la afirmación es verdadera o falsa.</p>	 <p><b>Escriba la respuesta</b> Pide a los jugadores que escriban una respuesta corta y correcta.</p>	 <p><b>Rompecabezas</b> Pide a los jugadores que coloquen las respuestas en el orden correcto.</p>	 <p><b>Encuesta</b> Haz que los jugadores elijan entre hasta 4 opiniones.</p>
<p>Quiz Give the players several alternatives to choose from.</p>	<p>True or false Allow the players to decide if the statement is true or false.</p>	<p>Write the answer Ask the players to write a short and correct answer.</p>	<p>Puzzle Ask the players to place the answers in the correct order.</p>	<p>Survey Have the players choose among four options.</p>
<p>Figure 3a. Quiz.</p>	<p>Figure 3b. True or false.</p>	<p>Figure 3c. Write the answer.</p>	<p>Figure 3d. Puzzle.</p>	<p>Figure 3e. Survey.</p>

Source: Activities available in the premium version of Kahoot.

### Data collection

Both teachers received training in task design in the *Designing interactive lessons in Kahoot* workshop given over the course of eight weeks. In response to COVID-19 restrictions, the workshop was held synchronously via Google Meet. In total, there were eight sessions that were recorded (one session each week) with an approximate duration of 2 hours. Likewise, Google Classroom was used to work on activities that supplemented the information presented in the virtual sessions. Excerpts were taken from the recordings for analysis, and from Classroom activities, the planning of a class was taken as evidence. Table 2 shows the purpose of each workshop session.

**Table 2-** Purpose of the workshop sessions

Session	Purpose
1	Know the general characteristics of Kahoot
2	
3	Know the reference meaning of the natural number
4	
5	Design assignments and plan a class
6	
7	Implementation and validation of tasks
8	

Source: Own creation.

Sessions 1 and 2 addressed aspects related to creating an account, the type of tasks, configuring tasks, among other functions of the resource. In sessions 3 and 4, the reference meaning of the natural number was discussed, emphasizing the type of situation-problems and the mathematical practices associated with each partial meaning of the mathematical object. Sessions 5 and 6 were devoted to the design of assignments and the planning of a class in which they were incorporated. Finally, in sessions 7 and 8 the tasks were implemented and validated; in the first moment, between the first author (researcher) and the participating teachers of the workshop, and in the second moment with the students of each teacher.

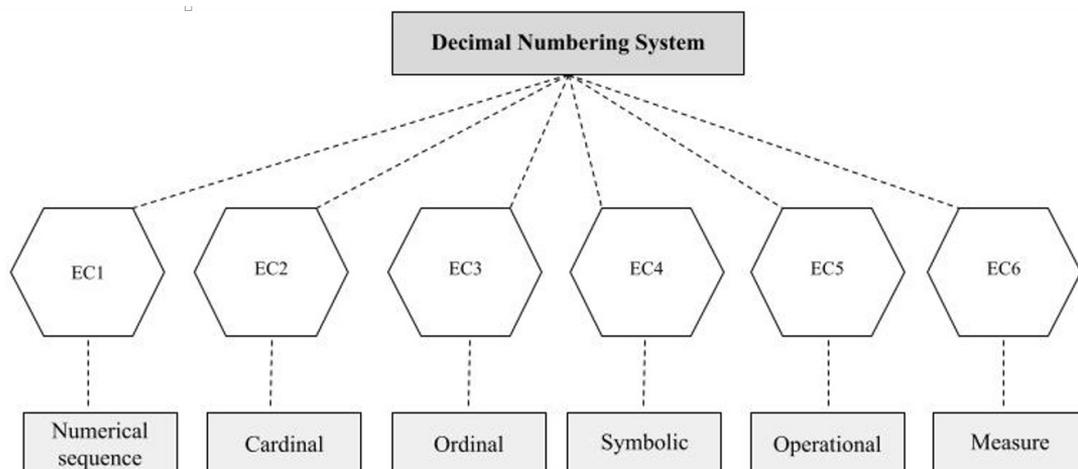
In general terms, the training experience consisted of providing two in-service teachers with specific knowledge about the use of Kahoot and the reference meaning of the natural number for the design of tasks. Subsequently, teachers were asked to plan and implement an instructional process that involved the tasks designed; and finally, the didactic suitability of the training experience was analysed.

## Results

In the following sections, the training experience is described by making a distinction between the four phases of didactic engineering and the use of the theoretical elements of the OSA.

### Preliminary analysis

In this phase, the reference meaning of the natural number in the Decimal Numbering System (DNS) was reconstructed from its contexts of use (MORALES-GARCIA; NAVARRO, 2021) and the system of practices involved, organised in epistemic configurations (EC) (MORALES-GARCIA; NAVARRO; DÍAZ-LEVICOY, 2021). In line with the above, six partial meanings of the natural number were established (Figure 4).

**Figure 4-** Reference meaning of the natural number in the Decimal Number System

Source: Morales García and Navarro (2021, p. 1344).

Each meaning is described below.

- *Meaning of numerical sequence.* Consider using the natural number to indicate the order for reciting or writing the sequence of natural numbers. For example, recite the sequence of numbers from 1 to 30.
- *Meaning of cardinal.* Using the number to indicate how many elements are in an assembly. For example, count the number of apples in a basket.
- *Ordinal meaning.* Numbers are used to indicate the position of an object in an ordered assembly. For example, indicating the runner's finishing position is in an athletics race.
- *Symbolic meaning.* In this case, numbers are used as tags to identify objects. For example, the numbers on the shirts of football players.
- *Operational meaning.* The use of numbers to perform arithmetic operations is highlighted. For example, calculate the result of  $30+2$ .
- *Meaning of measure.* Among other aspects, the use of numbers to indicate how much an object or person measures. For example, indicate the length of a book.

### Design of the didactic trajectory

In this phase, the teachers designed interactive lessons that were based on the tasks available in Kahoot (quiz, true or false, write the answer, puzzles, and survey) and the partial meanings of the natural number (cardinal, ordinal, numerical sequence, operational, measure, or symbolic). The designs were made after four sessions of the workshop, namely, based on the teachers' knowledge of Kahoot management (Sessions 1 and 2), and knowledge of the reference meaning of the natural number (Sessions 3

and 4). Each interactive lesson was made up of 10 tasks and addressed one of the partial meanings of the natural number. Table 3 contains specific information.

**Table 3-** Interactive lessons designed by the participants

Participant	Meaning of the natural number	Interactive lesson	Number of tasks
Teacher <sub>1</sub>	Number sequence	Four-digit number	10
		Order and sequence	10
	Operational	Basic operations	10
		Mental calculation 1	10
	Ordinal	Ordinal numbers	10
	Measure	Longitude	10
Teacher <sub>2</sub>	Number sequence	Which is greater?	10
		Number sequence	10
	Operational	Basic operations	10
		Additive decomposition	10
	Ordinal	Ordinal numbers	10
Total		11	110

Source: Own creation.

In this research, and to show the potential of the theoretical tools of the OSA, the didactic trajectory involved in the design and implementation of the interactive lesson order and sequence created by Teacher<sub>1</sub> is analysed. In this sense, the objective pursued in this phase was to identify the actions that Teacher<sub>1</sub> considered before the implementation of the interactive lesson in a real context (teaching trajectory) and the effectively implemented meaning of the natural number as a numerical sequence (epistemic trajectory).

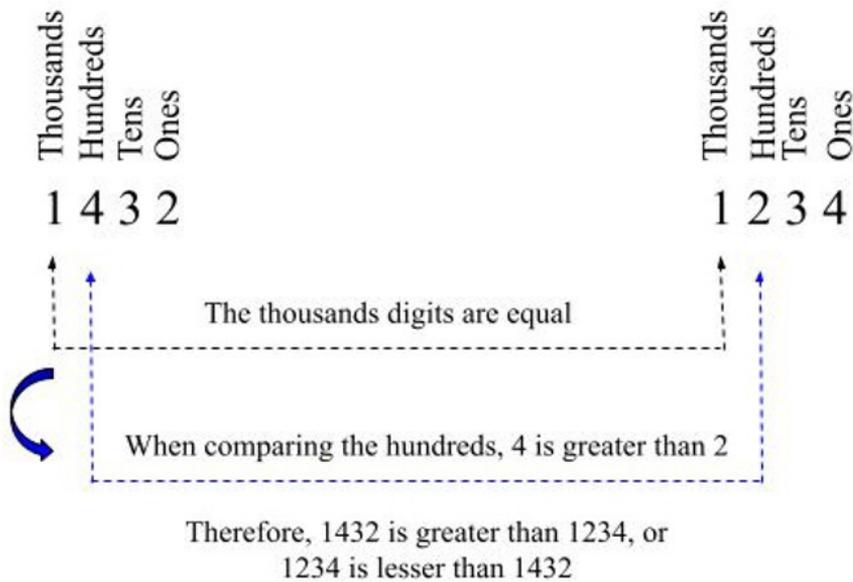
On the teaching trajectory, and in accordance with the planning of Teacher<sub>1</sub>, this teacher organises their class in three moments: beginning, where they present an introduction to the topic being studied, usually with some video about the content of the class; later in the development they work with activities included in their textbook, and finally, in the closing, some elements presented throughout the class that will not be clear, are discussed, and it is at this time where Teacher<sub>1</sub> incorporated the interactive lesson order and sequence that in the words of Teacher<sub>1</sub> “[...] will serve to reinforce the content worked on in the class sessions.” In that sense, the students had previous knowledge on how to solve the situation-problems established in the interactive lesson, which somehow allows greater success in their resolution.

Teacher<sub>1</sub>: [...] on Friday we write down in the notebook, how we can compare two numbers [natural numbers]; let’s start by comparing the thousands [the absolute value of the thousands] if they are equal, we go to the hundreds [we compare the absolute value of the hundreds]; if they

are equal, we go to the tens [the absolute value of the tens], if they are equal, we go to the ones [the absolute value of the ones]. That's why I put these activities [tasks in the interactive lesson].

The procedure suggested by Teacher<sub>1</sub> to determine when one number is greater than or less than another is to make comparisons between the absolute value of the digits of the compared numbers, starting with the digit of greater order (Figure 5).

**Figure 5-** Procedure to compare natural numbers

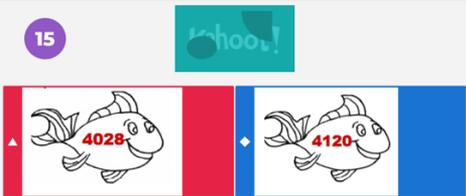
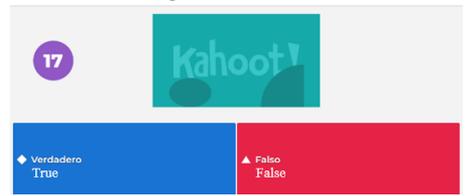
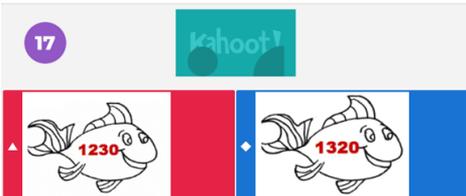


Source: Own creation.

In summary, Teacher<sub>1</sub> considered as important actions to address the procedure beforehand, during the beginning and development of the class. In that sense, the application of the interactive lesson was considered as a kind of evaluation of the learning achieved by the students on the comparison of natural numbers with the intention of reinforcing the content taught, hence the importance of including it in the closing of the class.

On the other hand, in the epistemic trajectory of the interactive lesson, the problem situations, the sequence of expected practices in their resolution, and the primary objects involved in each task are shown. This information was obtained by considering the speech of Teacher<sub>1</sub> when presenting the 10 tasks (session 7) that made up the interactive lesson and the description of each task, included in the planning of the class. Table 4 presents the ontosemiotic analysis (MORALES-GARCIA; DÍAZ-LEVICOY, 2022; MORALES-GARCIA; NAVARRO; DÍAZ-LEVICOY, 2021) of the tasks, identifying in the situation-problem the expected response and the time allocated for its response, the sequence of operational and discursive practices necessary to solve the task, and the primary objects involved in the resolution of each situation-problem.

**Table 4-** Ontosemiotic analysis of the interactive lesson order and sequence

Task (situation-problem)	Sequence of practices	Primary objects
<p>Select the image that contains the lesser number.</p>  <p>Expected response: 4028 Time: 20 seconds</p>	<ol style="list-style-type: none"> <li>1. A look at the two images is given to identify the numbers.</li> <li>2. The thousands digit is the same in both numbers.</li> <li>3. While the hundreds digit in the number 4028 is 0; and 1 in the number 4120.</li> <li>4. Therefore, the number 4028 is less than 4120, because the hundreds digit is lesser.</li> </ol>	<p><i>Language:</i> 4028, 4120. <i>Concepts:</i> place value, less than. <i>Procedure:</i> comparison of the digits of two numbers. <i>Proposition:</i> the number 4028 is less than 4120. <i>Argument:</i> the hundreds digit is lesser.</p>
<p>The number 3050 is greater than 3300.</p>  <p>Expected Response: False Time: 20 seconds</p>	<ol style="list-style-type: none"> <li>5. The thousands digit is 3 in both numbers.</li> <li>6. The hundreds digit is 0 in the number 3050 and 3 in the number 3300.</li> <li>7. Therefore, the number 3300 is greater, because the hundreds digit is greater.</li> <li>8. The answer is False.</li> </ol>	<p><i>Language:</i> 3050, 3300. <i>Concepts:</i> thousands, hundreds, greater than. <i>Procedure:</i> comparison of the absolute value of the hundreds digit. <i>Proposition:</i> The number 3050 is not greater than 3300.</p>
<p>Select the image that contains the lesser number</p>  <p>Expected response: 1230 Time: 20 seconds</p>	<ol style="list-style-type: none"> <li>9. In both numbers the thousands digit is 1.</li> <li>10. The number of the hundreds is 2 in the number 1230, and 3 in the number 1320.</li> <li>11. Therefore the lesser number is 1230, because the hundreds digit is lesser.</li> </ol>	<p><i>Language:</i> 1230, 1320. <i>Concepts:</i> digit, thousands, hundreds, less than. <i>Procedure:</i> comparison of the hundreds digits. <i>Proposition:</i> the number 1230 is lesser. <i>Argument:</i> the hundreds digit in 1230 is lesser.</p>
<p>Put the numbers in order starting with the greatest number.</p>  <p>Expected response: 5234, 5199, 4609, and 3210. Time: 20 seconds</p>	<ol style="list-style-type: none"> <li>12. Between the numbers 5199 and 5234, the greater number is 5234, because the hundreds digit is greater.</li> <li>13. The next greatest number is 5199, next is 4609, because the thousands digit is less than in 5199.</li> <li>14. The next one is 3210 because the thousands digit is less than in 4609.</li> <li>15. The correct order is: 5234, 5199, 4609, and 3210.</li> </ol>	<p><i>Language:</i> 3210, 5199, 5234 and 4609. <i>Concepts:</i> digit, thousands, hundreds, greater than. <i>Procedure:</i> Identify the greater number and make comparisons to determine the order of the remaining numbers.</p>
<p>Put the numbers in order starting with the lesser number.</p>  <p>Expected response: 1239, 1456, 4100, and 4250. Time: 20 seconds</p>	<ol style="list-style-type: none"> <li>16. Between the numbers 1456 and 1239, the lesser number is 1239, because the hundreds digit is lesser.</li> <li>17. The next is 1456.</li> <li>18. Between the numbers 4250 and 4100, the lesser is the number 4100 because the hundreds number is lesser.</li> <li>19. Therefore the order is: 1239, 1456, 4100, and 4250.</li> </ol>	<p><i>Language:</i> 4250, 1456, 1239, 4100. <i>Concepts:</i> place value, less than. <i>Procedures:</i> Identify the lesser number and make comparisons to determine the order of the remaining numbers.</p>

The number 6543 is greater than 3999

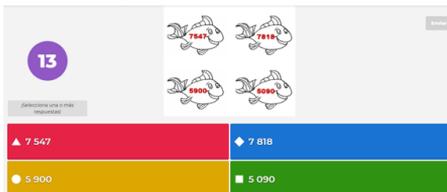


Expected answer: True.  
Time: 20 seconds

20. When comparing the numbers 6543 and 3999, the number 6543 is greater, because the thousands digit is greater.  
21. So the answer is True.

*Language:* 6543, 3999.  
*Concepts:* thousands, greater than.  
*Procedures:* comparison of the digits of a number.

Look at the image. Choose the largest and smallest number.



Expected response: 7818 and 5090  
Time: 20 seconds

22. Between the numbers 7547 and 7818, the greater number is 7818, because the hundreds digit is greater.  
23. The number 7547 follows because the thousands digit is greater compared to the remaining two numbers.  
24. Between the numbers 5900 and 5090, the number 5090 is less than, because the hundreds digit is lesser.  
25. Therefore the greater number is 7818 and the lesser is 5090.

*Language:* 7547, 7818, 5900, 5090.  
*Concepts:* thousands, greater than, less than.  
*Procedure:* identify the greater number to sort the remaining numbers, until you identify the lesser number.

Choose the sequence that is in the correct order from greatest to lesser.

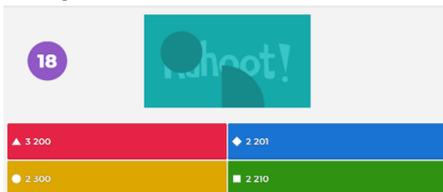


Expected response: 4532, 4440, 3412 and 2999.  
Time: 20 seconds

26. The sequence of numbers 4532, 4440, 3412, and 2999 is correctly ordered from greater to lesser.  
27. While 5674, 3432, 9123, and 2000, it is not ordered from greater to lesser, because 9123 is greater than 5674.  
28. The sequence of numbers 1234, 2342, 5320, and 5500 is not ordered from greater to lesser.  
29. The answer is therefore: 4532, 4440, 3412, and 2999.

*Language:* four-digit numbers.  
*Concepts:* number sequence, greater than, less than.  
*Procedure:* Apply the number comparison to each number sequence.

2100, 2200, \_\_\_\_, 2400, 2500. Which number is missing in this sequence?



Expected response: 2300  
Time: 20 seconds

30. Identify that the sequence is ascending by 100 at a time.  
31. The missing number in the sequence is 2300, since, if the sequence advances by 100 at a time, after 2200 the next is 2300.

*Language:* four-digit numbers.  
*Concepts:* numerical sequence.  
*Procedure:* counting by 100 at a time.

The number 999 is greater than 1300.



Expected Response: False  
Time: 20 seconds

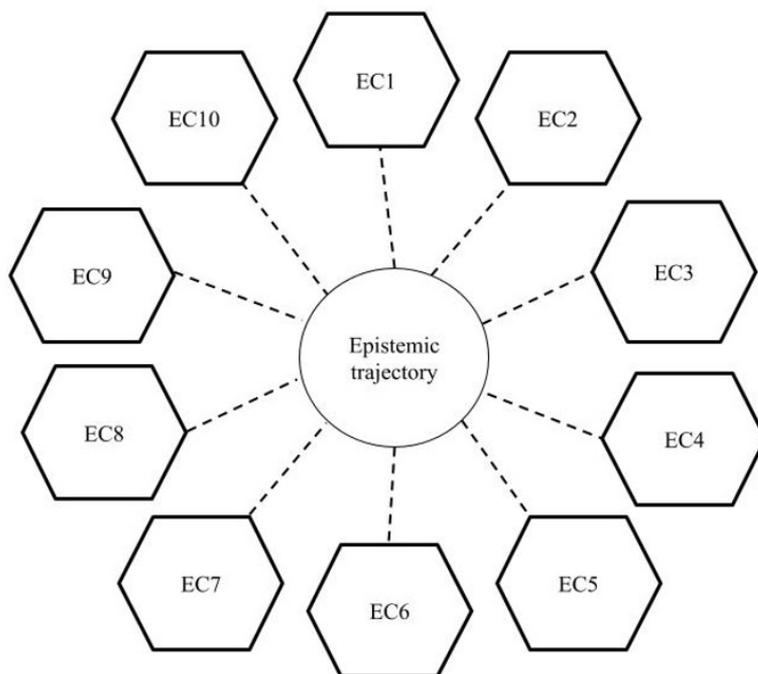
32. The number 999 is less than the number 1300 because it has fewer digits.  
33. Therefore the answer is False.

*Language:* 999, 1300.  
*Concepts:* digit, greater than.  
*Procedure:* comparison of two numbers based on the number of digits.

Source: Own creation.

The analysis of the epistemic trajectory (Figure 6) of the interactive lesson is important to show the effectively implemented meaning of the studied concept, in this case, the numerical sequence meaning of the natural number. For its analysis, the sequence of practices and the primary objects identified in each task, organised in epistemic configurations (EC), were considered. For example, the primary objects identified in Task 1 make up epistemic configuration 1 (EC1), the primary objects of Task 2, EC2, and so on for each task. It should be noted that each epistemic configuration has a function in the instruction process, for example, in EC1, EC2, EC3, and EC6 it was intended to put into practice the procedure taught for the comparison of two, four-digit natural numbers. Whereas, in EC4 and EC5 the procedure taught was applied, to put in order (ascending or descending) four numbers. On the other hand, in EC7 the level of difficulty was increased in some way since it is necessary to select among four numbers: the greatest and the least. In EC8 it was selected among three number sequences, which was correctly ordered from greater to lesser. In EC9 it was asked to indicate which is the number that completes the number sequence; here the student’s ability to recognise how much a number sequence increases and consequently identify which number completes it correctly is evaluated. Finally, in EC10 another procedure is presented to distinguish when one number is greater than another, considering the number of digits.

**Figure 6-** Epistemic trajectory of the interactive lesson *order and sequence*.

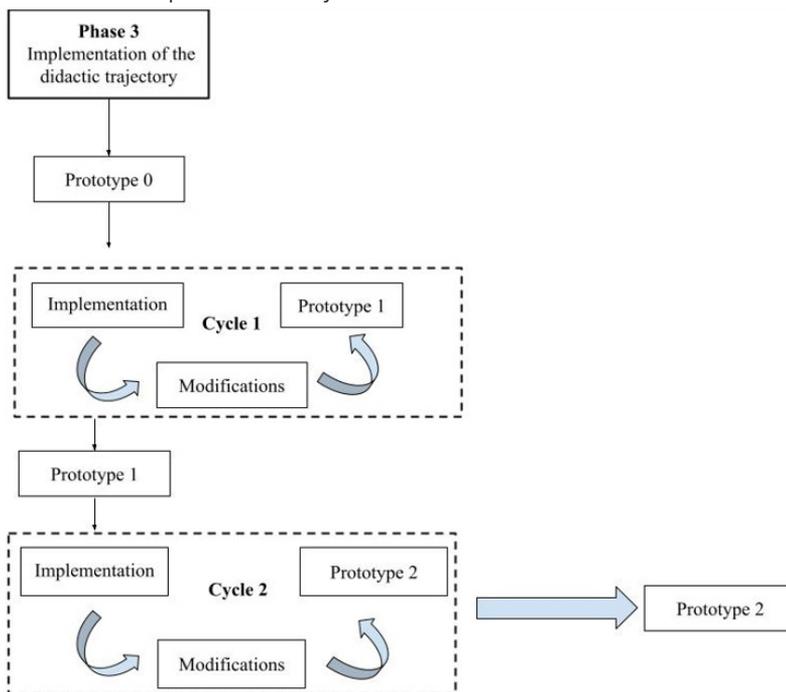


Source: Own creation.

### Implementation of the didactic trajectory

The tasks designed by Teacher<sub>1</sub> and analysed above make up Prototype 0 of the interactive lesson *order and sequence*. This was implemented twice; each implementation cycle was intended to validate and refine the included tasks by identifying Meaningful Didactic Facts (WILHELMI; FONT; GODINO, 2005). Figure 7 shows the deployment cycles.

**Figure 7-** Interactive lesson implementation cycles



Source: Own creation.

The following describes the Significant Didactic Facts (SDF) identified in the implementation cycles.

- *Task content (SDF1)*. Related to the mathematical content of the task. For example, errors in the order of answers or in the understanding of the task.
- *Time (SDF2)*. Related to the time allocated to respond to each of the tasks. For example, the time allotted to answer Task 1 was not enough.
- *Interaction with the technological resource (SDF3)*. Related to failures in the interaction with Kahoot. For example, you cannot answer tasks from your computer.

Cycle 1 of the application was carried out with the participants of the workshop, in this case, the person in charge of the workshop and first author (I) and Teacher<sub>2</sub> answered the 10 tasks that made up the lesson of Teacher<sub>1</sub>, to discuss their relevance (session 7). Based on this implementation, some adjustments were made to prototype 0. The first

modification was made to Task 5 since the response options were not ordered from lesser to greater (SDF1).

Teacher<sub>2</sub>: [...] I think that Task 5, is wrong because it was to order from lesser to greater the four numbers, and so I did, but it turns out that my answer is wrong.

Teacher<sub>1</sub>: you are right I think that in this task I was wrong when indicating the order in the numbers I must edit the answer in Kahoot, to resolve it.

The other modification was guided towards the time assigned to Task 8, where it was asked to select the numerical sequence that was correctly ordered from greater to lesser. Here initially Teacher<sub>1</sub> had assigned 20 seconds to respond, but according to the demand of the task, it is concluded that the time should be increased (SDF2) and that it should be increased to 40 seconds.

Teacher<sub>2</sub>: you do not think that, in this task, you would have to give it more time, 20 seconds is very little.

Teacher<sub>1</sub>: I think so, here I see that 20 seconds is very little, and the task demands a lot of activity [comparisons between numbers] on the part of the students because they must analyse each of the sequences.

I: You are correct, because there are three sequences, and the time must be increased [...]

The modifications made to prototype 0 were applied to the tasks, now generating Prototype 1 of the interactive lesson. In Cycle 2, Teacher<sub>1</sub> applied Prototype 1, but now to their 46 students in the 3rd grade of Primary Education. The results according to the Kahoot report (shows the percentage of correct answers), allowed to identify three difficult tasks; the first was Task 5 of the puzzle type. Here Teacher<sub>1</sub> pointed out that the students presented difficulties to drag the answer options on the computer (SDF3), since these returned to the initial place, and in the end only 8% of the answers were correct.

I: And how did the students do?

Teacher<sub>1</sub>: At first, they found it difficult to sort numbers [Kahoot's puzzle task] [...] because as you move them on the computer [the answer options] they move again [it was not as they wanted to order them], but I told them not to worry that they could try again.

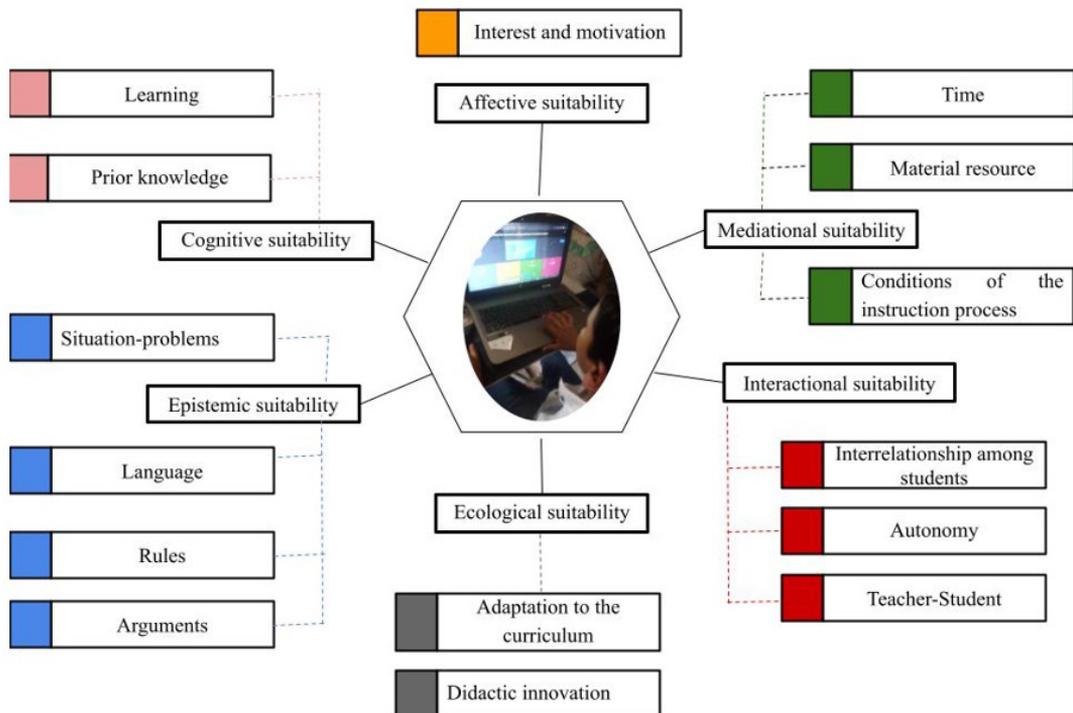
The second task is Task 7, where it was asked to select the greatest and least number, and you had 20 seconds to respond. Here only 27% of the students had correct answers, with the allotted time being insufficient to respond, so it was increased to 60 seconds (SDF2). The third task is 8, where it was asked to select the sequence that was correctly ordered from greater to lesser; for this, 40 seconds were available. In this case, only 31% of the answers were correct; for this reason, the modifications were focused on increasing the time to 60 seconds (SDF2) and/or changing the type of task (SDF1), trying to use fewer number sequences to decrease the process and reach the solution. The modifications made to Prototype 1 were applied to the tasks, allowing to generate Prototype 2 of the interactive lesson order and sequence.

Teacher<sub>1</sub>: [...] the most difficult tasks were Tasks 5, 7, and 8.  
 I: What happened in Task 7?  
 Teacher<sub>1</sub>: I think that there the time was not enough, I will increase the time to 60 seconds.  
 I: And what can you say about Task 8?  
 Teacher<sub>1</sub>: [...] well here I think it was the type of task [include three number sequences], although in the notebook we had already seen some examples, at the beginning [...] of the sessions, but still the understanding or I do not know [...].  
 Teacher<sub>2</sub>: ... or time.  
 Teacher<sub>1</sub>: yes, perhaps time...  
 Teacher<sub>2</sub>: How much time did you assign?  
 Teacher<sub>1</sub>: 40 seconds.  
 I: If you think it wasn't enough, you can increase it to 60 seconds.  
 Teacher<sub>1</sub>: [...] I still must work more on this type of task.

### Retrospective analysis of the training experience

In this last phase, the retrospective analysis was carried out using the components of didactic suitability (Figure 8). In line with the above, Table 5 presents the assessment of the epistemic, cognitive, affective, mediational, interactional, and ecological facets of the formative experience (GODINO, 2013).

**Figure 8-** Components of didactic suitability



Source: Created by the authors based on Godino (2013).

**Table 5-** Didactic suitability of the training experience

Facet	Assessment
<p><i>Epistemic</i></p> <p>The degree to which the implemented (or intended) meanings represent the reference meaning.</p>	<p>Situation-problems, language, procedures, concepts, propositions, and arguments conformed to the nature of the numerical sequence meaning.</p>
<p><i>Cognitive</i></p> <p>Proximity of the personal meanings achieved to those intended or implemented.</p>	<p>Students found it difficult to apply the procedure when homework required comparing more than two, four-digit numbers. This is due to the cognitive demand involved in applying the taught procedure, in numerical sequences of four natural numbers.</p>
<p><i>Affective</i></p> <p>Degree of involvement (interest and/or motivation) in the teaching-learning process.</p>	<p>Teachers and students were motivated during the design and implementation of the interactive lesson. Which suggests that the use of mobile devices positively impacts motivation.</p>
<p><i>Mediational</i></p> <p>Degree of availability and adequacy of the material and/or temporal resources necessary for the development or implementation of the instructional process.</p>	<p>On the availability of mobile devices, in this case, in the context of the pandemic, participants had mobile devices to carry out the design and implementation, such as a computer, tablet, or smartphone, as well as internet access.</p>
<p><i>Interactional</i></p> <p>Degree to which the configurations and didactic trajectories allow to resolve conflicts that occur during the process of instruction.</p>	<p>The teacher interacted synchronously, that is, they addressed only and exclusively their students who were connected, with their mobile devices to complete the tasks; and this allowed to identify and solve difficulties to adapt to the type of questions included in the interactive lesson.</p>
<p><i>Ecological</i></p> <p>Degree in which the study process is adjusted to the educational project of the centre, the school, society, and the conditioning of the environment in which it is developed.</p>	<p>In this regard, the teacher had the necessary conditions to carry out distance learning, such as access to the internet, mobile devices, and their students also had these resources. Since they were used to working through Zoom the teacher had no problems in the development of the instructional process.</p>

Source: Own creation.

## Discussion

In this research, a formative experience of two in-service Primary Education teachers was analysed, guided towards the design and implementation of tasks for mobile learning, based on the meaning of the natural number and the use of Kahoot. To this end, didactic engineering understood from the perspective of the OSA (GODINO *et al.*, 2014) and its tools (GODINO, 2021; GODINO *et al.*, 2017) allowed for the design, implementation, and analysis of the training experience. In addition, it made it possible to answer the research question: Which OSA tools can be used in a training intervention to achieve the implementation of mobile learning?

In line with the above, in the preliminary phase, the notion of reference meaning of the natural number (MORALES-GARCIA; NAVARRO, 2021) guided the type of tasks that could be designed, from the epistemology of the intended mathematical content (AKÉ *et al.*, 2014). The above is a contribution to mobile content design (BRAZUELO; GALLEGO,

2014), given that, in most researches, a specific mathematical concept studied is not identified (CROMPTON; BURKE, 2015). In this sense, considering the reference meaning of the natural number allowed to support the type of situation-problems that can be raised with respect to this mathematical content.

In the design phase, the notions of epistemic trajectory (GODINO *et al.*, 2006), Ontosemiotic analysis (MORALES-GARCIA; DÍAZ-LEVICOY, 2022; MORALES-GARCIA; NAVARRO; DÍAZ-LEVICOY, 2021), and epistemic configuration (FONT; GODINO, 2006) allowed to organise the frame of primary objects associated with the meaning of number sequence in the designed tasks. On the other hand, the notion of teaching career (GODINO; CONTRERAS; FONT, 2006), guided the analysis of the actions that the teacher considered necessary to achieve, in this case, the integration of the interactive lesson order and sequence in a real class context.

In the implementation phase, the notion of significant didactic fact (WILHELMI; FONT; GODINO, 2005) allowed to identify, in the cycles of application of the prototype of the interactive lesson, aspects that would allow to improve the tasks for its implementation in a real class context. In the retrospective *analysis* phase, the use of Godino's didactic suitability indicators (2013, 2021) allowed a systematic reflection on the implemented formative experience, which made it possible to establish potential improvements in the process.

In this sense, the retrospective analysis of the formative experience highlights six aspects: 1) the reference meaning of the natural number guided the design of tasks towards partial meanings, the identification of primary objects, and the Ontosemiotic analysis of them; 2) the previous knowledge that the student has about the objective of each interactive lesson must be clear; 3) the use of mobile devices and Kahoot motivate teachers and students; 4) the device that caused problems because of its use was the computer, and only with the puzzle-type tasks; 5) it would be important for teachers to incorporate the interactive lesson at the beginning and the development of the class, and not only in the closing; and 6) the context where mobile learning is used must have the availability of mobile devices, internet access, and a good organisation of the class.

On mobile learning, it is confirmed that it has a positive impact on affective aspects, in this case, motivation (FABIAN; TOPPING; BARRON, 2018; MALIK *et al.*, 2020). In addition, the mobile content designed has the potential to support the learning of mathematical concepts (CROMPTON, 2015; TUCKER; JOHNSON, 2020), in this case, the natural number.

Also, considering the context of the health emergency due to COVID-19, it is important that teachers not only have knowledge about the resources that are available online (BARRIGA; BELTRÁN-PELLICER, 2021; PINCHEIRA; VASQUEZ, 2021; VALENZUELA; BATANERO; BEGUÉ, 2021), but also be able to incorporate them into the school context. Consequently, it is essential to carry out research on training actions that guide teachers on the design, implementation, and evaluation of mobile content for the teaching of specific mathematical concepts. This can be achieved since teachers generally have a positive outlook on the use of mobile applications in the school context (HANDAL *et al.*, 2015; INGRAM; WILLIAMSON-LEADLEY; PRATT, 2015).

In this sense, with this research two training actions are proposed, aimed at in-service teachers: the first is the design of mobile content from the reference meaning of the natural number and its ontosemiotic analysis. The second training action is the assessment of the didactic suitability of teaching experiences mediated by mobile devices through the analysis of class episodes of the teachers themselves. According to Arjona-Heredia and Gámiz-Sánchez (2013), the detailed analysis of training experiences can draw revealing conclusions about the possible use of mobile learning in the educational field, therefore, the development of research that informs on this topic is open.

## Conclusions

Mobile learning in the teaching-learning of Mathematics is gaining interest in the research community (*e.g.*, BORBA *et al.*, 2016; CROMPTON, 2015), and mobile devices are considered as emerging and innovative tools (BENALI; ALLY, 2020). However, although there are different investigations that show the potential they have in the teaching-learning of mathematical concepts, it is considered that the studies should be guided towards promoting the design of mobile content by the teachers themselves, from the two training actions presented above, where the theoretical and methodological tools of the OSA play an important role.

Therefore, this research contributes to the knowledge about the use of other facets of OSA, such as cognitive, interactional, affective, and ecological suitability for the analysis of the didactic suitability of mobile learning, as it was well recommended in Morales-Garcia, Navarro, and García González (2022). On the other hand, although there are various resources for the design of content on mobile devices, in this case, Kahoot turned out to be a technological resource of easy use, and intuitive for in-service teachers.

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