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ORIGINAL ARTICLE

Model of appropriation of a curricular resource: a case of a digital game for the teaching of enumeration skills in kindergarten

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Abstract The rapid growth of the offer of available educational resources raises the issue of their appropriation by teachers. Although the term appropriation is widely used in mathematics education research, there is no clear conceptualization allowing researchers to understand the processes involved. In this paper, we attempt to fill this gap by proposing a model for studying appropriation of curricular resources by teachers. This model was elaborated drawing on conceptualizations of appropriation in social and management sciences and on the instrumental approach. It was then put to the test in an empirical study involving one kindergarten teacher who was offered a digital game for teaching and learning enumeration, in order to build and enact a teaching sequence using the game. The model is used as a framework for analysing the interactions between the teacher and the resource during the teaching sequence preparation and its enactment. Such analysis enables the highlighting of the teacher's transformations of the resource, aiming at adapting it to his needs and to the context of his classroom (instrumentalization), his choices of instrumental orchestration, as well as the evolution of his professional knowledge and practice (instrumentation).

Keywords Appropriation of a resource · Instrumental genesis · Instrumental orchestration · Digital game · Enumeration

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1 Introduction

With the rapid growth of open educational resource repositories, the question of their use and reuse is more than ever topical. According to Agostinho et al. (2004), the reuse of available resources (learning objects) is underpinned by the following three assumptions: (1) teachers are willing to use other people's resources; (2) resources are accompanied by a standard annotation to allow them to be found easily; and (3) when retrieved, teachers know how to make effective use of the resources within their instructional settings. The last assumption addresses the issue of appropriation of existing resources on which more research is needed, as stressed by Bennett et al. (2005): "more needs to be known about teachers' current understandings and uses of digital resources, and what approaches may be effective in enhancing their approaches" (p. 2392).

Yet, processes of appropriation of a curricular resource are seldom an object of study in mathematics education research. Researchers rather focus on teachers' use of curricula or curriculum enactment processes, paying attention to the deviation between planned and enacted curriculum (Remillard 2005; Remillard and Heck 2014). Others study documentational work of teachers, consisting in selecting, adapting and reshaping existing resources (Gueudet and Trouche 2009). In the case of digital resources or technologies, researchers rather use the term integration, meaning the adoption of resources/technologies by a teacher, which manifests itself in the regular use of these resources (integration into teaching practices, e.g., Aslan and Zhu 2016), or by incorporating these resources into the teacher's resource system (e.g., Poisard et al. 2011). Sometimes the term *appropriation of resources* is used, but in a rather common sense, with no specific conceptualization.

In the attempt to fill this gap, and feeling a need to better understand processes occurring when a teacher attempts to use a new resource, and factors likely to impact these processes, we propose in this paper a model of appropriation of a digital curricular resource. We draw on the concept of appropriation defined in social and management sciences, the instrumental approach, the concept of instrumental orchestration and the TPACK framework. The empirical study, aiming at testing whether and to what extent the model is operational, concerns a case of a kindergarten teacher who volunteered to implement in his classroom a digital game, specifically designed for teaching and learning enumeration skills.

The paper is organized as follows: in Sect. 2, we present various meanings of the term appropriation based on a literature review, and highlight a need for a frame shedding light on processes of resource appropriation by teachers. In Sect. 3, we propose our conceptualization of such a process resulting in a model of resource appropriation (Sect. 3.5). In Sect. 4, we report on a case study conducted in order to verify whether our model is operational for studying processes of resource appropriation. The results obtained are discussed in the concluding Sect. 5.

2 Notion of appropriation: literature review

The notion of appropriation is usually considered as an action aiming to adapt something to a specific purpose (Grimand 2012). Recent research on appropriation in different scientific domains seems to converge on rejecting a techno-centred perspective and considering appropriation as a cognitive process.

In management sciences, appropriation (of a management tool) is seen as a "long process that begins long before the phase of using the tool and continues long after the appearance of the first routines of use" (De Vaujany 2006, p. 118, our translation). The author distinguishes three phases in this process: (1) a *pre-appropriation* phase, occurring when the tool is presented, discussed or evoked for the first time, which may lead to the emergence of the first interpretations; (2) an *original appropriation* phase, when the tool is accepted, used and some usage routines are developed; and (3) a *re-appropriation* phase in which the instrument evolves repeatedly in the course of its use in various situations. Therefore, as the author claims, the appropriation process does not come to an end with the development of permanent routines (ibid.). The appropriation, according to the author, triggers cognitive processes resulting in the development of interpretations and usage routines. De Vaujany (2006) builds his conceptualization of the appropriation on several axioms among which the following appear to be of foremost importance: "Any tool (and object of management), designed at a distance from the actors or in co-design logic, presents some instrumental and interpretive flexibility (Axiom 2)" (p. 117). Indeed, without such flexibility, the appropriation could not even be envisaged.

This consideration is in line with the environmental psychology approach to appropriation expressed by Serfaty-Garzon (2003):

> The goal of this type of ownership is precisely to make own something, that is to say, to adapt it to oneself and thus turn this thing into a support of self-expression. Appropriation is thus both a seizure of the object and a dynamics of action on the material and social world aiming at a construction of the subject (p. 27).

Research on appropriation has intensified with the integration of digital technology in all sectors of human activity, including education. According to Proulx (2002), appropriation of a technology by a human agent requires a combination of three conditions: (a) a minimum cognitive and technical mastery of the technology; (b) a significant social integration of the use of this technology in the daily life of the human agent; and (c) the possibility that a creative act is made possible by the technology, that is to say that the use of the technology makes it emerge as a novelty in the life of the user (p. 182). Theureau (2011) considers appropriation as an

> integration, partial or total, of an object, a tool or a device, into the culture of the actor, (always) accompanied by an individuation of its use and (possibly) by more or less important transformations of the object, the tool or the device itself. (p. 11, our translation).

Carroll et al. (2002) claim that "[a]ppropriation occurs where the participants try and evaluate the technology, select and adapt some attributes and take possession of its capabilities in order to satisfy their needs" (p. 53). The authors continue: "The technology is appropriated and integrated into participants' everyday routines. Appropriation is not a one-off activity but rather is subject to ongoing reinforcement" (ibid.). Mangiante-Orsolla (2011), in her study of primary teachers' work with curricular resources, considers the resource appropriation as a teacher's contribution, through her interpretation of the resource and the adaptations she makes. This echoes Hoyles et al.'s (2013) findings according to which making a technology their own, teachers need to "move from adoption to adaptation, with a greater awareness, perhaps, of the potential of instrumentalisation".

From this literature review it appears that the various conceptualizations of appropriation seem to be joined in the idea that appropriation of an object (a tool, a resource)

is a cognitive process resulting in (more or less significant) modifications of the object, as well as in the development of interpretations and usage routines in the user. For studying appropriation processes, researchers usually focus either on observable transformations of the object (appropriation seen as adaptation), or they attempt to capture a longer-term use of the object (appropriation seen as integration). However, in our opinion, these methods, focusing rather on the outcomes of appropriation, do not allow researchers to gain a deep enough insight into the appropriation processes. For this reason, in what follows, we attempt to elaborate a model of appropriation of resources by teachers.

3 Model of appropriation of a resource

In this section, we develop a conceptualization of the concept of appropriation of a curricular resource drawing on the literature review (Sect. 3.1), the instrumental approach (Sect. 3.2), the concept of instrumental orchestration (Sect. 3.3) and the TPACK framework (Sect. 3.4), resulting in a model of appropriation of a curricular resource (Sect. 3.5).

3.1 Appropriation as a long and dynamic process

As we mention in Sect. 2, appropriation is a long-term process, subject to ongoing evolution, starting at the moment of the first encounter with the object (a tool, a resource, a device). The transposition of De Vaujany's (2006) view of a management tool appropriation to curricular resources appropriation by teachers appears promising. Indeed, in many cases, teachers need to "appropriate" resources that they have not (co-)designed. We can consider that the decision whether or not to use a given resource is a result of a *pre-appropriation* process, whereas its actual use and re-use represent phases of *original appropriation* and *re-appropriation* respectively.

Considering appropriation of an object as a process resulting in both modifications of the object and the development of usage routines in the user echoes the process of *instrumental genesis*, a core concept of the *instrumental approach* (Rabardel 2002). We present fundamentals of this approach in the next section, with the aim to explore its contribution to a further conceptualization of the notion of appropriation.

3.2 Instrumental approach

The instrumental approach, developed by Rabardel (2002) to better understand human–tool interactions, stresses the difference between an *artefact*, available to a person, and an *instrument*, which is a psychological construct composed from the artefact (or a part of it) and the associated utilization schemes. Trouche (2004) claims that the construction of an instrument, the so called *instrumental genesis*, "is a complex process, needing time, and linked to the artefact characteristics (its potentialities and its constraints) and to the subject's activity, his/her knowledge and former method of working" (pp. 285–6). The instrumental genesis can be seen as consisting of two interrelated processes: *instrumentalization* oriented toward the artefact, and the *instrumentation* oriented toward the subject (Fig. 1).

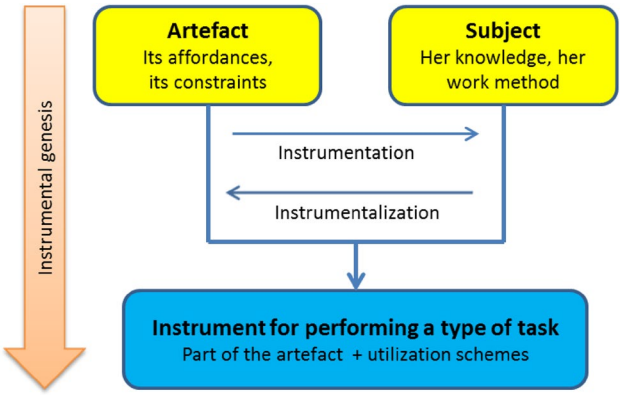

Fig. 1 Instrumental genesis (adapted from Trouche 2004, p. 289)

The processes of instrumentalization and instrumentation are defined by Rabardel (2002) as follows:

- *Instrumentalization processes* concern the emergence and evolution of artefact components of the instrument: selection, regrouping, production and institution of functions, deviations and catachreses, attribution of properties, transformation of the artifact (structure, functioning etc.) that prolong creations and realizations of artefacts whose limits are thus difficult to determine;
- *Instrumentation processes* are relative to the emergence and evolution of utilization schemes and instrument-mediated action: their constitution, their functioning, their evolution by adaptation, combination coordination, inclusion and reciprocal assimilation, the assimilation of new artefacts to already constituted schemes, etc. (p. 103)

The instrumental genesis seems to be in line with the view of appropriation as a twofold process, impacting both the object of appropriation (artefact/resource) by the action of a person, and the person in whom evolutions of knowledge or work methods occur. Thus, the concept of appropriation seems to be closely related to the concept of instrumental genesis.

In our case, the person/subject is a teacher and the artefact is a digital curricular resource that the teacher intends to use in her classroom. Planning an enactment of a resource requires relevant organization of the students' and the teacher's work space and time (Trouche 2004). The concept of *instrumental orchestration* presented in the following section addresses this aspect.

3.3 Instrumental orchestration

Trouche (2004) introduces the concept of instrumental orchestration to "point out the necessity (for a given institution—a teacher in her/his class, for example) of *external steering*[1] of students' instrumental genesis" (p. 296). An instrumental orchestration is defined by a didactic configuration, which is "an arrangement of artefacts in the environment, or, in other words, a configuration of the teaching setting and the artefacts involved in it", and by a mode of exploitation of a didactical configuration, which is

> the way the teacher decides to exploit it for the benefit of his didactical intentions. This includes decisions on the way a task is introduced and is worked on, on the possible roles of the artefacts to be played, and on the schemes and techniques to be developed and established by the students. (Drijvers et al. 2010, p. 1350).

Several types of instrumental orchestration have been identified, such as *Technical-demo, Link-screen-board, Discuss-the-screen* (Drijvers et al. 2013) or *Sherpa-at-work* (Trouche 2004) for the whole-class setting, and *Work-and-walk-by* for the setting in which students work individually or in groups (Drijvers et al. 2013).

We claim that appropriation of a resource results in its re-use by the teacher, which leads to the emergence of regularities in instrumental orchestrations. These can then be seen as utilization schemes related to the resource.

3.4 Teachers' professional knowledge: the TPACK model

Since the process of instrumentalization of a resource by a teacher aiming at adapting it to her educational goal and school context bears the marks of her professional knowledge, we claim, as do other researchers (e.g., Behm and Lloyd 2009), that the latter is one of the most influential factors impacting the resource appropriation. In turn, in the process of instrumentation of the resource, the teacher's knowledge evolves.

In order to explore the influence of a teacher's knowledge on the processes of appropriation of a digital curricular resource, we refer to the TPACK framework (Mishra and Koehler 2006) that highlights the *Technological Pedagogical Content Knowledge*, which designates the knowledge and skills teachers need to meaningfully integrate technology into the teaching of specific content areas. The notion of TPACK emerged from Shulman's (1986, 1987) construct of *pedagogical content knowledge* (PCK), leading to considering a unique type of knowledge, "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (Shulman 1987, p. 8), rather than two separate bodies of knowledge related respectively to pedagogy (PK) and content (CK).

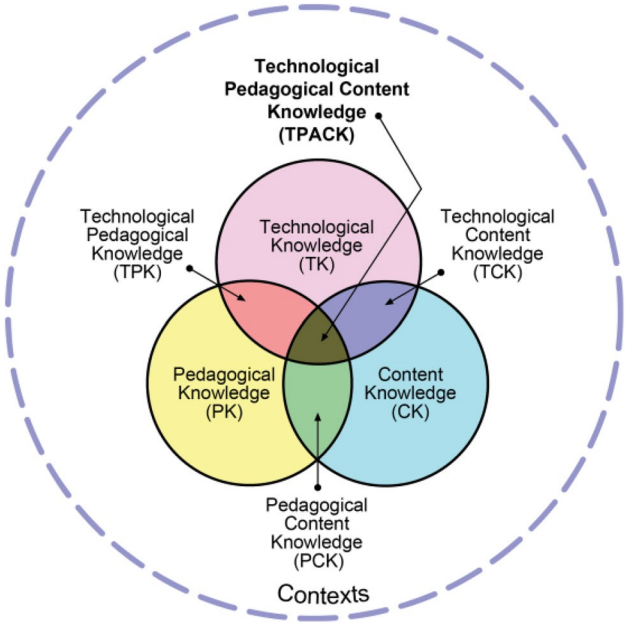

Fig. 2 TPACK Model (http://www.tpack.org/)

Along a similar line of thought, Mishra and Koehler (ibid.) suggested an additional body of knowledge, technological knowledge (TK). They emphasized the new kinds of knowledge that lie at the intersections of TK with PK and CK, representing three more knowledge bases for teaching with technology (Fig. 2): technological content knowledge (TCK), technological pedagogical knowledge (TPK), and the technological pedagogical content knowledge (TPACK).

3.5 Modelling the process of appropriation of a resource

Based on the above considerations, we propose a conceptual model for studying the processes of appropriation of a curricular resource by a teacher.

[1] Stressed by the author.

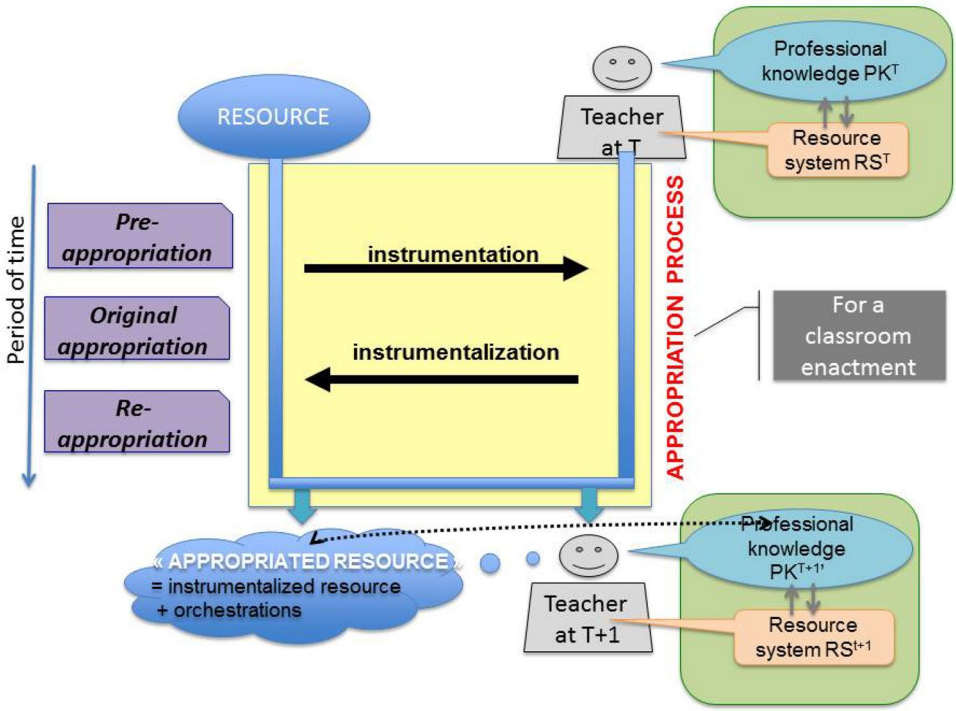

Fig. 3 Model of appropriation of a new resource by a teacher

Drawing on the instrumental approach, we consider the process of appropriation of a resource by a teacher as consisting of both processes of instrumentalization, i.e., adaptation and reshaping of the resource, and instrumentation, i.e., evolution of the teacher's professional knowledge. Following De Vaujany (2006), we consider three phases in the appropriation process: (1) pre-appropriation, corresponding to a priori inspection of the resource by the teacher; (2) original appropriation, corresponding to the first enactment of the resource; and (3) re-appropriation, corresponding to possible revisions of the resource and its further usages. Instrumental orchestrations concerned with the resource enactment in a classroom are of foremost importance as a window on the instrumental processes and the evolution of teacher's professional knowledge. The process of appropriation gives birth to an "appropriated" resource that can be defined by the following equation: "appropriated resource = instrumentalized resource + instrumental orchestrations". We assume that appropriation of a resource manifests itself through stable and effective orchestrations, a sign of the development in the teacher of utilization schemes associated with the resource, and through the integration of the resource into the teacher's resource system.[2] Figure 3 presents the model of appropriation of a resource by a teacher aiming at enacting the resource in her classroom. The model takes into account the three phases of appropriation (pre-, original and re-appropriation) and highlights both the adaptation of the resource (instrumentalization) and the evolution of teacher's professional knowledge (instrumentation) and of her resource system to which the "appropriated" resource is integrated.

Considering that the model was built on theoretical considerations, we conducted an empirical case study, reported in the following section, to test the model. Our research questions are as follows:

- To what extent do the instrumentation and instrumentalization processes characterize the appropriation of a resource by teachers?
- How are the instrumental orchestrations chosen by the teachers related to the resource appropriation?
- How does the teacher's professional knowledge intervene in her appropriation of a resource?

4 Test of the model: a case study

The case study concerns a digital game for teaching and learning enumeration skills. The game was proposed to one kindergarten teacher who was asked to prepare and enact a teaching sequence integrating the game for his pupils. The choice of enumeration was motivated by the ambiguous status of this mathematical piece of knowledge in the

[2] Gueudet and Trouche (2009) claim that a teacher's set of resources is organized according to her professional activities. They call *resource system* such an organized set of resources.

French curriculum: on the one hand, enumeration is recognized as an important skill intervening in numerous mathematical and non-mathematical situations, and on the other hand, it appears that teachers do not consider it as knowledge to be taught.

We start by presenting briefly the knowledge at stake (Sect. 4.1) and the game specifically designed for its teaching and learning (Sect. 4.2). We then outline our research methodology (Sect. 4.3) and the analysis of the case study (Sect. 4.4).

4.1 Enumeration

Enumeration skills are necessary in a variety of mathematical domains, such as number theory, combinatorics, or set theory. They are also involved in everyday life situations, such as counting. Sarama and Clements (2009) observed enumeration skills in the free play of children. However, for these authors, the concept of enumeration includes several mathematical skills such as "saying number words, counting, instantly recognizing a number of objects […], or reading or writing numerals" (p. 314). Enumeration in this sense seems to be related to counting and involves numbers. As we explain in the following section, the term enumeration has a different meaning in the French system of mathematics education.

4.1.1 Concept of enumeration

Briand (1999) claims that in order to count the number of objects in a finite visible collection, a pupil needs to do the following:

1. **Be able to distinguish between two objects of a given set**.
2. **Choose an object of a collection**.
3. Tell a number-word. ("one" or the successor of the previous one in a sequence of numbers).
4. **Memorize the collection of objects that have already been chosen**.
5. **Perceive the collection of objects that have not been chosen yet**.
6. **Repeat (for the collection of objects not yet chosen) steps 2-3-4-5 until the collection of objects to choose is empty**.
7. **Know that the last object has been chosen**.
8. Tell the last number-word. (p. 16–17, our translation).

The steps in bold characters (1, 2, 4, 5, 6, 7) constitute a task Briand (ibid.) calls an "inventory task" that consists in reviewing all objects of a finite collection once and only once, and enumeration is the (piece of) knowledge characterized by this task.

Brousseau (1984) points out that enumeration is a notion having no cultural status in mathematics, although it can be linked to important concepts and theories. He claims that this might be a reason why teachers do not consider enumeration as knowledge to be taught. As a consequence, students at all school levels, from primary to university classes, face difficulties in various situations involving enumeration, such as establishing one-to-one correspondence between the elements of a collection and the number-words while counting elements of the collection at the primary level, or controlling results in combinatorics at the upper school levels.

This finding has stimulated research aiming at designing didactic situations for teaching and learning enumeration. In the next section, some of the most known situations are presented.

4.1.2 Curricular resources for teaching enumeration

A number of situations exist in which enumeration of objects of a finite collection is the solution of a problem. These situations are variations of the situation "one matchstick in each matchbox" analysed by Briand et al. (2000). The situation, aimed at 4–5 year old children, is described as follows:

> A pupil has in front of her (on a table) a bunch of identical matchboxes with a small hole on one side for the passage of a matchstick. […]. These sticks, in large number, are in a plastic box. The task consists in putting one stick and only one in each box without opening it, and recognizing when the task is completed. When the pupil feels she has finished, she checks or asks another pupil (or the teacher at the beginning) to check. To do so, the pupils observe opening the boxes. If there is one stick in each box and if no box is empty, then the pupil succeeded (p. 10).

The authors provide a detailed analysis of the situation. They consider several parameters (didactical variables) of the situation that can be set up by the teacher in order to adapt the situation to the age or to the skills of the children and to favour or prevent certain strategies. The authors consider the following three main variables among others:

(V1) *Number of matchboxes* 8, 15 and 20 boxes respectively are considered in the successive phases of the situation.

(V2) *Movable or non-movable matchboxes* In the first case, the problem can be solved by putting progressively aside boxes in which a stick has been placed. In the latter, one has to memorize a path that allows distinguishing, as one goes along, the boxes in which a stick has been placed from these that are empty.

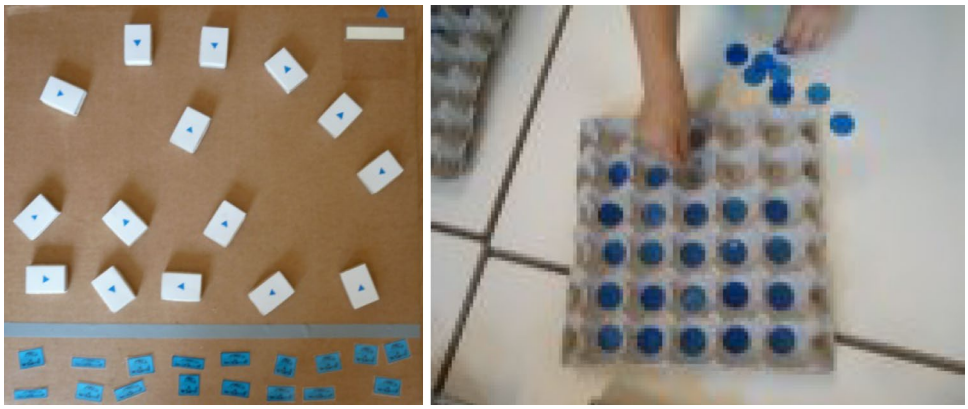

Fig. 4 Examples of manipulatives for the "One car in each garage" (Rousson 2010) (*left*) and "Tokens in an egg-box" (http://www.ac-grenoble.fr/ecole/matcondorcet.valence/spip.php?article146&lang=fr) (*right*) situations

(V3) *Spatial organization of the matchboxes* This variable makes the search of such a path easier or more difficult.

According to the context, different variants of the situation are reported (Fig. 4), e.g., "one car in each garage" (Rousson 2010) in which the objects to enumerate are movable, or "tokens in an egg-box" where a structure in lines and columns is provided (Argaud et al. 1999).

Although enumeration is a properly identified and defined piece of knowledge and a number of learning situations facilitating its acquisition exist and are available to teachers, it seems that it is often not given the importance it warrants in the teaching. As Margolinas (2012) points out, "it is as if this knowledge remained "transparent" for teachers […], as if they were passing by without seeing it, somehow. However, the teachers have themselves the enumeration skills, and they know […] the difficulties related to enumeration" (p. 15, our translation).

This finding raises the question of appropriation by the teachers of such didactical situations, which we explore in this paper. We focus on the appropriation of a digital version of the above-mentioned situations specifically designed in order to overcome some of the drawbacks of its material version. In the next section, we present the digital version of the situation, explain the main design choices and provide a rationale for them.

4.2 Digital game for learning enumeration at kindergarten

Although the situations described above have a documented learning potential, they also have drawbacks, making their enactment in a classroom difficult. First, from the practical point of view, material conditions of the situations are often constraining as they require a large number of boxes and the preparation before class is time-consuming (arrange and/or paste the boxes according to a given configuration). From the pedagogical point of view, it is difficult for the teacher to personalize the spatial organization of the boxes and to observe, for each pupil, a strategy used to solve the problem. Finally, from the didactical point of view, a second collection (matchsticks) has to be used to embody the collection of enumerated boxes, which makes the situation significantly more complex (Briand 1999).

For these reasons, a digital game was designed and developed for 3–6 year old children to develop enumeration skills (Rousson 2015). The game is a variant of the "one stick in each matchbox" situation presented above (Sect. 4.1.2).

4.2.1 Design choices

A farm context was chosen enabling the integration of didactical variables and playful elements. Two *worlds* are designed, following the values of the variable V2 (movable or non-movable objects) thus fostering various enumeration strategies:

- in the "animal world",[3] the objects (animals) are movable, the expected strategies rely on creating two subcollections of objects already treated (fed animals) and objects not yet treated (animals to be fed) respectively;
- in the "plant world", the objects (plants) cannot be moved; the expected strategies consist in perceiving and following a path through the collection enabling the enumeration (watering the plants).

Within a given world, various *activities* are designed with increasing difficulty by varying values of some didactical variables, such as nature of the objects (identical or not); marking of objects having been treated (permanent or temporary); hint (on demand, marking of objects already treated appearing for a short while or automatic, after three successive failures, the objects appear overlapping, creating the need to move them apart). The levels of difficulty

[3] The "animal" world is the only one available in the prototype of the game.

Table 1 Activities in the "animal world" according to the values of didactical variables

	Marking	Number of objects	Nature of objects	Hints
Activity A	Permanent	3–20 animals	Different animals	None
Activity B	Temporary	3–16 animals	Different animals	On demand Real time
Activity C	Permanent	3–20 animals	Identical animals	None
Activity D	Temporary	3–16 animals	Identical animals	On demand Real time
Activity E	Temporary	3–16 animals	Identical animals	Real time

within an activity are related to the evolution of the values of the variable V1 (number of objects) in the course of the activity, each value of V1 determining a *round*.

The following table shows the activities defined by the values of some didactic variables (Table 1).

The game starts with a pre-activity aiming at helping the child to gain familiarity with it, and understand the context of the game, its functionalities and feedback. Each activity starts with three animals the player has to feed or water by providing each animal with food or water exactly once in a round. This is done by clicking on the animal. The system sends feedback in the form of food or a bowl of water in front of each animal that has been fed or watered. If the player succeeds the enumeration, i.e., each animal has been clicked on once and only once, the number of animals increases (multiplied by a given factor–1.5 approximately). If not, animals that have not been clicked or have been clicked more than once leave the farm, which makes the number of animals decrease. Such feedback is both meaningful with respect to the game and didactically sound as, in the course of the rounds, the number of animals changes (increases or decreases) according to the success or failure of the player who can thus reach the next level or get back to the previous one. When the player succeeds in enumerating 16 (or 20, according to the activity) animals, she gets a feedback (animals kissing the avatar) meaning both that the given level of the game (the activity) is won and that the player developed the enumeration skills expected in the class of situations defined by the given values of didactic variables. Indeed, the game was designed in a way to integrate playful and didactic principles such that winning the game would mean the development of the enumeration skills.

4.2.2 A priori analysis of the game: possible uses

We outline below the various ways the digital resource presented above can be used by teachers. We focus on instrumentalization processes and instrumental orchestrations that can be envisaged.

Possible instrumentalization of the resource

Because the resource is implemented within an authoring environment that does not allow easy customization, the values of didactic variables had to be set up by the designer. Therefore, the teachers using the resource cannot adapt these to their classroom context. They can however choose the pathway through the resource: they can either let the pupils follow the predefined path from activity A to activity E, or they can set up a path through the activities in any order.

The choice of functionalities that the teachers decide whether or not to present to pupils is also part of the instrumentalization process. Two main functionalities are implemented to provide help to pupils on demand: an "eraser" allowing the resetting of a round when the pupil realizes that she committed an error, and a "hint" displaying momentarily the objects that have already been enumerated. Given the age of pupils for whom the game is aimed, the teacher's intervention seems necessary in order for the pupils to get acquainted with and understand these functionalities.

Possible instrumental orchestrations

As we mentioned in Sect. 3.3, several types of instrumental orchestration have been identified in the literature, both for the whole-class setting and for individual or pair work. However, these orchestrations are relevant in particular in computer room lesson settings. Besnier (2016) identifies other types of orchestrations that she observes in kindergarten classes. Indeed, the specificities of this level of classes, such as prevalence of oral interactions, work in small groups, or presence of a teacher's assistant, require specific spatial and material organization of the classroom.

Moreover, the digital game under study is designed for touchscreen tablets in order to facilitate manipulations by kindergarten pupils aged 3–5.

Taking into account the specificities of the kindergarten teaching and the material conditions (six tablets available), we propose adaptations of the identified types of instrumental orchestrations, as well as a few new types that can be envisaged. The orchestrations are classified into two groups: orchestrations of collective work and those of individual or group work.

In the case of collective work, the main artefact is a central screen (tablet, computer or interactive whiteboard) visible to all pupils at the same time. Table 2 below shows possible instrumental orchestrations.

Table 2 Orchestrations of collective work

	Didactical configuration	Exploitation mode
Technical demo, DT	Pupils (whole class, group) sitting in front of a central screen (tablet, computer, IWB). They can have a tablet at their disposal to perform for themselves the actions shown by the teacher	The teacher explains technical details on how to use the tool
Explain the screen, EE	Pupils (whole class, group) sitting in front of a central screen (tablet, computer, IWB)	The teacher's explanations go beyond technical details and involve math content or game context. She can show a solution of a given task with the tool or expose one pupil's or one group's work
Link screen with other material, Le/s	Pupils (whole class, group) sitting in front of a central screen (tablet, computer, IWB). They see a screen and other material (textbook, blackboard, manipulatives…) simultaneously	The teacher establishes links between representations on the screen and representations of the same mathematics or game objects shown in the textbook, on the screen or with manipulatives
Discuss the screen, DE	Pupils (whole class, group) sitting in front of a central screen (tablet, computer, IWB). They are arranged in a way to see and hear each other while discussing	Whole class or group discussion led by the teacher about what is happening on the screen with the aim of assisting collective instrumental geneses of the pupils
Sherpa at work, ST	Pupils (whole class, group) sitting in front of a central screen (tablet, computer, IWB). The classroom is organized so that Sherpa (pupil or teacher) can use the technology and the other participants are able to follow Sherpa's actions	One pupil or the teacher manipulates the technology. S/he shows elements to discuss to the whole class or to a group. Sherpa is guided by another actor (pupils or teacher). According to who are the actors, three cases can be distinguished (below)
Sherpa-pupil, ST-Sel		One pupil manipulates the technology. She is guided by the teacher
Sherpa-teacher, ST-Sens		The teacher manipulates the technology. She is guided by another pupil or pupils
Sherpa-pair, ST-p		One pupil manipulates the technology. She is guided by another pupil or pupils

In the case of individual or group work, several didactical configurations can be considered according to pupils' and teacher's roles. The pupils within a group can have identical or different roles, such as actor, observer, adviser etc. The teacher can let the pupils work autonomously, or can provide more or less strong guidance. The possible orchestrations are summarized in Table 3 below.

According to Stylianides (2016), "[c]urricular resources include the different kinds of materials (digital or physical) that teachers use in or for their teaching (textbooks, lesson plans, etc.) and have a significant influence on students' opportunities to learn". Likewise, Remillard (2005) uses the term *curricular material* to refer to "resources designed for use by teachers and students during instruction" (p. 213). The game designed for the teaching and learning enumeration can thus be considered as a curricular resource that the teachers can use with their pupils.

4.3 Methodology

The game presented in the previous section was offered to a kindergarten teacher, named Tom, in order to observe how he implements it in his classroom and to analyse appropriation processes taking place in the course of the use of the resource.

4.3.1 Data gathering

A preliminary "portrait" interview was carried out with Tom aiming at establishing his portrait (see Sect. 4.4.1) in terms of his career as a teacher, university education and training, resource system for teaching mathematics, personal and/or professional use of digital tools etc.

From the pre-appropriation phase, Tom's lesson plans were collected and discussed during an interview before the sequence enactment in order to have access to his envisioned resource implementation in the classroom. The actual implementation took place over nine sessions that were observed and videotaped. Before and after each session, an interview was carried out to collect data about Tom's decisions related to the game enactment and their rationale. These interviews were audiotaped. After the last session of the game implementation, an interview was carried out aiming at drawing up a report of the game use in terms of the perceived pedagogical interest, impact on the pupils' enumeration performances, and evolution of Tom's own practices.

4.3.2 Data analysis

The analysis of the collected data corresponding to the sequence of the game enacted by Tom (Sect. 4.4), refers to the a priori analysis of the game and its possible uses

reported in Sect. 4.2.2, which guides the identification of the teacher's decisions. Searching for the factors underpinning these decisions leads to inferring the teacher's professional knowledge, following the TPACK model, from his lesson plans and the interviews, in particular those conducted after each classroom session.

In the attempt to identify instrumentalization and instrumentation processes related to the resource at stake, we looked for regularities in the teacher's decisions, especially regarding the choices of instrumental orchestrations.

4.4 Case study analysis: Tom's appropriation of the resource

In this section, we describe and analyze Tom's use of the game in his kindergarten class. We start by presenting Tom's portrait (Sect. 4.4.1), his pre-appropriation (Sect. 4.4.2) and original appropriation (Sect. 4.4.3) of the resource.

4.4.1 Tom's portrait

Tom is a young primary school teacher (5 years of experience, mostly in kindergarten), with a scientific background[4]. In his teaching, he attaches great importance to manipulation by the pupils. He often creates playful activities "so that they are attractive and fun" (excerpt from the interview with Tom). Tom's predominant class organization is working with half of the pupils, alternating the two groups during a day. The pupils regularly work in pairs and whole class discussions of the pupils' strategies and productions are common in Tom's class.

Regarding Tom's resources for mathematics teaching, these are relatively limited. The main resource is a CD-Rom[5] offering 23 learning situations with a detailed didactical analysis. Tom also uses two textbooks, one of which is an ERMEL[6] book. Digital resources are also part of Tom's resource system: he regularly uses Beneylu School,[7] an online digital environment for primary schools, applications for touchscreen tablets mostly for exercises and other curricular resources (e.g., eduscol).[8] Tom's school is equipped with iPad tablets that Tom uses regularly with his pupils, mostly for practicing acquired knowledge.

Regarding enumeration, Tom is aware of the importance of developing enumeration skills in pupils claiming: "enumeration skills are necessary for counting" (excerpt from an interview). He gives a clear definition of what enumeration is for him: "**Enumerate**. It is **taking into account once and only once each element** of the collection. Pupils have to organize themselves in order not to feed an already fed animal. This assumes that the pupil has taken over the control and inventory of three collections: (1) the initial collection of animals, (2) the animals fed, and (3) the animals to be fed". (excerpt from Tom's sequence plan).

For the teaching of enumeration, he uses the "one stick in each matchbox" situation (see Sect. 4.1.2).

4.4.2 Tom's pre-appropriation of the resource

The resource was presented to the teacher by a researcher who designed the game (second author of this paper). The teacher was given the prototype of the game and was asked to "play" with it during summer 2015 and plan a teaching sequence involving the game for the next school year. The teacher's sequence plan, sent to the researcher beforehand, was discussed with the latter during an interview taking place before the sequence implementation.

The analysis of Tom's sequence plan (Table 4) shows the first adaptations of the resource, residing in the choice of activities to include in the teaching sequence. Indeed, Tom decided not to propose the activities A and B, in which all animals are different, considering these activities as too simple for his pupils. Instead, he chose to start directly with the activity C that presents identical animals and provides the pupils with permanent marking of the enumerated elements. This choice relies on Tom's deep understanding of the game structure evidenced by a table he provided at the end of his sequence plan summarizing the analysis of the activities embedded in the game with regard to the evolution of didactic variables (number of animals, food permanently visible or not, initial position of animals—spread or overlapping, hint available or not…).

The orchestrations envisaged by Tom bear the marks of his usual management of didactic situations: first, the pupils work individually, and then in pairs with different roles within a pair: actor and observer, actor and observer-advisor, or first actor and second actor.

Tom's sequence is purely digital, with no other non-digital support used. From the pre-appropriation phase, Tom envisages adaptations of the game to his own use. He

[4] Tom obtained a "baccalauréat série scientifique", a high school diploma in a scientific programme.

[5] Briand et al. (2004). Apprentissages mathématiques en maternelle–Situations et analyses [Learning mathematics in kindergarten–situations and analyses]. CD-ROM Hatier Pédagogie.

[6] ERMEL (2005). Apprentissages numériques et résolution de problems-grande section [Learning numbers and solving problems–3rd year of kindergarten]. Hatier. The ERMEL collection is a series of books that results from many years of research on learning numbers, geometry and problem solving, carried out by a team of teachers and researchers in mathematics education.

[7] https://beneylu.com.

[8] http://eduscol.education.fr/.

Table 3 Orchestrations of individual or group work

Work and guide orchestration	Individual	Group work	
		Identical roles within the group	Different roles within the group
Guided use	Pupils work individually with technology. The teacher walks by, monitors their progress and guides them from technical, mathematical, and contextual points of view. The work pace can be free or imposed by the teacher (e.g., the pace of the slowest pupil) *TA-i-UA*	Pupils work in groups with technology. The teacher walks by, monitors their progress and guides them from technical, mathematical, and contextual points of view. The work pace can be free or imposed by the teacher *TA-gRi-UA*	Pupils work with technology in groups playing different roles (first actor/ second actor; actor/ silent observer; actor/adviser; actor/guide; emitter/ receiver) The teacher walks by, monitors their progress and guides them from technical, mathematical, and contextual points of view *TA-gRd-UA*
Guided use/autonomous use	Pupils performing well work individually in an autonomous way with the tool. The teacher passes by occasionally to observe their work. Pupils identified as needing help benefit from the teacher's guiding regarding mathematics, technicalities and context *TA-i-UA/Ua*	Groups performing well work individually in an autonomous way with the tool. The teacher passes by occasionally to observe their work. Groups identified as needing help benefit from the teacher's guiding regarding mathematics, technicalities and context *TA-gRi-UA/Ua*	Pupils work collectively with different roles. Pupils performing well work individually in an autonomous way with the tool. The teacher can pass by occasionally to observe their work. Pupils identified as needing help benefit from the teacher's guiding regarding mathematics, technicalities and context *TA-gRd-UA/Ua*
Assistance when needed	Pupils work individually with the tool. The teacher walks by, monitors their progress and provides hints when needed (e.g., at the pupil's demand) *TA-i-AL*	Pupils work in groups with technology. The teacher walks by, monitors their progress and provides hints when needed *TA-gRi-AL*	Pupils work with technology in groups playing different roles (first actor/ second actor; actor/ silent observer; actor/adviser; actor/guide; emitter/ receiver). The teacher walks by, monitors their progress and provides hints when needed (e.g., at the pupil's demand) *TA-gRd-AL*

Table 4 Elements from Tom's sequence plan

Session 1 Get familiarized with the situation and with the artefact	Action situation *Activity "Familiarization with the tablet"*	
Session 2 Elaborate enumeration strategies	Action situation Game* Activity C	
Session 3 Elaborate enumeration strategies	Action situation Game* Activity C *Simplification: Activity A*	
Session 4 Appropriate enumeration strategies	Action situation Game** Activity D *Simplification : Activity D bis or activities B and B bis*	
Session 5 Appropriate enumeration strategies Practice Start formulations own action	Action situation Game** Activity D	Pair: actor and observer-advisor
Session 6 Use enumeration strategies	Action situation Game*** Activity E	
Session 7 Use enumeration strategies Practice	Action situation Game*** Activity E	Pair: actor and observer
Session 8 Spread enumeration strategies: verbalize own action	Formulation situation Game*** Activity E	Pair : first actor and second actor
Session 9 Spread enumeration strategies: verbalize own action Practice and assess	Formulation situation Game*** Activity E	Pair: first actor and second actor

chooses the activities C, D and E, keeping the activities A and B, considered as simpler, for remediation. This is possible only thanks to Tom's in-depth knowledge of the game and the didactic choices in all activities.

It is worth noticing that, in his description of the sequence plan, Tom uses vocabulary specific to the didactics of mathematics (didactic variables, action and formulation situation, devolution). In addition, the planned enactment of the game follows the usual implementation of didactic situations (action situation, followed by formulation and validation situations), suggested for example in the ERMEL book that is part of Tom's resource system. These considerations show Tom's solid didactic knowledge (PCK). For the game enactment, Tom plans remedial activities, as well as work in pairs, elements he takes into account in his everyday teaching.

Tom's in-depth knowledge of the game is evidenced also by his noticing that a result table is generated at the end of each activity, displaying the pupils' achievements (success or failure, number of animals successfully enumerated, number of trials, number of resets, number of hint requests…). He plans to consult these tables to monitor his pupils' performances.

4.4.3 Tom's original appropriation of the resource

The game was enacted in Tom's class comprising 25 pupils (8 pupils are 4–5 years old and 17 are 5–6 years old). The pupils were separated into two groups, G1 and G2 of 12 and 13 pupils respectively. In each group, one sub-group of 6–7 pupils was working with the game on tablets, while the other sub-group worked autonomously. The two sub-groups alternated during the day. The other group was working with the classroom assistant.[9] It has to be noted that the choice to work with 6–7 pupils on tablets is due to the material constraints; indeed, only six tablets are available. Tom would prefer working as usual, with each half of the class, alternating during a day.

The teaching sequence comprised nine sessions, one session per week, which took place between November 2015 and January 2016. The first session was devoted to the devolution of the game: Tom introduced the context of the farm and explained the aim of the game: "learn how to take care of animals in a farm school". The pupils were asked to go through the pre-activity that aims at introducing the game environment. During the sessions 2–8, the pupils played the game, first individually and later in pairs. The last session 9 was devoted to the assessment via realizing a specific activity of the game that Tom asked the designer to develop.

Instrumentation/instrumentalization of the resource

[9] In France, there is a specialized helper in pre-school, present in all kindergarten classes, who helps the teacher with the classroom management and organization.

Recall that from the pre-appropriation phase, Tom decided to let the pupils go through the activities in the order suggested by the game designers, nevertheless, he skipped the activities A and B, the only two activities in which the animals are not identical.

During sessions 2 and 3, while the pupils were working on activities C and D (identical animals, permanent marking in C and help on demand in D), Tom observed that some pupils encountered difficulties with the enumeration, in particular in the activity D where the marking was not permanent any more. Tom realized that the pupils were not using the displacement strategy consisting in creating two sub-collections of treated objects and objects yet to be treated respectively. In order to make this strategy emerge, Tom decided to propose the activity D-bis. The "bis" activities are associated with all activities A–E and they were conceptualized by the designers as feedback sent to pupils after five successive failures in a given activity. Indeed, they propose configurations in which the objects to enumerate are overlapping; it is therefore necessary to move them in order to separate them and enable their enumeration. These activities thus favour displacement strategies. This choice is a striking example of Tom's instrumentalization of the game showing his ability to exploit the learning potential of the activities, which he understands remarkably well, to achieve his educational goal. Another example of Tom's instrumentalization of the resource is the development of two specific activities, activity F and assessment activity, on his demand and according to his specifications. Indeed, two activities were added to the game prototype during Tom's enactment: the activity F in which three rounds are proposed, each starting with eight identical animals, and the assessment activity proposing to enumerate, with no hint available, 14 identical animals in three successive rounds, each with animals of a different kind.

In order to monitor the pupils' progress, Tom was looking for a means to keep track of their performance. He started by noting, at the end of a session, the number of the last page on which each pupil arrived. Later, he realized that the tablet enables the taking of pictures of the screen, which opened to him a new way of gathering data related to the pupils' activity (instrumentation) that he exploited in order to be able to adapt the follow-up activities to the pupils' capabilities.

Tom's professional knowledge certainly underpins this choice, in particular his knowledge of the mathematical content at stake (enumeration-CK) and the related didactic knowledge (enumeration strategies-PCK: "displacement, make two collections, this is when it is movable; then non movable, it is elaborate paths, there can be various types of paths, either a bit arbitrary, or horizontal, vertical… marking, marking the object to indicate that it has been taken into account"—excerpt of the interview with Tom).

We can suppose that Tom's didactical knowledge (e.g., values of didactical variables and their effects on the learning situation, formative assessment-PCK) was an important factor of his appropriation of the resource, enabling him to analyse it thoroughly, understand its learning potential and thus make relevant choices when using it in his class.

Instrumental orchestrations

Regarding the instrumental orchestrations, in the first five sessions, as well as in the last two, we observe the alternation of the following:

1. collective configurations, with "technical demo-DT", "discuss the screen-DE/ discuss without support-DSS"[10] or "explain the screen-EE/explain without support-ESS" orchestrations, aiming at recalling the work of the previous session and devolving the activity to be done,
2. individual work with "assistance when needed-TA-i-AL" or "guided use/ autonomous use-TA-i-UA/ Ua" orchestrations, and
3. whole group discussions with "discuss the screen—DE/discuss without support-DSS" and "Sherpa at work-ST" orchestrations to allow the pupils to show their productions and collectively discuss their validity and efficiency (see Table 5). In sessions 6 and 7, instead of working individually, the pupils worked in pairs with different roles: while one of the pupils was working on the given activity, the other played the role of observer-advisor, helping her classmate.

It is worth noticing that these orchestrations correspond to Tom's practices, showing the importance attached to collective work (sharing and discussing pupils' strategies by using "Sherpa at work" orchestrations), as well as to a specific modality of pair work where the pupils play different roles (e.g., actor and observer–advisor) used by Tom to manage the class heterogeneity by organizing mutual assistance between pupils. We can consider that these practices are underpinned by Tom's professional knowledge related to the organization of the group work: alternating collective and individual work, group work with specific roles assigned to pupils, whole group discussions, and teacher's interventions (PK).

On the other hand, the orchestrations observed in the game-based sequence show a difference in didactic configurations comparing to the orchestrations Tom used before.

[10] This orchestration was not expected in our a priori analysis. It is characterized by a didactical configuration in which pupils (whole class, group) are arranged in such a way that they can see and hear each other while discussing, and a mode of exploitation corresponding to whole class or group discussion led by the teacher about a particular aspect related to the game.

Table 5 Tom's instrumental orchestrations in the game enactment

	Devolution	Pupils' work	Whole group discussion
Session 1	ESS, DT	TA-i-AL	DSS
Session 2	DSS, DE, ESS-EE, DT	TA-i-AL	DSS, DE
Session 3	DSS	TA-i-UA, TA-i-UA/Ua	DSS, ST-Sel
Session 4	DSS	TA-i-AL, ST-Sel/DE	ST-Sens, ST-Sel
Session 5	DE - ST-Sens, ESS	TA-i-AL, DE	DE
Session 6	DSS, ST-Sens	TA-gRd-AL	DSS
Session 7	DSS	TA-gRd-AL	DSS
Session 8	DSS	TA-i-AL	DSS
Session 9	EE	TA-i-AL	EE—ESS

Indeed, he used tablets regularly to allow pupils to practice newly acquired knowledge, in which case the pupils were scattered in the class and worked individually. Because the game was used to teach new knowledge, Tom wished to have all pupils close to him to be able to monitor their work. For this reason, he tried out various configurations before adopting the one that he eventually adopted for the individual pupils' work (Fig. 5): pupils' tables grouped together allowing "a quick intervention and a close teacher's observation" (excerpt from Tom's presentation of his use of the resource during a workshop).

This is a striking example of the development of utilization schemes by Tom while using the resource (instrumentation).

5 Conclusion

Our aim was to question the concept of appropriation of a resource by a teacher, given that this term is often used by researchers, however in a rather common sense. Drawing on conceptualizations of the appropriation in social and management sciences, as well as on theoretical frames used in mathematics education, we proposed a model of the resource appropriation process. We reported on a case study of a teacher using a digital game for teaching and learning enumeration in kindergarten to test the model. We thus explored the following research questions:

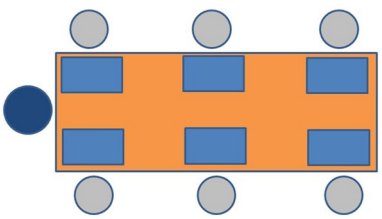

Fig. 5 Didactic configuration adopted by Tom for pupils' individual work

- To what extent do the instrumentation and instrumentalization processes characterize the appropriation of a resource by teachers?
- How are the instrumental orchestrations chosen by the teachers related to the resource appropriation?
- How does the teacher's professional knowledge intervene in the appropriation of a resource by a teacher?

With respect to the first two questions, it appears that the appropriation of a resource requires flexibility, allowing the processes of instrumentalization to occur. Indeed, in Tom's case, the possibility of deciding the order of the activities and especially the possibility of proposing a specific activity fostering a strategy corresponding to Tom's educational goal was critical for the resource appropriation by Tom. On the other hand, the resource appropriation contributes to the professional development of the teacher. In our case study, the nature of the resource (a game with activities of increasing difficulty, requiring an enactment over several sessions) led the teacher to think of continuous formative assessment in order to monitor the pupils' progress, look for the most suitable instrumental orchestrations, and adapt his teaching intervention.

Regarding the third research question, it seems that solid mathematical and didactical knowledge (PCK) related to the mathematical content at stake in the resource was of foremost importance in the teacher appropriation process. Indeed, this knowledge appeared as a key to the understanding of the design choices and the resulting learning potential of the resource gained in the pre-appropriation phase, enabling the teacher to take appropriate decisions. This finding suggests that the pre-appropriation of a resource is a predictor for the original appropriation.

In this paper we reported a unique case study that seems to suggest that the proposed model is operational for analyzing the processes of appropriation of a new resource by a teacher. Further research is still necessary to confirm these preliminary results by considering cases of teachers with different profiles (non-scientific background, more distanced relationship with digital technologies…) and

resources with different characteristics. Also, new questions arise: is the appropriation of a resource impacted only by the teachers' professional knowledge, or are there elements of the resource itself that facilitate its appropriation? Is it possible to define levels or degrees of appropriation of a resource? These questions open new avenues for research on teachers' appropriation and use of curricular resources.

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