OCINAEE

Objets connectés et interfaces numériques pour l'apprentissage à l'école élémentaire

LIVRABLE Tâche 6.2

ARTICLES ET COMMUNICATIONS SCIENTIFIQUES SPECIALISES

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1 Introduction

OCINAEE est un projet qui allie les secteurs de la recherche et de l'industrie et dont le produit, est à destination des enseignants et leurs élèves, Ce livrable présente ici la valorisation d'un point de vue scientifique d'une partie de nos travaux. Le dispositif OCINAEE faisant émerger des questions au croisement des mathématiques, de la robotique et des IHM, nous avons choisi de diffuser notre travail dans l'ensemble de ces communautés.

	Type de communications	Public
RIE 2016	Communication orale avec actes publiés	Chercheurs en robotique et en éducation
COPIRELEM 2016	Communication orale sans actes publiés	Professeurs et Chercheurs en mathématiques et didactiques des mathématiques
ICME 2016	Communication orale sans actes publiés	Chercheurs en didactique
IHM 2016	Communication orale sans actes publiés	Chercheurs autour des IHM

2 Article et communication scientifiques avec actes publiés

2.1 RIE — Robotic In Education

Une conférence a été donnée à Vienne (Autriche) en Avril 2016 dans le cadre de la conférence internationale annuelle Robotic in education (RIE). RIE rassemble majoritairement des chercheurs mais aussi quelques industriels. Son objectif est de présenter des méthodes et des résultats de recherche dans le domaine de la robotique éducationnelle.

Elle a permis de présenter une expérimentation menée auprès d'élèves de CP et CE1 dans le cadre du projet OCINAEE. Cette expérimentation recourait au jeu du Nombre Cible dans sa version cartes et a notamment permis de mettre en évidence des stratégies différentes des élèves dans la résolution de problèmes mathématiques tout comme un positionnement différent vis-à-vis du robot qui retourne les feedback sur la validité des réponses.

Lien vers la conférence : http://rie2016.info/

Références à citer : Mandin, S, De Simone, M, & Soury-Lavergne, S. (2016). Robot Moves as Tangible Feedback in a Mathematical Game at Primary School. In M. Merdan, W. Lepuschitz, G. Koppensteiner & R. Balogh (Eds). *Advances in Intelligent Systems and Computing: Vol. 457. Robotics in Education: Research and Practices for Robotics in STEM Education* (pp 245-257). From : http://link.springer.com/book/10.1007/978-3-319-42975-5/page/1.

Actes soumis à la conférence :

Robot moves as tangible feedback in a mathematical game at primary school

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Abstract. We study how elementary school pupils give sense to the moves of a mobile robot in a mathematical game. The game consists in choosing 3 numbers out of 6, whose sum is a given target number. The robot moves on a game board have been implemented to provide pupils with a tangible feedback about their answer. We have studied strategies of pupils to solve the problem and their evolution. Our methodology included interviews, aloud verbalization and video observations of 28 pupils in grade 1 and 2 while they are playing. The pursuit of a mastery goal encourages a trial and error strategy for only some of the pupils. We conclude that some aspects of the moves of the robot, like its position, are perceived as a form of help and not as a threat, even if they are only partially understood.

Keywords: robot, tangible feedback, learning, solving strategy, mathematics

1 Introduction

The OCINAEE project[1] – Connected Objects and Digital Interfaces for Learning at Primary School – aims to explore and design mathematics learning situations with a system of connected objects. The system is a set of interacting devices either concrete like cards or a game board, or digital, like a smartphone. Connection between the two classes of objects is implemented by a mobile robot that can read some tangible objects such as playing cards or any specific printed material. In this project, we develop several games, which address mathematics for pupils from grade 1 to 6.

Our research deals with the interface of such a complex system of tangible and digital objects including a robot: how are users taking action on the system? How does the system provide feedback to the user? What should the designers choose? How do users understand the feedback? We study specifically actions and feedback of OCINAEE system in the tangible world, which are different from actions and feedback on a computer screen. Tangible objects like a set of cards and a robot moving on a board may be means of action and feedback.

[1] Funded by the French Bank for Public Investments, it is a partnership between two companies, digiSchool and Awabot, and two public institutions, Erasme and the French Institute of Education.

Our theoretical framework crosses cognitive psychology and mathematical education, while mainly referring to objects that belong to computer sciences. After a presentation of this theoretical framework, which has framed the design of our games and the experiment we present here, we will describe the OCINAEE system for one of the games and the study of how the implemented feedback is understood by 28 French pupils in grade 1 and grade 2.

2 Theoretical Framework

2.1 Handling and tangible devices

The physical handling of concepts promotes the children's learning including the transfer of learning [1]. Many research works in education, psychology or specific to mathematics education have shown that mathematical concepts are bodily embedded and concepts are developed on tangible and physical manipulations [2,3]. Concreteness is also used as a way to produce tangible feedback in the theory of didactical situations in mathematics [4].

Also, new interfaces have to be figured out as « *cognitive tools for promoting thinking and adaptive learning, rather than only emphasizing technology for interpersonal communication* » [5] (p. 25). But tangible and connected objects allow to link physical and virtual worlds. Therefore, in a learning perspective, we want to study their possible uses and the actions, manipulations and feedback they create.

Tangible interfaces can be described as objects handled by users and used to control a computer [6]. Using such interfaces in a learning situation, like a pedagogical game supports learning in different ways. Involvement of the pupils in the learning process is improved. Africano *et al.* [7] and later Kubicki *et al.* [8] have shown that tangibility through interactive tables allows to increase the active handling time of the concepts and a simultaneous activity and collaboration among pupils. Nevertheless, involvement is necessary but not enough to provoke learning. Tangible feedback provides information about mathematical solving strategy of the pupils. According to Brousseau's theory of didactical situations [4], learning situations are modeled by a game in which the possibility of different choices of actions for the player and appropriate material feedback are conditions for learning to occur. Moreover, pupils have to know by themselves if they have succeeded or not in solving the problem, independently from an external evaluation. Actions and feedback of the tangible world offer additional system of representations for mathematical concepts. According to Vergnaud [9] then Balacheff [10], mathematical concepts and knowledge are defined by a set of elements among which a semiotic system of linguistics and symbolic representations. Balacheff *"emphasis the importance of the manipulation of representation systems"* [10] (p. 8). Learning develops when using and translating from one system to another, including tangible experience. Sylla *et al.* [11] use cards with some chosen representations of concepts in their *Tangible interface for storytelling*. They are images to combine in order to create stories. Tangible cards support pupils in developing meaningful stories by easily changing their sequence.

Tangible objects and concrete phenomena may be used to drive the virtual system. Feedback concerns the reaction of the system toward the user. It is usually virtual, on the screen of a computer. Now with a mobile robot, the virtual system may drive the behavior of a concrete object and therefore produce tangible feedback. In the OCINAEE system, we have implemented a tangible feedback, which consists in the moves and the positions of a robot on a game board. It belongs to the concrete world and may translate some mathematical properties into a physical behavior. We want to study how learners interpret and give sense, a mathematical sense if any, to the tangible feedback of the robot.

2.2 Feedback

As anticipated above, we are interested in analyzing the feedback of the system on pupils. In general, we will refer to the term *feedback* as a return from action. We will introduce studies concerning feedback in different research fields. In particular, on the one hand, we consider feedback as "metacognitive" feedback and, on the other hand, as "didactical" feedback more focused on the mathematical task.

In research about games in general, integrated feedback is studied by Salen and Zimmerman [12]. For a meaningful game, users have to perceive feedback and consequences of their choices and actions on the game. Moreover, to improve players' experiences, Sweetser and Wyeth [13] highlight the importance of immediate feedback about the progression toward the goal of the game, for instance by making the score always accessible.

From a cognitive point of view and in a learning context, feedback aims to allow the learners to focus on the gap between their performance and the goals to reach [14,15] by providing information on the accuracy of the answer or clues to reach the goals [16].

Noury *et al.* [17] link feedback and help, considering different types of feedback as helps. They highlight the relations between self-fulfillment, metacognitive judgment and nature of the helps used by learners. They distinguish between two types of helps: the instrumental helps providing clues to learners and the executive helps providing the answers. In their experiment, undergraduate students have used both types of helps after an error feedback, especially when they were following a mastery goal. However, learners use less instrumental help when they perceive it as a threat to their need for autonomy. They also avoid the executive help when they perceive it as a threat to their skills revealing their incompetence (performance-avoidance goals). There is no observed effects of the students' desire to demonstrate their skills (performance-approach goal) on the use of the helps. With OCINAEE, the moves of the robot can help pupils by showing the gap between their answer and the expected one. Thus the robot moves could be qualified as instrumental help. However, if this help is a necessary step to move on with the game and if it is not available on demand as in the experiment of Noury *et al.* [17] it can be perceived as a threat.

Rodet [18] distinguishes between cognitive feedback whose aim is the assessment of a work (taking into account the final result or the learner's approach), metacognitive feedback on cognitive processes of learners (in order to encourage to a personal reflection) and methodology feedback concerning appropriate strategies in order to improve later uses. These types of feedback are related to the actions, the cognitive processes and the knowledge of learners. Two types of feedback in Rodet's approach [18] are in line with a more didactical point of view. Didactical feedback is a response of the system that has some meaning from the learners' point of view in relation to the knowledge at stake [4]. Mackrell, Maschietto and Soury-Lavergne [19] distinguish between evaluation feedback in response to the achievement of the task and its success or failure and strategy feedback in response to a strategy of resolution in order to support evolutions of the strategy, therefore learning. Moreover, they highlight direct manipulation feedback as any immediate environment answer to the action of users. The two former types of feedback are built starting from the last one. From a didactical point of view, the design of feedback does not rely on knowledge about the learner as an individual, but rather on the components of the tasks and the knowledge involved in the solving strategies.

3 Description of the game

We describe the implementation of the target number game with the OCINAEE system of devices, first by presenting the tangibles and virtual objects, then the scenario of the game, finally the design of feedback.

The target number is a problem solving situation which consists in choosing three numbers out of six, whose sum is a given target number. The target number is automatically chosen by the system, displayed on a smartphone. The six possible numbers are printed on six playing cards. The player has to choose three cards among the six and to submit them to the system. A game is played in 6 untimed rounds, by a single player or a group.

Fig. 1. The target number game devices and an example of a 6 card set (the purple one). To the right, submission of a card to the robot.

The kit includes the following devices (see **Fig. 1**): a robot with a smartphone, a game board with a picture on which the robot moves, and 39 playing cards.

Technically, two sensors placed under the robot allow to scan any code on the game board and on the cards (the code is not visible by eye). At any time, the system knows the robot location and can determine its trajectory and positions. The robot eyes light up in different colors. The cards are grouped in 6 sets of 6 cards. Each card presents a number and each set of cards is associated with a color. When users select a card and want to submit it to the system, they scan it under the robot (see **Fig. 1**, right). Three other cards are available to "validate" the scanned cards, to "cancel" the scan of all the cards and to "listen" to the target number. The picture of the game board represents a landscape with five characters aligned on the skyline. They materialized different final positions of the robot.

Colors of the cards	Number written on the cards					
Dark blue	1	2	3	4	5	6
Purple	2	4	6	7	8	9
Green	1	2	3	4	10	15
Red	2	3	5	8	16	17
Light blue	1	3	5	10	20	30
Yellow	1	3	6	10	40	50

Fig. 2. Numbers on each of the six sets of cards

At the beginning of the game, once pupils have placed the robot on the game board, the system displays a target number on the smartphone with a colored background. This indicates the color of the set of cards to use (see **Fig. 2**). Pupils have to select and scan three cards whose sum has to be equal to the target number. The robot eyes light up each time a card is scanned: in white for a correct scan and in red in case of a card of the wrong color or twice the same card. There is no immediate feedback if the number of cards is not three.

Then, pupils have to submit the "validate" card to get an evaluation from the system. Hence, the system computes the sum of the numbers on the chosen cards. According to this sum, the robot moves to one of the different characters on the game board. The robot final position is: (i) on the marmot when the sum is lower and far from the target number, (ii) on the sheep when it is lower but close to the target number, (iii) on the shed when it is equal to the target number (success), (iv) on the snowman when it is above and close to the target and (v) on the yeti when the sum is above and far from the target. The characters are aligned to mediate the number line.

Additional feedback is implemented. The smartphone displays a congratulation message or messages telling the pupils that their sum is too small or too big or that they have scanned a wrong number of cards (different from 3). In case of errors, pupils have two other attempts to try again. The robot finally performs a "dance" when pupils have succeeded in all of the six rounds of the game.

4 Research questions

We are going to study tangible feedback through its effect on pupils' solving strategies and through the way pupils transform it into a possible help. The tangible feedback in

OCINAEE system is constituted by a robot, which moves and reaches a final position on the game board.

Our question concerns the perception and exploitation of this tangible feedback by pupils. It has been designed as an evaluation feedback produced when requested. Does the position of the robot inform pupils about the validity of their answer and does this feedback have consequences on pupils' solving strategies? In other words, we wonder if a tangible feedback may be an evaluation and/or a strategy feedback.

Moreover, pupils can consider feedback as possible helps. But according to the kinds of goal they are following, mastery and/or self-fulfillment, they may consider instrumental help as a threat to autonomy, therefore ignoring the feedback. Consequently, in our observations, we are going to identify pupils' goal and their perception of threat through the feedback.

5 Methodology: participants and experimental setting

To answer the research questions above, we have conducted an exploratory study with some of the pupils of the 35 teachers involved in the OCINAEE project. The OCINAEE project concerns 39 classes from grade 1 to 6 in 14 schools and 4 junior high schools. Ongoing studies concerning all the classes will also drive us in the improvement of the games and the robot moves as feedback. As we are interested in mathematical skills of the curriculum of the early classes, we limit our study to pupils in grades 1 and 2. The 28 pupils of the experiment come from 5 different classes, 8 pupils belong to 2 grade 1 classes and 20 pupils belong to 3 grade 2 classes. The observations were held during three weeks around Christmas holidays. To minimize the effect of isolating one pupil at a time, we have observed pairs of pupils, which indeed is the usual configuration chosen by teachers when they use the game in their class. In each class, pupils have been randomly selected two by two and extracted from the classroom for about one hour corresponding to the duration of the different steps of the experiment. These pupils have already played with other versions of OCINAEE games, under the supervision of their teachers. They have also played the target number game, but without any moves of the robot. These teaching sequences could not be controlled. However it has no consequences on our experiment, because the pupils use the dynamic version of the game for the first time.

The experimental setting consists in four steps: think-aloud training, interview before playing framed by a short questionnaire, play, interview after playing framed by a long questionnaire. The questionnaires have a total of 19 questions (6 open-ended and 13 close-ended questions with requests for explanations sometimes). Some questions aim only to open dialogue or allow pupils to recall the play (e.g., *Have you played to target number before? Did you see the robot move?)*. Other questions propose some choices to help the children to answer (e.g., *When you were playing, you would: 1) like to show that you are doing well? 2) avoid showing you can make errors 3) improve yourself in calculations?*)

Think aloud was a mean to perceive the pupils' strategies during the play. It has been used in many areas, like to identify processes involved in the understanding of a text

[20], the writing process [21] or mathematical problems solving [22]. It is not an easy task for young pupils. To make them more comfortable, we trained them with 2 exercises that we assumed to be familiar. The first is an individual exercise of continuation of a necklace in accordance with a color code. The second is a game of noughts and crosses. It is a strategic exercise, which requires to alternate the speaking times. Throughout training, when pupils were not verbalizing aloud their thoughts, the researcher was fostering it with questions (e.g., *what are you doing? Where do you put your cross? Why?*). The training lasted approximately 15 minutes.

The first interview aims to catch how pupils understand the game board and the dynamic version of the game when they discover it for the first time. In particular, we have asked the pupils to comment on the usefulness of the characters, including the shed, on the game board. Just after the first interview and before the play, a short explanation of the breakpoints has been provided to the pupils by the researcher.

At the beginning of the game, pupils have selected the range of the target numbers (number target up to 20, 40 or 100). However the difficulty of the game doesn't lie in the size of the target number but in some features of the solution, like the possibility or not to find two cards whose sum is a multiple ten or the presence of distractive cards. During the play, we have videotaped the pupils. In the analysis, we focus on the handling of the playing cards and their thinking aloud. Despite the think aloud training, we have anticipated two risks. A first risk is the simultaneous recording of two pupils' voices and therefore difficulty to understand their talk afterwards. A second risk is that despite training, thinking aloud remains difficult for young pupils. We therefore carried out a combined analysis focusing on both their speech and their actions. All data have been manually analyzed according to our theoretical framework.

The after game interview is more complete. It allows to compare the pupils' declaration to their actual achievement during play. We analyze the self-fulfillment of the pupils (mastery *vs* performance goals) and their representation and exploitation of the robot moves on the game board. The after game interview was administered to 25 of the 28 pupils observed (it was not possible to run the interview with 3 pupils).

6 Results

The results focus on the interpretation of the game board by the pupils, their involvement during the game and the evolution of their solving strategies.

6.1 Interpretation of the game board and the moves of the robot

The answers of the pupils to the first interview show that the positions represented by the different characters on the game board have a meaning within the task only for grade 2 pupils.

In grade 1, 2 out of 8 pupils separate the game board in two opposite team sides and identify the different spots as symbolizing a failure or a success for each team. The other pupils propose purely fictional explanations. 8 out of 20 grade 2 pupils interpret these characters as positions of the robot, meaning that the sum of the numbers is too big or too small with respect to the target number. Among them, 4 pupils perceive a shorter and more rarely a longer distance to target number when the robot stops on the Yeti, and 3 pupils correctly interpret the positions represented by the characters. One grade 2 pupil reacts as grade 1 pupils above-mentioned, the others do not give any explanation.

The most frequent explanation of the aligned positions of the characters is the facilitation of the robot move (6 pupils out of 28). This justification highlights the focus of the pupils on the robot. But 4 pupils in grade 2 mention that characters are sorted in ascending order according to the sum of the chosen numbers. This can be analyzed as an initial mathematical interpretation going toward the concept of number line. The others were undecided or gave off topic answers.

After the play, pupils still have misconceptions of the game board, with a better interpretation in grade 2. The absence of materialization of the starting area led to a confusion with the first position of the robot represented by the marmot (6 pupils out of 25). The shed is the best understood character (19 pupils out of 25) compared to the other four spots (correctly interpreted by 13 to 16 pupils out of 25).

6.2 Involvement and goals of pupils during the play

As shown in **Fig. 3**, interviews after playing reveal that 4 out of 6 grade 1 pupils try to progress (approach performance goal) while 13 out of 19 grade 2 pupils try to improve their skills in computing (mastery goal) and only 3 grade 2 pupils pursue a performance-avoidance goal. Their main goal is avoiding errors. This may explain why they wrongly answer the question about their success at first attempt (one of them wrongly read the target number and found a correct sum according to the targeted number). Indeed, none of the grade 1 pupils were pursuing performance-avoidance goal and they all answered correctly the same question.

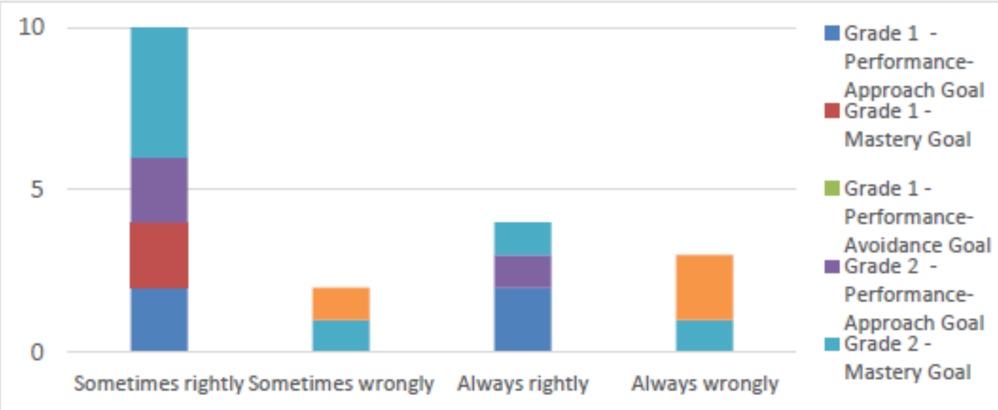

Fig. 3. Distribution of pupils according to their answer to the question of achievement (*have you found the answer at the first attempt always/sometimes or never?*) in comparison with their achievement observed in the game (*rightly* if the answer corresponds to the observation else *wrongly*) and their goals of self-fulfillment.

6.3 "Trial and error" or "compute and check" strategies

Pupils explaining what they do in order to play mainly refer to their mental processes: count, search, think (4 grade 1 and 16 grade 2 pupils). Scanning the cards is also frequently mentioned (2 grade 1 and 5 grade 2 pupils). They rarely mentioned the testing of a combination of cards (1 pupil only at each grade). These declarations are consistent with the observed behaviors during the play. Videos allowed us to count the number of pupils showing a trial and error strategy. These pupils do not anticipate the sum of their combination of cards but first submit the cards to the robot to get its feedback. We call them "testers". We oppose this strategy to a compute and check strategy. In this case, pupils add the numbers on the cards before scanning them, they are "checkers". There are more "testers" than we presupposed according to the pupils' answers in the interview (7 pupils out of 25) but they are much fewer than the "checkers" (16 pupils out of 25). Moreover, the "trial and error' strategy has been often triggered by the experimenter to help some pupils facing difficulties and hesitations. The "testers" also seem to be mostly pupils pursuing a mastery goal (5 "testers" out of 7) while the "checkers" are better distributed between the different goals of self-fulfillment (9 "checkers" pursue a mastery goal out of 16).

6.4 Effects of the robot moves as feedback on the pupils' strategies

In case of successive trials, it is expected that the robot moves have consequences on the evolution of strategies like the new selection of playing cards.

But, according to the interview after play, less than half of pupils speaks of the robot moves (8 out of 19 pupils, see **Fig. 4**). Five of them mention the moves for checking if their sum of numbers is too small or too large or right or wrong. The other 3 pupils do not bring precision. Indeed, as we see below, pupils modify their combinations of cards according to the overshoot of the target number rather than to the distance between their sum and the target number. Among the 11 pupils who do not claim to have used the robot, 7 pupils do not understand the meaning and therefore the usefulness of the robot positions and moves. Only two pupils give a reason for not using them while they correctly understand them. Both pupils claim they want to succeed by themselves. Thus, the robot move is not generally perceived as a threat neither on need for autonomy nor on skills.

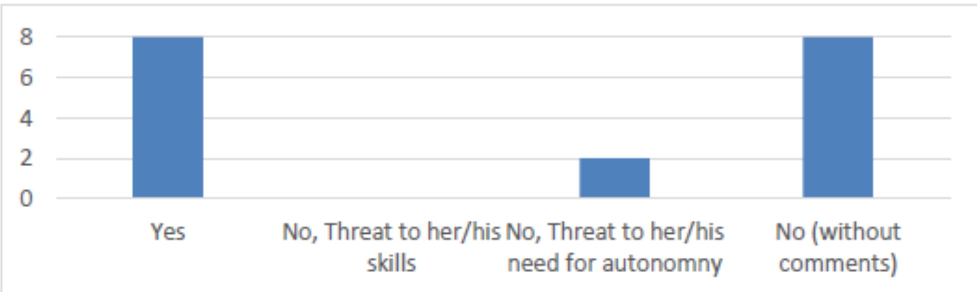

Fig. 4. Distribution of pupils according to the perception of the moves of robot

The effect of robot feedback on strategies evolution is not direct. Among the 21 pupils who had another trial after errors (not due to a bug, a wrong number of playing cards or scanning the same card twice), 10 pupils affirm they start again from their previous combination by changing one or two cards sometimes or often (3 grade 1 pupils and 7 grade 2). For them, the robot moves work as a strategy feedback. The other pupils start again as with a new target number. However, in the 25 second or third attempts concerning 10 pairs of pupils, 18 combinations involve the change of only one card. In 11 of these trials, the new card replaces the smallest card of the previous combination (see **Fig. 5**). The number of cards that are modified between two attempts seems very strongly linked to the sum, smaller or bigger than the target number. If the sum exceeds the target number, pupils usually change two playing cards (3 cases out of 7). With a sum smaller that the target number, pupils change only one playing card (14 out of 18), usually the smallest (10 out of 14).

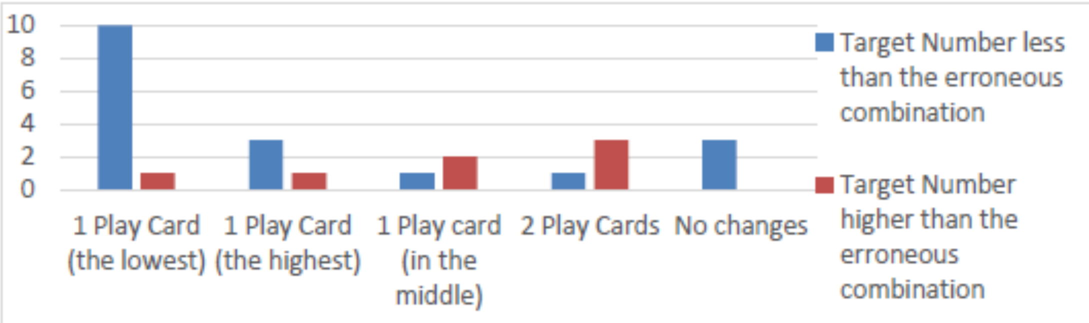

Fig. 5. Distribution of changes of cards according to the value of the previous combination

These observations show that these pupils seem guided by a strategy that leads them to exceed the target number and then get closer by changing the smallest card as if it would "go down" more gradually. The game as a whole allows to highlight the strategies and foster their evolution. But, for the moment there is no evidence that strategies evolve towards more efficient ones.

7 Conclusion

In this paper, we have described an experiment which aimed to highlight the interpretation and exploitation of a robot moves on a game board as tangible feedback by grade 1 and grade 2 pupils. The target number game is played with cards that has to be scanned under a robot. According to the sum of the numbers printed on the cards, the robot moves to a position, indicating the distance between the sum and the target.

We have noted several differences between the pupils according to their grade. First, the game board is designed so as to mediate the number line. However the meaning of the picture and the aligned position of the characters are not understood by all pupils, especially the pupils in grade 1. They do not make connections between the game board and the mathematical concepts involved in the game. Second, it concerns the goals of self-fulfillment. The grade 1 pupils want to demonstrate their skills (performance-approach goal) while most of the grade 2 pupils want to improve them (mastery goal) and only some of them want to avoid showing they may make errors (performance-avoidance goal). These different goals of self-fulfillment appear to influence the pupil strategies in the way they use the robot. Some of them test their combinations of cards without anticipation whereas others scan their cards only once they are sure of their sum. Most of the "testers" pursue a mastery goal as if they were aware that the robot may supports the evolution of their strategies. Nevertheless, it remains interesting that the help provided by the robot moves is not perceived as a threat. Therefore, we can assume that most of the pupils have not ignored the tangible feedback of the system. Finally, tangible feedback is an evaluation feedback for about three quarter of the pupils. The others rely on the message on the smartphone instead of the robot position to evaluate their answer. Also tangible feedback is a strategy feedback for only about half of the pupils, the ones who modify their strategy according to the robot moves. This is not surprising because many of them have not understood the meaning of the robot positions except for the shed. Didactically, it is also interesting to observe that pupils modify their invalid combination according to how it exceeds the target number and not according to its distance to the target number. If the sum exceeds the target number, only the lowest number is changed, otherwise two cards are most often replaced. This strategy isn't the most efficient one and asks for further adaptations of the game and its feedback.

Actually, the evolution of pupils' strategies could also be obtained by a personalization of the learning situation, based on a learner profile [23]. In our game, for pupils using a strategy based on considering if the sum is just exceeding the target number instead of considering the distance between the sum and the target number, the system should provide new target numbers that make pupils aware of the limitation of their previous strategy.

This study is interesting to frame research about how concrete objects and phenomena produce tangible and immediate feedback and it has to be continued in order to study long-term evolution of pupils' strategies.

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3 Articles et communications scientifiques sans actes publiés

3.1 Colloque annuel de la COPIRELEM

Le colloque national de la COPIRELEM, pour des professeurs et formateurs de mathématiques du premier degré, s'est tenu du 14 au 16 juin 2016 au Puy-en-Velay. Il est ouvert aux chercheurs en didactique ou en sciences de l'éducation mais aussi aux formateurs des ESPE et IREM, inspecteurs et conseillers pédagogiques. L'accent a été mis cette année sur les nouveaux programmes scolaires, l'interdisciplinarité et l'évolution de la formation professorale.
Différents ateliers ont été organisés. OCINAEE a fait l'objet de l'un d'entre eux (atelier A26). L'objectif était de mener les auditeurs à une analyse didactique des situations d'apprentissage créée par l'utilisation des jeux OCINAEE

Compte rendu scientifique du séminaire : http://www.copirelem.free.fr/presentation.php

Référence à citer : Rabatel, J.-P., & Soury-Lavergne, S. (2016). *Faire des mathématiques avec des cartes et un robot, le projet OCINAEE*. 43^{e} Colloque COPIRELEM. Atelier A26. 14-16 juin 2016, Puy-en-Velay.

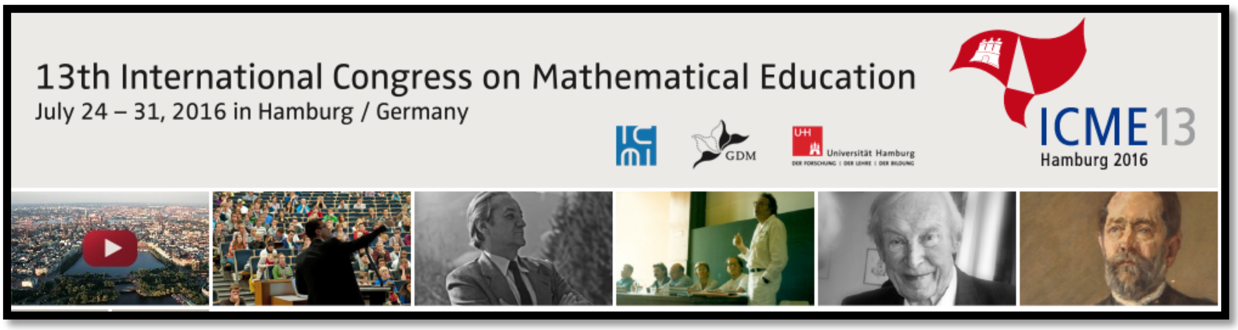
Résumé de l'atelier : http://www.copirelem.free.fr/ateliers_A2.php#A26

Résumé :
Le projet OCINAÉÉ, http://ocinaee.blogs.laclasse.com/ est mené par 4 partenaires : 2 PME de la région lyonnaise, Kreactive–digiSchool et Awabot, Erasme, le living Lab de la Métropole de Lyon et l'ENS–IFÉ organisme de recherche public (De Simone et al. 2016). Le projet conçoit plusieurs jeux mathématiques dans les domaines du calcul, de la numération et du repérage des positions et des déplacements dans le plan. Chaque jeu propose différents menus qui s'adressent à tous les élèves des cycles 2 et 3, du CP à la 6e sans indication de niveau.
Une première question traitée par le projet est celle de la génération des parties de jeu, nécessitant en particulier d'en caractériser la difficulté. Une analyse en terme de variables didactiques nous a permis d'y répondre (Mackrell et al. 2013). Les expérimentations à venir pourront confirmer le modèle élaboré et orienter son évolution.
Une autre question posée par le projet est celle de l'articulation du virtuel et du matériel pour les apprentissages (Riou-Azou et Soury-Lavergne 2014). Dans l'élaboration des situations d'apprentissage, il faut choisir les moyens d'action sur le système offerts aux élèves. Par exemple, dans le jeu du nombre cible les élèves peuvent utiliser soit des cartes tangibles sur lesquelles sont écrits des nombres, soit une tablette numérique qui affiche les nombres dans des bulles. Le choix entre virtuel et matériel se pose également pour les rétroactions du système : des messages virtuels sur un smartphone ou bien un robot qui se déplace dans le monde matériel. Les observations des utilisations en classe apportent les premiers résultats sur les différentes stratégies des élèves avec le dispositif, en version matérielle ou virtuelle.
Modalités de l'atelier :
Après une courte présentation du projet, les participants testeront les jeux existants et seront amenés à les analyser selon les cadres théoriques proposés ou le cas échéant selon leurs propres critères d'analyse. Ils pourront confronter leurs résultats et leurs critiques aux observations des usages en classe, que les animateurs

3.2 ICME 13 — International Commission on Mathematical Education

La conférence internationale de l'*International Commission on Mathematical Education* a été organisée en juillet 2016 par la *Society of Didactics of Mathematics* au sein de l'université d'Hambourg (Allemagne). Ce congrès mondial, référence internationale pour les recherches sur l'enseignement et l'apprentissage des mathématiques, a lieu tous les quatre ans.
Le projet OCINAEE et ses kits sont présentés conjointement à la Pascaline pour mettre en avant l'intérêt de la manipulation d'objets tangibles et de leur articulation avec les manipulations d'objets virtuels dans les processus d'apprentissage.

Lien vers la conférence : http://www.icme13.org/



Référence à citer : Soury-Lavergne, S. (2016). Duos of Artefacts, Connecting Technology and Manipulatives to Enhance Mathematical Learning. 13th International Congress on Mathematical Education. Hamburg, 24-31 July 2016.

Actes soumis à la conférence :

13th International Congress on Mathematical Education
Hamburg, 24-31 July 2016

DUOS OF ARTEFACTS, CONNECTING TECHNOLOGY AND MANIPULATIVES TO ENHANCE MATHEMATICAL LEARNING

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We present the idea of duo of artefacts and an example: the pascaline, a mechanical arithmetic tool and the e-pascaline, its digital counterpart. The duo of artefacts enables us to create learning situations supporting the transfer of procedures, thus toning down the physical properties of the concrete manipulative irrelevant to mathematics. We analyze the added value of this duo to learning situations in terms of feedback. We finally present a new kind of learning situation involving directly-connected concrete and virtual manipulatives.

CONNECTING MANIPULATIVES AND TECHNOLOGICAL TOOLS

The use of information and communication technology by French primary school teachers is still not as developed could be expected considering the level of equipment and the learning attainments achieved by technology (Ravenstein & Ladage, 2014). One of the reasons may be the teachers' poor understanding of technology as an added value to learn mathematical concepts. They are not convinced of its usefulness. When considering manipulatives, like base-ten kits, sets of cards, coins, dice and so on, the situation is not similar (Moyer-Packenham, Slakind, & Bolyard, 2008). Teachers are aware of the role of manipulation providing physical and perceptual experience as well as solid mathematical conceptualization as regards longs-standing research on education. Even though the use of concrete manipulatives may also raise difficulties for students, because they embed perceptual and mechanical elements irrelevant to mathematical knowledge or limit knowledge transfer from one situation to another, teachers actually use such teaching resources.

Therefore, our proposal is to design duos of artefacts, associating a concrete manipulative tool to a technological tool to combine the advantages of both types of learning tools and to overcome some of their limits. It may be an invitation to use both tools and especially technology at primary school level. Thus, our question is about the characteristics of a duo of artefacts in order to improve the learning experience of students. The use of concrete tools implies physical engagement. Many works from different research fields have established thenecessity for mathematical conceptualization ((Lakoff & Nunez, 2000) (Edwards, Radford, & Arzarello, 2009) (Kalenine, Pinet, & Gentaz, 2011)). The technological tool of the duo must present some evolution in comparison to the physical one in order to help students overcome some of the manipulatives limits. It may offer students a new opportunity to identify the mathematical properties embedded in the artefact behavior. Moreover, virtual parts of the duo may evolve toward a more abstract and conventional representation of mathematical objects.

According to Fyfe and al. (2014), there is no opposition between the use of concrete materials and abstract materials in such learning experience, but a continuity that helps students build the mathematical concepts in that it fades away the characteristics of concrete material. Following Bruner's theory, they design a concreteness fading instructional process in three steps aiming at organizing a progressive evolution of students' mathematical understanding. They stress the necessity of three distinct steps pointing out obvious links between them. The process begins with a situation of the manipulation of concrete objects, providing "embodied perceptual and physical experiences" (Fyfe et al., 2014, p. 12). It goes on describing a situation where students interact with analogical representations of these objects (graphics and pictures) that help them disregard properties irrelevant to the mathematics in play. It ends with a situation involving symbolic and abstract representations, useful for the generalization and transfer to other situations. Such an interesting proposal is consistent with Vergnaud's "conceptual field" (2009). He defines a conceptual field that invests with meaning a given mathematical concept by the set of situations in which it is carried out:

> "It is at the same time a set of situations and a set of concepts tied together. By this, I mean that a concept's meaning does not come from one situation only but from a variety of situations and that, reciprocally, a situation cannot be analysed with one concept alone, but rather with several concepts, forming systems." (Vergnaud, 2009, p. 86).

He concludes that students come to face contrasting situations about a given concept. The concreteness fading process is a method providing a set of distinct situations. But it raises the question of how to characterize and design situations and manipulatives at each step of the process for a given mathematical concept. In this regard, Fyfe's proposal isn't fully complete. According to Fyfe and al., the first step may include virtual manipulatives. But any virtual environment, either on a tablet or a computer screen deals with computer representations of objects, engaging distinct operational invariants and situations. It is an evolution in comparison with the manipulation of concrete objects. In that regard, it may also pertain to the second step. Therefore, the characteristic of objects and models for each step may be further investigated, tested and defined.

Some recent studies explore the combination of concrete and virtual manipulatives for conceptual learning in mathematics (Ladel & Kortenkamp, 2015), (Soury-Lavergne & Maschietto, 2015). But currently there does not exist a methodology to design such duos. The purpose of this ICME contribution is to explicit some principles that might be efficient for the design of duo of artefacts and to discuss their possible application to the concreteness fading process. Mainly, we use the theory of didactical situations (Brousseau, 1997) and especially the concept of feedback in the interaction subject-milieu to design didactical situations including concrete and virtual artefacts (Mackrell, Maschietto, & Soury-Lavergne, 2013).

THE PASCALINE AND THE E-PASCALINE, FOR THE LEARNING OF NUMBERS, PLACE VALUE AND COMPUTATION

We have designed a first duo of artefacts composed of a concrete manipulative, the pascaline, and a virtual counterpart, the e-pascaline, with the principle that each artefact complements the other one (Figure 1). The pascaline is an arithmetic machine developed after the historical machine of the French mathematician Blaise Pascal. Produced by Italian research on mathematical machines, it is already used in Italy (Maschietto, 2015). The e-pascaline has been developed with the Cabri Elem technology and is a fixture of a collection of e-books (Soury-Lavergne & Maschietto, 2015).

The duo pascaline and e-pascaline aims at teaching place value notation and computation ; moreover it offers a rich mathematical experience on numbers to the students.

From the pascaline to the e-pascaline

The pascaline is a simple mechanical machine made up of gears providing a symbolic representation of three digit numbers, thus adequate for arithmetic operations. Each of the five wheels has ten cogs. The digits from 0 to 9 are stamped on the lower yellow wheels that display units, tens and hundreds from the right to the left. When the units wheel initialized to 0 rotates fully clockwise, the right upper wheel makes the tens wheel rotate in the same direction one tooth forward. This automatic mechanical motion of each lower wheel illustrates the idea of packing ten units into one ten or ten tens into one hundred. Likewise, the jerky motion of the wheel supports the recursive approach to numbers as it rotates one tooth at a time, adding or subtracting 1 according to the rotation clockwise or anticlockwise. It links addition and subtraction as inverse operations.

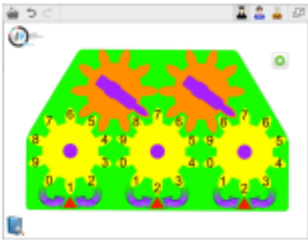

Figure 1. The pascaline (right) and the e-pascaline in a Cabri Elem e-book (left), both displaying number 122 (the 3 digits above the red triangles).

We have designed a virtual machine with some chosen elements of continuities and discontinuities in relation with the physical pascaline (Maschietto & Soury-Lavergne, 2013). The aim was to support the transfer of students' ideas concerning relevant mathematical meanings and to impede those irrelevant to mathematical interpretation at primary school level. Therefore, we have analyzed both students' schemes of uses as well as the way they use the pascaline in order to know what physical components and actions of the machine they have clearly identified. We have selected some of these elements to design the e-pascaline. As a result, the e-pascaline looks like the pascaline with just a few meaningful differences. For instance, with the e-pascaline, it is no longer possible to directly move the upper wheels. Blocking the upper wheels is a means to reinforce the association between a direction of rotation and an operation (the upper wheels turn in the opposite direction due to the principle of gear rotation). Likewise it is no longer possible to subtract 1 from 0 or to add 1 to 999. The e-pascaline only allows operations between 0 and 999, which is the full range of numbers displayed by the e-pascaline and the pascaline.

Moreover, the e-pascaline comes with additional components such as action arrows. Indeed, the rotation of the physical pascaline wheels produces sound and haptic feedback each time a tooth revolves. Students use these clicks to control their action on the machine and to perform operations. The e-pascaline makes it explicit by displaying two arrows on each side of the wheels. These arrows are buttons on which the user clicks to actuate the e-pascaline wheels. They express a possible action on the virtual machine and the direction of the wheel rotation. Other examples of additional components are the reset button (to reset the three wheels to zero) or the "counter of clicks" to display the number of clicks performed by the user since the last reset of the counter. All these e-pascaline components created added value and can be used to design problem-solving situations.

The last additional element of the virtual part to the duo of artefacts is the collection of e-books offering several didactical situations possible with the e-pascaline.

Three different levels of feedback in the duo of artefacts

The didactical situations with the e-pascaline are developed in e-books created with the Cabri Elem technology. From one page to the other, the designers must set the didactical variable values and implement appropriate feedback to provoke the evolution of the students' solving strategies and thus learning (Mackrell et al., 2013). One of the most important design principles at the basis of Cabri Elem authoring environment is direct manipulation (Laborde & Laborde, 2011) which involves both action and feedback on action. In the process of situation design with the authoring environment, we have identified three kinds of feedback, one of them being "direct manipulation feedback":

Direct manipulation feedback is the response of the environment to any student's action and may be combined to produce the other two types of feedback. An example of direct manipulation feedback is the fact that the rotation of the e-pascaline wheels is displayed continuously when a student clicks on the action arrow. Direct manipulation feedback resides mainly in choosing what elements are displayed or hidden, the successive positions of these elements and their dynamic update (the counter of click is automatically updated when clicking on a wheel).

Strategy feedback aims at supporting a student in his solving strategy. It is a response to a student's strategy with a mathematical value. To implement strategy feedback, the designers need to identify (i) configurations that are typical of a strategy and induce a diagnosis of this strategy and (ii) new objects or actions that can provide help to the student without changing the nature of the task or giving the answer. Such feedback may consist of help alerts or signs pointing out some contradictory elements in the student's strategy that call his attention to his current strategy limitations. It may also consist of canceling direct manipulation feedback. Below, we present examples of strategy feedback in the e-pascaline e-books.

Evaluation feedback is related to the completion of the task. Such feedback is necessary for the students to know how successful their strategies are to solve the problem. In the e-pascaline collection of e-books, it is mainly a smiling smiley displayed on the page that indicates success and a sad smiley that indicates error. Moreover, the successive smileys obtained after each problem remain on the page. They provide information about the global achievement of the students. If the evaluation feedback is automatically displayed, it may happen independently of the students' request. Then, the students may develop a trial and error strategy seeking the unplanned pop-up of a smiley without looking for a solution. So, in the e-pascaline e-books, the evaluation is given only after an explicit request from the students.

These three levels of feedback appear relevant to design and to analyse didactical situations including each kind of artefact, either physical or virtual.

Adding with the pascaline and the e-pascaline

There are two main procedures to add two numbers with the pascaline, both starting from the first term displayed on this device. Once the first term is displayed, the *iteration procedure* consists in repeating the operation of pushing the units wheel, one tooth at a time clockwise until the number of clicks corresponds to the second term of the sum. For instance, when adding 26 by iteration, the student clicks 26 times on the units wheel. The *decomposition procedure* consists in pushing each of the three wheels by a number of clicks equal to the corresponding digit of the second term. For instance, when adding 26 by decomposition, the user clicks 6 times on the units wheel and twice on the tens wheel (the order between the wheels does not matter). The iteration procedure is based on the quantity represented by the number while the decomposition procedure is based on the meaning of the digits in place value notation. Hence, the evolution of students' procedures from iteration to decomposition corresponds to the transition from a procedure based on the quantity represented by the number (adding by counting one by one) to a procedure based on place value notation. It indicates an evolution of the mathematical meanings associated to place value notation and their possible use for performing operation.

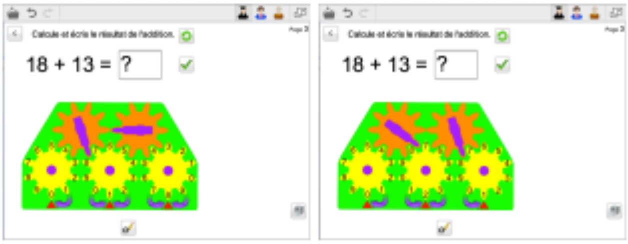

Figure 2. On the left, the first term 18 is written, the e-pascaline is waiting for the second term. On the right, the second term is added, by using the units wheel. After 3 clicks, the adding unit arrow disappears.

In term of feedback of the pascaline when adding two numbers, there is an asymmetric direct manipulation feedback corresponding to the two terms of the addition. When the students add two numbers, the pascaline continuously displays the first term and never the second one. For the second term, the feedback is reduced to the clicks produced by the moving wheels and the boosted haptic feedback when two or three of the lower wheels turn simultaneously. About the strategy feedback, using the physical pascaline enables the students to realize that the two procedures are not equivalent. For instance, adding a large number like 100 requires 100 clicks on the units wheel and only one click on the hundreds wheel. Students may be conscious of this difference but the physical machine does not compel the transfer from one to the other procedure. Finally, there is no evaluation feedback with the pascaline. This last level of feedback relies on the intervention of a human agent, mainly a teacher.

The addition e-book deals with the crucial and tricky passage from the iteration procedure to the decomposition procedure. Most six-year-old pupils apply the iteration procedure even with large numbers (Soury-Lavergne & Maschietto, 2015). The e-book consists of three pages with the same structure and components (Figure 2). The differences from one page to another concern the size of the proposed numbers for addition (up to 30 in pages 1 and 2, up to 69 in page 3) and the type of feedback given by the e-pascaline in response to the students' procedures. We have implemented feedback to compel students' procedures to evolve from iteration to decomposition. We used the possibility of hiding the action arrows on the units wheel to compel the students to consider and use another wheel, the tens one. It is possible and efficient because the iteration procedure requires only addition on the unit wheels, although decomposition procedure requires the use of the units wheel and the tens wheel as soon as the second term is a two-digit number. In the first page of the e-book, all procedures are feasible. It supports appropriation and devolution of the situation. In the next two pages, the unit wheel can only be used a number of times equal to the sum of the unit digits of the two terms. For example, to add 18+13 (Figure 2), the user can only click 8+3 times on the units wheel before the addition arrow disappears. The iteration procedure, which needs 13 clicks on the units wheel is no longer possible. In such a way, students have to look for another strategy to perform the addition. The fact that the action arrow is concealed corresponds to a strategy feedback. It occurs in response to the iteration procedure and makes explicit to the students that iteration on the units wheel is no longer possible, yet does not give the appropriate procedure. Such a feedback is not possible with the pascaline. The possibility to design different kinds of feedback contributes to the added value of the e-pascaline to the duo of artefacts.

The differences between the situations with the pascaline and the e-pascaline are sufficiently clear-cut to support students' evolution of procedures and therefore conceptualization of place value notation. Situations including the pascaline and the e-pascaline have characteristics of each of the three steps of the concreteness fading process. They involve concrete manipulatives (step 1), iconic and pictorial model (step 2) and symbolic representations (step 3) with strong links between the three aspects. The duo of artefacts permits to create situations and problems that link physical manipulations to different kinds of representation and particularly symbolic representation. As Fyfe and her colleagues claim: *"it links the concrete and the abstract instantiations as mutual references"* (2014, p. 12).

But in the case of the duo of artefacts, it is up to the students to make the connection between the pascaline and e-pascaline, just as they do between each step of the concreteness fading process. There is no direct interaction between the two types of artefacts independently from the users. An action of the pupils on one of the duo of artefacts does not produce feedback from the other. It is now possible to connect the world of physical manipulatives to the one of digital manipulatives.

A ROBOT TO CONNECT PHYSICAL AND DIGITAL MANIPULATIVES

The OCINAEE project[1] – Connected Objects and Digital Interfaces for Learning at Primary School – aims to explore and design mathematics learning situations with a system of connected objects. The OCINAEE system is a set of interacting devices either concrete like cards or dice, or digital, like tablets and smartphones. Connection between the two classes of objects is actuated by a mobile robot that can read physical elements such as cards or any printed material. The robot itself has properties of the two classes. Like any concrete manipulative, it has mechanical and physical properties. However, it is also a digital artefact because its behavior results from instructions given

[1] Funded by the French Bank for Public Investments, it is a partnership between two companies, digiSchool and Awabot, and two public institutions, Erasme and the French Institute of Education.

by a digital environment (automatically generated or piloted by a user). We are currently trying to define the different kinds of feedback that such a complex environment can provide in response to students' actions in a learning situation.

Figure 3. Some of the connected objects of OCINAEE project in scenario "the target number": moving robot, smartphone displaying the target number 12, game board and sets of cards.

For instance, in a scenario named "the target number", students have to choose 3 numbers out of 6 whose sum is the target number. In the current OCINAEE version, the target number is displayed on a smartphone and the numbers to be added are printed on cards with their symbolic writing. Students have to present cards to the robot. Then the robot moves on a line toward the target and stops before or after the target according to the sum. It also announces if the number of presented cards is correct or not. To implement such scenario with OCINAEE devices, we had to create direct manipulation feedback but also choose whether it is to be produced by a concrete or virtual object. For instance, the movement of the robot on the board is a strategy feedback in the concrete space because it tells students something about their strategies (too small or too big). Moreover, even though it is a rather simple kind of feedback, this simple movement of the robot mediates the notion of number line. It is also an evaluation feedback, since reaching the target point indicates success. Another example of feedback is the fact that the robot's eyes flash each time a card is presented but then, no indication of the numbers of cards already presented is revealed. This choice results from a didactical analysis: students need to know that the system takes a card into account but they have to deal with the fact that the result is a sum of three terms. They have to control it and they can succeed if they manage the cards and separate the ones they have already presented from the others. We are also creating a tablet version of the scenario to compare students' strategies with concrete cards or virtual representations of numbers.

CONCLUSION

With the idea of duo of artefacts, we propose a hands-on tool to design learning situations that take advantage of both physical and digital manipulatives. With the connected objects, we have a new opportunity to design situations and enlarge the possibilities of action and feedback. Moreover, it may be now possible to create learning situations with concrete manipulatives for a range of mathematical concepts by selecting the behavior of the robot and implementing appropriate feedback that may be either physical, in the world of concrete objects or virtual, at the interface of the digital world.

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3.3 IHM — Interaction Homme-Machine

La 28e conférence sur les Interactions Homme-Machine (IHM 2016) s'est déroulée à Fribourg (Suisse), du 25 au 28 octobre 2016. Elle a pour objectif de faire se rencontrer des chercheurs dont les problématiques se centrent sur les questions d'interfaces homme-machine.

Nos différents jeux ont été présentés à IHM pour montrer non seulement le dispositif mais aussi et surtout comment les élèves interagissent avec les différents objets connectés. Une attention toute particulière a été portée sur l'utilisation de l'espace physique dans le monde réel et l'espace physique inscrit dans un monde virtuel (tablette).

Lien vers la conférence :

http://ihm2016.afihm.org/

Diaporama présenté à la conférence :

Projet e-éducation
Investissement d'avenir

OCINAEE

Objets Connectés et Interfaces Numériques pour l'Apprentissage à l'École Élémentaire

Leslie Guillaume - Jean-Pierre Rabatel – Equipe EducTice IFE
Conférence IHM 2016 - Fribourg - 25 octobre 2016

Sommaire

- Présentation du projet
- Présentation des expérimentations en cours
- Questions de recherche
- Protocole expérimental
- Parcours utilisateur
- Questions et échanges


Présentation du projet

Objectifs du projet :

- Développement et diffusion de jeux mathématiques avec des objets tangibles et connectés pour l'école, impact sur le terrain
- Production de questions et de résultats de recherche relatifs aux apprentissages des mathématiques avec un dispositif hybride

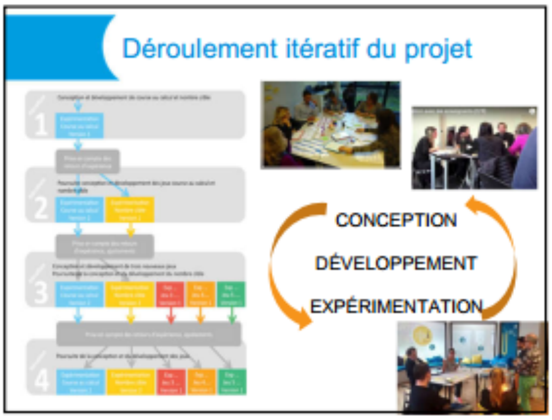

Les jeux

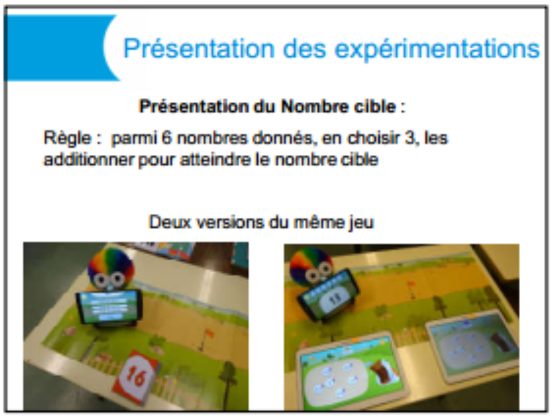
- La course au calcul
  Automatisation des calculs
- Le nombre cible
  Somme de trois nombres entiers ou décimaux
- Voyage dans le plan
  Orientation, repérage de positions et codage de trajectoires, déplacements du robot dans le plan
- Chiffroscope
  Codage et décodage du nombre : écritures et encadrement des entiers et des décimaux
- Problèmes de partage
  De la résolution de problèmes à l'algorithme de la division

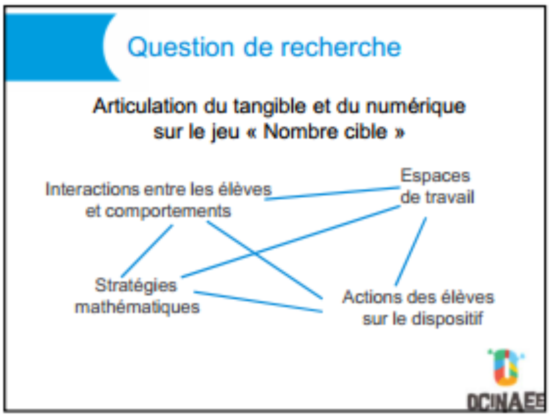
Quatre partenaires

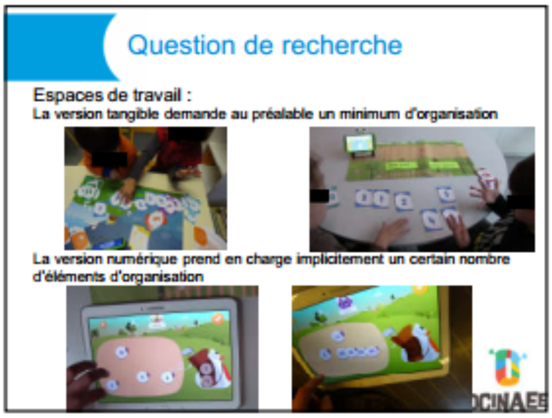
Démonstrateur de terrain

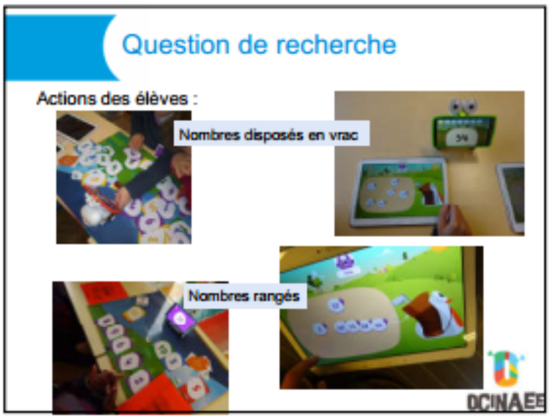
	2014-2015	2015-2016	Sept-déc.2016
Élèves	366	969	732
Cycle 2	152	320	368
Cycle 3	214	428 et 221 6ème	364
Écoles	6	14	11
Collèges	0	4	3
Enseignants	14	35	28
Classes	14 du CP au CM2	39 du CP à la 6ème	30 du CP à la 6ème
Jeux dans les classes	1	3	3 (4)

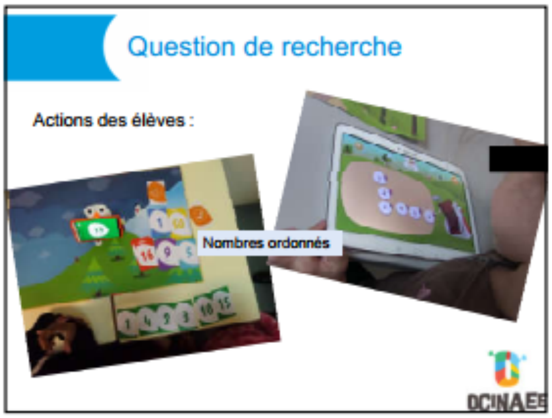

Déroulement itératif du projet
CONCEPTION
DÉVELOPPEMENT
EXPÉRIMENTATION


Présentation des expérimentations
Présentation du Nombre cible :
Règle : parmi 6 nombres donnés, en choisir 3, les additionner pour atteindre le nombre cible
Deux versions du même jeu


Question de recherche
Articulation du tangible et du numérique sur le jeu « Nombre cible »
Interactions entre les élèves et comportements
Espaces de travail
Stratégies mathématiques
Actions des élèves sur le dispositif
OCINAEE

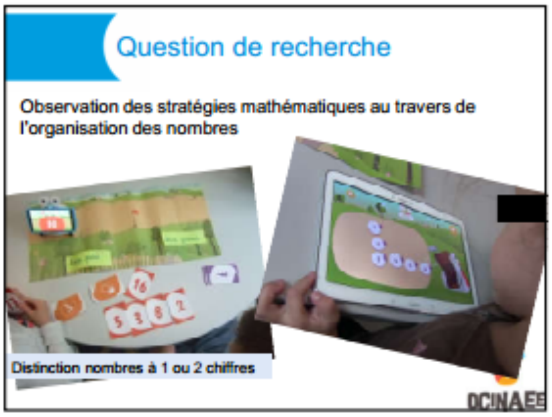

Question de recherche
Espaces de travail :
La version tangible demande au préalable un minimum d'organisation
La version numérique prend en charge implicitement un certain nombre d'éléments d'organisation
OCINAEE

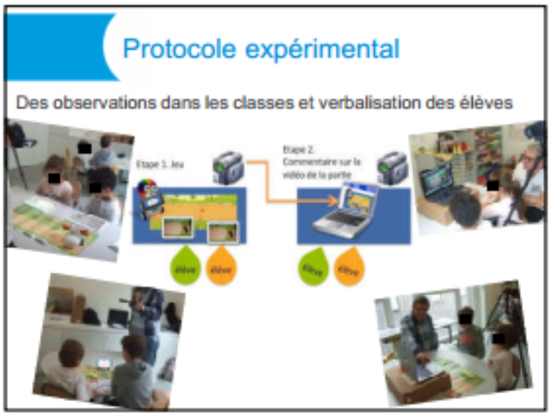

Question de recherche
Actions des élèves :
Nombres disposés en vrac
Nombres rangés
OCINAEE


Question de recherche
Actions des élèves :
Nombres ordonnés
OCINAEE

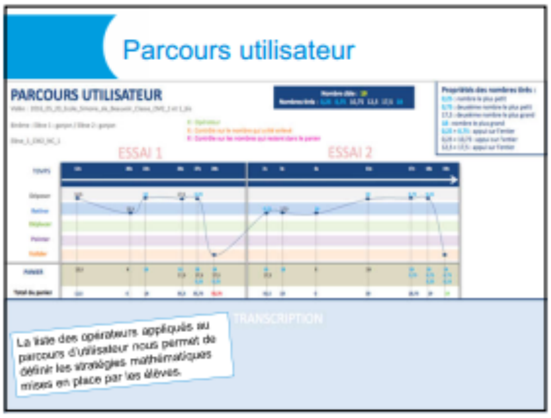

Question de recherche
Actions des élèves :
Soumission du nombre


Question de recherche
Interactions entre les élèves :
Compter seul ou à plusieurs


Question de recherche
Observation des stratégies mathématiques au travers de l'organisation des nombres
Distinction nombres à 1 ou 2 chiffres


Protocole expérimental
Des observations dans les classes et verbalisation des élèves
Etape 1. Jeu
Etape 2. Commentaire sur la vidéo de la partie
élève
élève
élève
élève


Découpage des actions des élèves
Utilisation du logiciel ELAN
Transcription des verbalisations des élèves


Parcours utilisateur
PARCOURS UTILISATEUR
ESSAI 1
ESSAI 2
TRANSCRIPTION
La liste des opérateurs appliqués au parcours d'utilisateur nous permet de définir les stratégies mathématiques mises en place par les élèves

4 Conclusion

Ces différentes communications nous ont permis de faire connaître notre travail et nous l'espérons d'en faire émerger de nouveaux. Nous avons également pu nous rendre compte du côté véritablement innovant de notre dispositif qui met au centre de la recherche à la fois des aspects didactiques et d'interfaces, non directement homme-machine, mais homme-virtuel-matériel. Dans le domaine éducatif, d'un côté les recherches en IHM se centrent sur les interactions qui existent entre la machine, l'apprenant et les contenus à apprendre. De l'autre, les recherches en robotique se centrent sur la mise en place d'activités pédagogiques centrées sur le robot comme remplaçant de l'ordinateur, ou bien elles se centrent sur des activités dans lesquelles la construction du robot est une finalité en soi. Ces recherches ne permettent pas de différencier ce qui doit être attribué de préférence à la manipulation d'objets tangibles de ce qui doit être attribué à la manipulation virtuelle. Les expériences que nous avons menées nous confortent dans l'idée qu'il y a nécessité d'avancer vers un modèle permettant de mieux identifier les activités à distribuer en fonction des situations didactiques que nous souhaitons instaurer. Cette nécessité est d'autant plus importante que la technologie évolue aujourd'hui non plus en termes de performance et de diversification logicielle mais vers la multiplication de nouveaux objets dont les usages sont à développer.