

Identify and understand the difficulties of the students in class by analysing their activity in the case of prescribed tasks with the spreadsheet

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ABSTRACT

The objective of this study is to provide teachers with indicators to help them take into account the difficulties' students face when performing tasks prescribed with a computer tool like the spreadsheet. Trying to identify these difficulties should allow teachers to better understand why students learn or not. We analysed the activity of 12 students from a professional course. The results of two representative students are presented in detail in this article as case studies. Finally, we propose to use these results for educational implications, results obtained from behaviours that could be identified in class by the teacher.

KEY WORDS

Analyse of the activity, strategy, behaviour, spreadsheet, learning

RÉSUMÉ

L'objectif de cette étude est de fournir aux enseignants des indicateurs pour les aider à prendre en compte les difficultés rencontrées par les élèves lors de l'exécution des tâches prescrites avec un outil informatique comme le tableur. Essayer d'identifier ces difficultés devrait permettre aux enseignants de mieux comprendre pourquoi les élèves apprennent ou non. Nous avons analysé l'activité de 12 étudiants de formation professionnelle. Les résultats de deux étudiants représentatifs sont présentés en détail dans cet article en tant qu'études de cas. Enfin, nous proposons d'utiliser ces résultats pour des implications éducatives,

résultats obtenus à partir de comportements qui pourraient être identifiés en classe par l'enseignant.

MOTS-CLÉS

Analyse de l'activité, stratégie, comportement, tableur, apprentissage

INTRODUCTION

In France, IT tools are present in many teaching situations. A number of authors have attempted to observe the impact of using these tools with regard to one's skills (Mc Inerney, Mc Inerney & Sinclair, 1994; Berry & Ritz, 2004), or concerning 'more positive attitudes' (Huang & Liu, 2003, p. 462). Some authors (Baron & Bruillard, 2001; Amadiou & Tricot, 2006) underline the importance of the skills that students must acquire in order to effectively use IT tools with efficiency from the point of view of their learning. The use of spreadsheets is one such example. Among spreadsheets' research works, some authors focused on the problem of spreadsheet errors (Chadwick & Sue, 2001; Przasnyski, Leon & Seal, 2011) and others on its usage in an educational context (Handler, 1993; Blondel & Tort, 2007).

From the point of view of the user, spreadsheet software is first and foremost office automation software; it is not software used in teaching methods, and even less, one that supports learning. Spreadsheet software is used by people who understand tasks that require using IT of this kind. The designers of the tool think that these users have, or are presumed to have, a mastery of the concepts of arithmetic averages, data extraction and classification, and connectives. However, spreadsheet software is used by teachers as a tool in a teaching situation.

In France, the spreadsheet is mainly used in class as an IT tool in the implementation of a teaching situation. Thus, at junior high school, official instructions for the curricula indicate that the spreadsheet is a tool for representing data (tables and graphs) and for making some calculations of statistics. At senior high school, the spreadsheet is widely used in mathematics for algebra, and remains a tool to solve a problem. In the vocational courses, the spreadsheet is an element of the curriculum for learning business accounting, for example (Haspekian, 2006; Aoudé, 2012).

At school, a student has to learn how to use the software to solve the problem of the task prescribed by the teacher within an interactive dynamic environment (Watson, 1995) in the context of learning tasks or assessments. As a result, the use of spreadsheets in activities of this kind forces the student to learn, to master how to use spreadsheets *and* to solve the set problem of the prescribed task (Amadiou & Tricot, 2006).

Hence, if the task that the student is set corresponds to a problem-solving activity in a situational context which is unfamiliar to her/him (the student is not an expert

in using spreadsheets, she/he is in class to learn to use this kind of IT tool), then the specifics of the spreadsheet situation do not always allow the appropriate knowledge to be used. Furthermore, to achieve the prescribed task, students use prior knowledge built in previous situations in order to execute the prescribed task if the students do not have the appropriate knowledge. But this prior knowledge is not always relevant to the present situation (Mayer, 2008), a 'spreadsheet situation'. Then, the students need to learn the proper knowledge relevant to the present situation (Anderson, 2000; Bastien & Bastien-Toniazzo, 2004).

Moreover, to develop an appropriate mental representation of the task involves existing (declarative and procedural) knowledge in the relevant context to the prescribed task ('context-specific knowledge') because prior knowledge plays a critical role for the comprehension of the task in order to know what to do (Bastien, 2002; Mayer, 2008; Lavidas, Komis & Gialamas, 2013); and, if this is not the case, then the student uses strategies such as exploration and search for solution, search for information, or the student uses a testing strategy (Richard, Poitrenaud & Tijus, 1993; van der Linden et al., 2001). Identifying and understanding the strategies used by the student in her/his search for a solution to the problem posed by the prescribed task makes it possible to give meaning to behaviours that may seem incoherent if one limits oneself to taking into account only the results of the test or the assessment (Clément, 2003). Identifying and understanding a student's difficulties in class is a preliminary and essential step in any remediation. Nowadays, it is inconceivable to think that only data from a test or an assessment can objectively give an answer for a remediation that is truly effective from the point of view of student learning (Clément, 2005).

To highlight this, we chose to analyse the activity of students using spreadsheets in class. From our point of view, this analysis of the students' activity could then be a good possibility to offer teachers some indicators of students' difficulties in using an IT tool like a spreadsheet. Our research focuses, therefore, on the possibility of identifying strategies used by a student to execute the prescribed task when a student does not use the relevant information from the situation, and exhibits behaviours considered as indicators of difficulties. Then, a qualitative analysis of this activity of the student must make it possible to understand the choices made by the student to elaborate her/his answer to the prescribed task (Clément, 2003).

ANALYSIS OF THE STUDENT'S ACTIVITY WHEN USING SPREADSHEETS IN CLASS

In class, the use of IT tools like spreadsheets requires a better understanding of the cognitive processes and knowledge used by students when they are confronted with spreadsheet problem-solving tasks. Indeed, the use of spreadsheets requires, on the

one hand, doing the task prescribed by the teacher, and on the other hand, activating adequate procedural knowledge related to using spreadsheets. Therefore, the cognitive load that this dual cognitive task puts on the student's cognitive system could be important if the student has not built the appropriate knowledge in memory. Sweller's cognitive load theory is a psychological theory taking into account phenomena of cognitive overload in comprehension and learning activities (Sweller, van Merriënboer & Paas, 1998; Chanquoy, Tricot & Sweller, 2007). Cognitive load theory makes a distinction between three forms of cognitive load (Sweller & van Merriënboer, 2005): intrinsic cognitive load, which is linked to the cognitive resources that are attributed to the memorising of information in the working memory; essential cognitive load, which is linked to the construction and automation of knowledge schemas; and extraneous cognitive load, which is linked to resources allocated by the cognitive system to activities that do not directly contribute to performing the main activity, like solving a problem for instance. Relationships between the three forms of cognitive load are additional and asymmetrical. A high extraneous cognitive load will limit the possibility of using resources linked to essential cognitive load, thereby limiting the acquisition and automation of schemas (Amadiou & Tricot, 2006), and, as a result, rendering them difficult to recall. Hence, it is necessary, as previous research shows, that students acquire the basic skills for the manipulation of spreadsheet functionalities (Lavidas et al., 2013).

The use of spreadsheets requires the student to have an interpretation of the prescribed task, allowing her/him to use 'spreadsheet' knowledge. She/he has to observe, extract, abstract, construct, look for, reproduce and re-translate in a language that is spreadsheet specific. If the student has constructed enough declarative and procedural knowledge (Anderson, 2000), relevant to the spreadsheet's situations, she/he will be able to use a procedure for doing the prescribed task. If the opposite is true, the student will try to answer anyway, even without necessarily having sufficient knowledge to be able to do so. For example, Petrina, Feng and Kim (2008) showed that novices mainly look for solutions to a problem without really reasoning. In a task with IT tools, Carroll & Rosson (1987) noticed that the users of the tool, and particularly novices, focused more upon completing the task than upon mastering their use of the tool itself (Babin, Tricot & Mariné, 2009). Hence, in a task with an IT tool like spreadsheets, the student has to focus on the relevant information (such as the spreadsheet functions, for example), in order for the cognitive system of the student to integrate this information with prior knowledge from long-term memory and to activate suitable procedural knowledge for the prescribed task (Mayer, 2001; Le Bohec & Jamet, 2005).

It is also useful to differentiate between executing activities and problem-solving ones (Richard, 2005). Faced with a task prescribed by a teacher in the context of a school activity, the student will once again have to have sufficient knowledge in her/his memory, either in the form of action plans that have already been made, or of

knowledge allowing the necessary procedures to be devised. If she/he does not have sufficient knowledge to be able to carry out this execution activity, the student then finds her/himself in a problem-solving situation (Richard, 2005). It is not easy to move from a problem-solving situation to one of execution. In a situation-specific context, the student must be able to design different sub goals that will enable the action to be scheduled, which implies that the student has the knowledge and procedures to define these sub-goals. If the student does not possess such knowledge, then she/he will either use other knowledge by trying to adapt it to the context of spreadsheets, or she/he will enter into a process of failure by exploring a problem area that is much too vast for her/him to be able to create a suitable procedure to solve the problem (Bastien, 2002). In that case, different strategies are used by people.

From this point of view, it is then possible, through an analysis of their activities, to describe some indicators of students' behaviours for strategies used by them in performing prescribed tasks with an IT tool like a spreadsheet.

First, there is the interpretation of the task, the mental representation of the task: a mental organisation of relevant information from the situation (the prescribed task, the using task of the tool) and prior knowledge retrieved from long-term memory (Richard et al., 1993; Mayer & Moreno, 2002; van Gog, Paas & van Merriënboer, 2006).

Secondly, possible strategies are:

- 1) systematic exploration: an optimal pattern of actions (van der Linden et al., 2001);
- 2) using inadequate prior knowledge: in a situational context which is unfamiliar to the student, like using spreadsheets, often, the student uses prior knowledge that is not appropriate, knowledge learned in previous situations (like solving arithmetic problems on the paper for instance); when knowledge is used inappropriately, it can impede learning, and it has also consequences on the number and type of errors in complex tasks like spreadsheet tasks for novice students (Cooper et al., 2001; Bastien & Bastien-Toniazzi, 2004; Baviskar, Hartle & Whitney, 2009; Schneider & Stern, 2010; Hérold, 2014);
- 3) sequence of actions related to 'deadlock': repetitions of the same sequence of actions, back to the initial state ..., after a no-action stage; the phases of deadlock are moments during which the student does not know what to do (due to the nature of the mental representation of the task at this moment); during a deadlock state, the student can eventually change her/his mental representation of the task (Richard et al., 1993);
- 4) 'trial-and-error strategy': carrying out actions without displaying signs of planning or evaluation, like, for instance, randomly clicking on menu-options, moving the mouse pointer without a sense of direction (Richard et al., 1993; van der Linden et al., 2001; Richard, 2005);

- 5) 'rigid exploration': set of ineffective actions, like selecting cells without knowing why (van der Linden et al., 2001; Richard, 2005);
- 6) 'encapsulation in information seeking': excessive search for information, like staying in the help menu for a long time, exploring the different possibilities without displaying signs of understanding (van der Linden et al., 2001; Hérold & Ginestié, 2011).

In addition, this kind of information can be used by the teacher in order to better understand the difficulties of the students (van der Linden et al., 2001). The aim of this paper is then to show that an analysis of the activity of a student allows for highlighting certain indicators of strategies in the behaviours of the students in class. Identifying and locating in student activity, the behaviours in strategies used by the student, can allow a teacher to better understand the reasons for the student's difficulties (Clément, 2003), and thus enable the teacher to adapt the instruction to each student. Therefore, for the teachers, it allows them to go beyond the observation, right answer or wrong answer, specific to the summative assessment of students at school.

EXPERIMENTAL PROCEDURE

Scope

This study is the continuation of a research, the DidaTab project (*DIDActique du TABLEUR* or 'spreadsheets teaching methods'), looking at understanding the real uses of spreadsheets in the French education system and assessing the competency levels of students with spreadsheet software (Blondel, Bruillard & Tort, 2008). In the framework of this project, students had to perform different tasks in a spreadsheet environment: change cells' format, write a formula, create a graphic, sort data, etc. (Blondel et al., 2008). Results (Tort et al., 2009) show that, in general, students have a fairly good grasp of using spreadsheets to give the correct forms to cells and tables, but they struggle with writing formulae and that this involves operators, operands, references, functions, etc., and notably the spreadsheet's more specific aspects.

In this study, an analysis of the student's activity was conducted in order to distinguish the knowledge and strategies effectively used by students when using spreadsheets. In the analysis of the students' activity, we are trying to find out how their knowledge allows them to create action plans or strategies that they use, and evaluations that they carry out on the results of the procedures used (see Mioduser & Kiperman, 2002) for an example of a suggestion of this type). From this point of view, the question is essentially how students proceed when working with spreadsheet software.

Methodology

This study was conducted on 12 students (17 years old or year 12) from a vocational course in a vocational school in the south of France. In the curriculum for this course, spreadsheets are considered as an IT tool, among others, which can be used to organise, sort and present data. So, the course about spreadsheets is about teaching the basic techniques of spreadsheets with very basic tasks such as changing cells' format, writing a formula, creating a graphic and sorting data. Most of the students were novices in the use of spreadsheets before the course even though most of them are experienced users of ICT.

At the end of the course, a computer-based test elaborated by the DidaTab project's team on basic tasks (Tort et al., 2009) was administered. Eleven prescribed tasks with questions were put into an Excel file, in which each sheet represented a task. Each prescribed task was of varying difficulty and looked at cell format, using graphs, the use of single and multiple sorting:

- Q1 = change the presentation format for decimal numbers;
- Q2 = change the presentation of wording and data;
- Q3 = calculations of the sum and the average of a vector of 4 marks;
- Q4 = change the presentation format for a rational number by putting it in fraction form;
- Q5 = simple data calculations (subtractions and multiplications);
- Q6 = automatic copying of the date;
- Q7 = choose a data representation graph;
- Q8 = simple calculations (subtraction and division) and using copy/paste;
- Q9 = simple data sorting in a chart;
- Q10 = graphic representation of a list of percentages;
- Q11 = multiple sorting.

The application software was Microsoft Excel© 2003. Each session lasted for an hour. All the students did the same tasks on the spreadsheet with the same displayed toolbar. Data collection for process analysis was done with records of detailed views of the use of spreadsheets. To capture all actions appearing on the screen during interaction, the software Camtasia Studio© by TechSmith was used. A free video player was used to re-play all recorded videos.

In order to categorise strategies, we used the screen capture videos of all students by coding the behaviours of the students (van der Linden, 2001; Richard, 2005). The descriptions are in Table I.

TABLE 1*Descriptions of strategies and some examples of student behaviour in spreadsheet activities*

Strategies	Description (summary)	Examples of behaviour (indicators)
Systematic exploration	Using the spreadsheet in a reflective manner with planning and evaluation of action outcomes.	Choosing the good menu option and being able to make the good choice in submenus. Mouse movements are directional and without wait times.
Using inadequate prior knowledge	Using prior knowledge learned in previous situations but not appropriate to the spreadsheets' situations.	Putting an '=' into the cell of a result (to make a calculation) instead of using a formula.
Deadlock	Repetitions of the same sequence of actions; back to the initial state.	Clicking many times on the same button. Select a cell, click on a button, hesitate and abandon the subtask or the task.
Trial and error	Performing actions without displaying signs of planning or evaluation.	Randomly doing actions without a sense of direction. Select the icons one after another without making a real choice. Trying different possibilities.
Rigid exploration	Repetition of ineffective actions or holding on to faulty ideas.	Opening a window and closing it, and repeating the same sequence many times. Keep on editing a cell with something and waiting.
Encapsulation in information seeking	Information searching without any progress in task flow.	Staying in the help menu and reading information without making a choice.

In this paper, we chose to detail the work of 2 students, particularly representative from the point of view of the analysis of the activity: one student in the learning phase and one student in great difficulty.

Student 1 has made a correct answer to most of the questions of the various prescribed tasks; student 1 displayed a good performance on this test. Contrary to this, student 2 correctly answered only the questions for the first two prescribed tasks and was in great difficulty with other tasks.

This data was triangulated with direct observations (field notes of experimenters, one for each student) and student interviews after passing the test. The research data consist of screen capture videos, field notes and transcribed interviews. The goal here was to determine, first, whether the observed behaviours can provide the teacher with enough relevant indicators to better help students learn, and second, if these indicators are easy to observe by a teacher in class.

RESULTS

Global results

All students were successful in the first two tasks (Q1 and Q2). For task 3 (Q3), only 2 students succeeded in tackling the issue by using the functions of the spreadsheet software and 10 students offered the right answers, but without using the functions of the spreadsheet software (the students wrote formulae based on sums and divided the result by the number of values). 5 students passed task 4 (Q4).

Task 5 (Q5) was massively failed: only 2 students passed the task (in using spreadsheet formulas). For task 6 (Q6), 8 students captured values cell by cell, rather than using the function of the incremented copy. 10 students did task 7 (Q7) by providing a suitable graph and 10 students succeeded with task 10 (Q10), in making a correct association between data and graph. For task 8 (Q8), only 2 students passed the questions of the task by using the functions of the spreadsheet software and 9 students offered good answers but without using the functions of the spreadsheet software. Task 9 (Q9) was successful for 6 students. For task 11 (Q11), only 3 students answered correctly (using spreadsheet functions).

To sum up, the analysis of all screen capture videos revealed a limited use of the functions of the spreadsheet software, which is consistent with the results of the Dida-Tab project. The spreadsheet tool has not been mastered by most students. If sometimes the results are correct, implemented procedures use predominantly inadequate knowledge because it is not relevant to spreadsheet situations.

The identification of the different strategies

We are going to detail the different behaviours observed by illustrating them with traces of the activity of student 1 and of student 2. Indeed, the analysis of their activity makes it possible to highlight the different strategies adopted for this study (see Table 1).

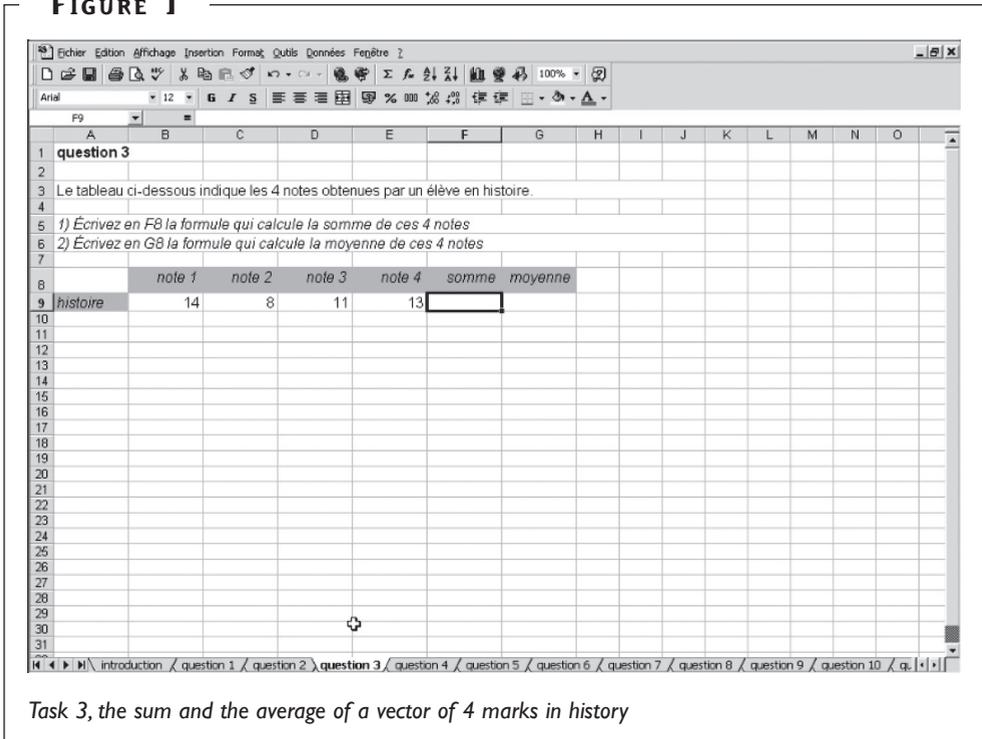
A sequence of actions is delimited by states of interpretation of the task, a mental construction of the task. In the case of spreadsheet activities, these steps are steps with no action on the screen from the student (no mouse move or mouse moves to read the question). Durations of these steps are quite similar, about 20" for most of the students (sometimes more: 30" to 40", but it was quite rare). These steps can be interpreted as corresponding to the construction of a mental representation, an interpretation of the problem-situation, or an interpretation of the task, that can lead to new sequence of actions (sometimes, renunciation). Thus, we can label these events as 'markers' of sequences of actions in our analysis of the student's activity.

Systematic exploration. When the mouse movements are directional and actions followed one another at a high rhythm, as is particularly clearly shown in the screen capture videos of student 1 for the questions for tasks 1 and 2 -for these two tasks,

the student was able to consider the situation as one of execution, using knowledge of the spreadsheet tool- we can consider these sequences of actions as ‘systematic exploration’ strategy.

Using inadequate prior knowledge. To illustrate this strategy, we take the example of the Task 3. Task 3 (calculations of the sum and the average of a vector of 4 marks) caused more problems for students. Task 3 is shown in Figure 1.

FIGURE 1



The transcription of the events during this task for student 1 is given in Table 2 (extract).

Steps 1 and 3 are steps with no action on the screen (the pointer of the mouse does not move). Duration of these steps are quite similar, about 18". Hence, we can say that they correspond to the mental representation of the task (an interpretation of the task) that leads to a new sequence of actions in step 2. We can categorise the sequence of actions in step 2, following the marker of step 1, as ‘using inadequate prior knowledge’ (see Table 1). The student uses prior knowledge that results from previous situations which seem to be ‘paper’ situations. But this knowledge does not fit for spreadsheets (for spreadsheets, we must use functions to do this task).

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TABLE 2

Activity of student 1, task 3 (extract)

Step	Start Time	Action/Event	Comment	Duration
1	1' 51"	No mouse movement.	Read the question. <i>Construction of a mental representation</i>	18"
2	2' 09"	Puts '=' in cell F9 active. Selects the 4 cells where the marks are written. '=B9:E9' appears in result F9 cell.	<i>Using inadequate prior knowledge</i>	5"
3		No mouse movement.	<i>Construction of mental representation</i>	18"

Student 1 used an 'inadequate prior knowledge' strategy many times. Another example is given by task 5 (see Table 3). For task 5, concerning simple data calculations (subtractions and multiplications), the text of the task was ambiguous and the student needed to know the use of formulas in Excel well (see Figure 2).

TABLE 3

Activity of student 1, task 5 (extract)

Step	Start Time	Action/Event	Comment	Duration
3	9' 07"	No mouse movement.	<i>Construction of mental representation</i>	18"
4	9' 24"	Put an '=' sign in cell E13. Then the student selects the cells C13 and D13 corresponding to the column headings 'number of hours' and 'hourly salary'.	<i>Using inadequate prior knowledge</i>	5"
5	9' 29"	"C13:D13" appears in E13.	That does not correspond with the expected operation.	

FIGURE 2

The screenshot shows an Excel spreadsheet with the following content:

question 5

Le tableau ci-dessous est extrait d'un état récapitulatif de salaires.

Sachant que :

Salaire brut = Nombre d'heures * Salaire horaire

Cotisation salariale = Salaire brut * 0,38

Salaire net = Salaire brut - Cotisation salariale

Ecrire les formules qui calculent ces valeurs en E13, F13, G13.

	Nombre d'heures	Salaire horaire	Salaire brut	Cotisation salariale	Salaire net
Armelle	38	15,00 €			

Task 5, simple data calculations (subtractions and multiplications)

Deadlock. Behaviour strongly present corresponded at 'deadlock'. This is an example with student 2 on task 3 (see Table 4).

TABLE 4

Activity of student 2, task 3 (extract)

	Start Time	Action/Event	Comment	
1	2' 28"	No mouse movement.	Read the question. <i>Construction of mental representation</i>	40"
2	3' 08"	Select the cell F8 with the mouse.	Hesitate.	2"
3	3' 10"	No mouse movement.	Construction of mental representation	18"
4	3' 28"	Select the cell F8 with the mouse.Wait.	However, in F8, there is already 'something', the column heading with the word 'Sum'.	7 10"
5	3' 55"	Select the cell F9 with the mouse.		2"
6	3' 57"	Select the cell F8 with the mouse.	Student moves the mouse on screen several times before abandoning the question. <i>Deadlock.</i>	44"

The first question of task 3 was: 'In F8, write down the formula which calculates the sum of these 4 marks' (see Figure 1). However, in F8, there is already 'something', the column heading with the word 'Sum'. The student correctly picks out the cell F8 (the mouse movement is clearly visible on the video), but the student is in 'deadlock' (selecting cell

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F8 several times, re-reading the question, which is visible on the video), before finally abandoning the question and moving on to task 4 and going back to task 3.

Student 1 was once in 'deadlock' for task 4 (Q4 = change the presentation format for a rational number by putting it in fraction form). For this question, student 1 fails to correctly perceive the problem that is set (see Table 5).

TABLE 5

Activity of student 1, task 4 (extract)

Step	Start Time	Action/Event	Comment	Duration
10	5' 18"	No mouse movement.	<i>Construction of mental representation</i>	18"
11	5' 36"	Click on 'Format' thumbnail. The window 'Format' pops up. The student hesitates again and then closes the window.		8"
12	5' 44"	Deletes '0.666' in the cell and writes the value again.		12"
13	5' 56"	Click on 'Format' thumbnail again, looks at the available types, chooses another type and confirms.		20"
14	6' 16"	Start the same procedure again: 'Format', 'Fraction'...	All in all, for this exercise, the student has clicked on 'Format' 8 times. <i>Deadlock.</i>	1' 46"
15	8' 02"	Mouse moves on the screen.	End up getting lost and abandoning it.	22"

Trial-and-error strategy. An example of behaviour that corresponds to the strategy 'trial and error' is given by Table 6 (student 1, task 4).

TABLE 6

Activity of student 1, task 4 (extract)

Step	Start Time	Action/Event	Comment	Duration
4	4' 37"	No mouse movement.	<i>Construction of mental representation</i>	18"
5	4' 55"	Looks at the 'Options' menu and ends up selecting 'Calculate'.		5"
6	5' 00"	Moves on to the 'Modification' submenu, hesitates and closes the window.	The student doesn't know exactly what to do.	3"
7	5' 03"	Clicks on 'Format' again, chooses 'Cell', drags the mouse over the different thumbnail drop-down menus 'Alignment', 'Font', 'Border', 'Pattern', 'Protection' and chooses 'Number'.	Tries another thing.	7"
8	5' 10"	Tries different things; ends up opting for the 'Fraction' category from the submenu.	Hesitates, looks for something but the student seems not to know exactly what it is.	6"
9	5' 16"	Hesitates over making a choice in the 'Type' drop-down, and clicks on 'OK' button.	The different possibilities in the 'Type' dropdown don't make sense for the student (see Figure 3). Nothing happens: '0.666' is still written in the cell... <i>Trial and error.</i>	2"

We can see here that student 1 tries different actions without displaying signs of planning (steps 6 to 9). Another example is given by Table 7 with the activity of student 2, task 3.

TABLE 7

Activity of the student 2, task 3 (extract)

Step	Start Time	Action/Event	Comment	Duration
7	4' 41"	No mouse movement.	Construction of mental representation	18"
8	4' 42"	Select the cell F8, hesitates (15"), puts in an '=', selects the cells for the 4 marks; then, clicks the 'Sum' command button. '#####' appears in F8.	No sign of planning. Hesitation.	22"
9	5' 04"	Widen the column, click on 'Sum' again.	Why have expanded column? Trial and error.	9"

Rigid exploration. An example of 'rigid exploration' strategy is given by the sequence of actions from the screen capture video of student 1 (steps 2 and 3) with the task 4.

TABLE 8

Activity of student 1, task 4 (extract)

Step	Start Time	Action/Event	Comment	Duration
1	4' 06"	No mouse movement	Read the question. Construction of mental representation	19"
2	4' 25"	Put '0.666' in the appropriate cell. Wait.		8"
3	4' 33"	Click on 'Format' first, then 'Tools' and confirms by clicking 'Options'. Wait.	Rigid exploration	4"

Here, it is the fact that the student does an inappropriate action in step 2 followed by a waiting phase and holds on to this faulty idea in step 3 that categorises this sequence of actions as rigid exploration (see Table 1).

Encapsulation in information seeking. The last strategy used in our analysis is the 'encapsulation in information seeking' strategy (student 1, task 3).

TABLE 9

Activity of student 1, task 3 (extract)

Step	Start Time	Action/Event	Comment	Duration
10	3' 07"	Reads question 2. No mouse movement.	Construction of mental representation	19"
11	3' 26"	Hit cell G9 and puts '=' in the cell.		9"
12	3' 35"	Clicks on 'Average' button and reads the explanations in the pop-up window. No mouse movement.	The explanations read don't help the student (see the text of the pop-up window in Figure 2).	26"
13	4' 01"	Closes the pop-up window. No mouse movement.	The student moves on to the next task (question of task 4). Encapsulation in information seeking	15"

Here, the student does not make a choice of actions after reading the help of the software and moves on to the next task (no progress in the task 3 flow).

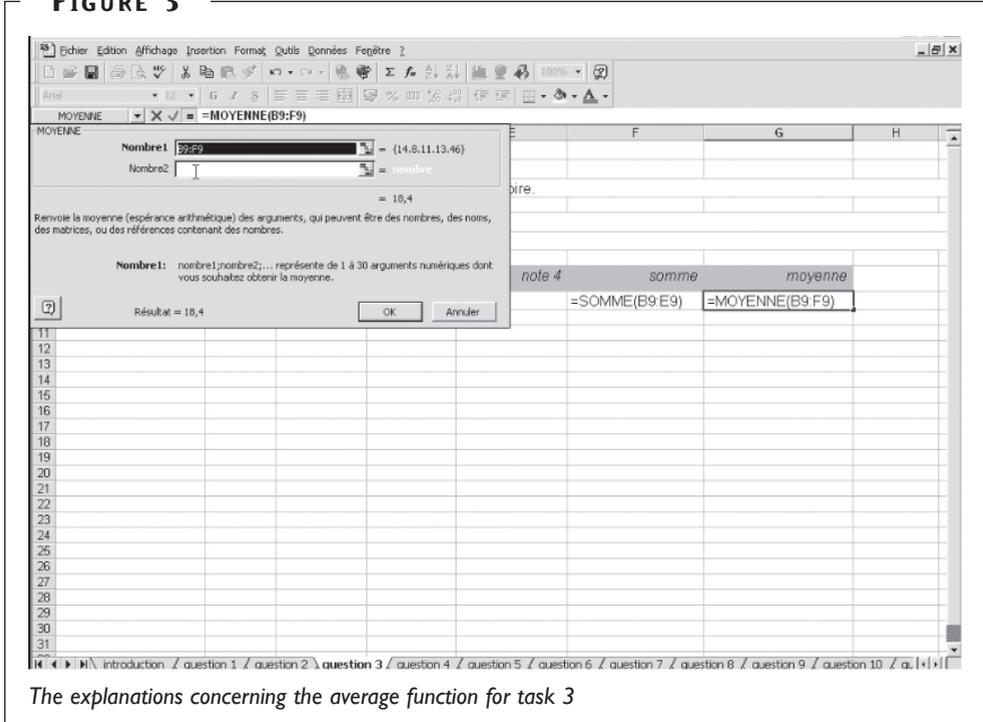
Synthesis of the analysis of activity for student 1 and student 2

Student 1 has a good grasp of the spreadsheet tool interface. Data from screen capture videos and field notes show that, effectively, student 1 does actions without much hesitation. Student 1 seems to have knowledge about the tool: student 1 knows where it is necessary to click in the menu of HMI. For example, when student 1 tries to answer question 2 of task 3 (see Figure 1), student 1, using the help of the software, knows that even the explanations from Excel do not generally help effectively (see the screenshot of the pop-up window in Figure 3), because these explanations are difficult to understand for novices (student 1 is not an 'expert' in spreadsheets; student 1 is at school in order to learn how to use this kind of software). As student 1 says in the interview: '*I had no problem posting formulas. But I did not know how to make it*'.

The questions for tasks 6, 7, 8 and 9 do not really pose any problems that confirm a relatively good knowledge of the spreadsheet tool. Student 1 correctly answered the question for task 10 (Q10 = graphic representation of a list of percentages). The student hesitated for a while over the choice of graph to use (duration: 50 seconds) before making a choice, after having looked at the different graphs made available by the tool. Once again, however, the wording of the question does not help the students: '*Use a bar graph to show this*'. It is not necessarily straightforward to choose a bar chart (is this the expected answer?), even more so given that a bar graph is one existing way of showing data in graphic form. The question related to task 11 was well done (Q11 = multiple sorting). The student again hesitated over what command button to use: sort-

ing data in ascending or descending order. It must be said that the command symbol does not help. The symbol is an image of *alphabetic* data sorting, but the question asks the students to sort *numbers* (that represent the different years).

FIGURE 3



The explanations concerning the average function for task 3

Globally, we can say that student I mainly used a 'systematic exploration' strategy. When student I was in difficulty, student I often used an 'inadequate prior knowledge' strategy. When student I used prior knowledge which resulted from previous situations, mainly 'paper' situations, it was due to the fact that the student did not have the adequate knowledge in her/his long-term memory to do the task: student I did not use 'spreadsheet' knowledge -some procedural knowledge adequate for a spreadsheet task- to do the task. Sometimes, the screen capture video of student I shows some hesitation in the sequence of actions. These hesitations reflect certain fragility in the construction of procedural knowledge in using spreadsheet tool.

To sum up, the analysis of the activity of the student I shows that the main behaviour corresponds to 'systematic exploration'. When student I was in difficulty then the student mainly used an 'inadequate prior knowledge' strategy. Student I was once in 'deadlock' and it was due to the fact that the purpose of the task (task 4) was about rational numbers. When student I used the 'trial and error' strategy (for task 4), student I tried many different actions.

This is not the case for student 2. For the same strategy, student 2 tried one or two actions, no more, and often abandoned them. Student 2 went on to abandon lots of the questions. Although the student persevered (during the interview, the student 2 often repeated: *'I try to understand what to do', 'I tried'*-and for this student, the test lasted for more than 45 minutes, whereas student 1 did the test in 23 minutes), only questions related to tasks 1 and 2 were answered correctly.

In the activity of student 2, there were multiple times with no action (1 minute and 27 seconds without moving the mouse at all for task 4, 1 minute and 40 seconds for task 6). Student 2 was mainly in 'deadlock', often abandoning the question and going back to another one, often hesitating. For example, for task 7, student 2 was able to select the graph assistant, but then hesitated, and ended up choosing a graph of the sub-type *'Curves. Enter a trend in the time given, or on different x coordinates'*. The student hesitated once more and did not know how to place the table data into the graph zone. Student 2 abandoned the question and went to the question of task 8. When student 2 moved on to the question for task 9 (Q9 = simple data sorting in a chart), student 2 selected the cells one by one and decided to sort the data using *'cut/paste'* (inappropriate procedure). The student filled the cells with copied values, then hesitated a moment later, and abandoning the question.

In a few words, we can establish that student 2 is a student in great difficulty with spreadsheets activities. The student needs to learn the appropriate knowledge (the 'spreadsheet knowledge') which is declarative and procedural knowledge.

Student 2 was often in deadlock. Hence, this behaviour could be good indicator of great difficulty for spreadsheets activities. The fact that as student 2 says *'I read the question with the mouse'* (which was not at all the case of student 1), can be regarded as an indicator of difficulties in understanding the prescribed tasks? This point needs further exploration.

DISCUSSION

The aim of this research is to know if it is possible to provide information for teachers about difficulties of students from behaviours, as indicators, and corresponding strategies used by students when using IT tools like spreadsheets, for example.

We can see on the transcriptions of the two students the different steps which seem to correspond to the (re)construction of mental representations (student 1, task 3, step 1, 3 or step 10 for example; student 2, task 3, step 1, 3, 10, 13, 16, 18 or step 22 for example). So, these steps can be clearly identified (no mouse move during many seconds, about 20"). The construction of a mental representation corresponds to the beginning of a new sequence of actions. Identifying the nature of this sequence of actions from indicators previously described seems to be a good way for a teacher

to have some information about the student's difficulties in doing prescribed tasks for learning the basic techniques of spreadsheets.

Hence, results show either that a student is in great difficulty (like student 2) or not (like student 1), that a student can use inadequate prior knowledge after a mental representation change when she/he does not know how to do the task, and sometimes after an evaluation of her/his actions (like student 1, task 5 for instance). This inadequate prior knowledge has been built in situations other than those using spreadsheets. That is why this inadequate prior knowledge is not suitable to situations using spreadsheets (Cooper et al., 2001). Indeed, the use of a spreadsheet requires the student to elaborate mental representations of tasks that are very different from those she/he has already memorised. If student has no relevant prior knowledge in her/his long-term memory, the cognitive system will select similar prior knowledge from her/his long-term memory, but this knowledge is activated inappropriately, and is inadequate. The fact that the mental representation of the prescribed task is not made with relevant knowledge may have cognitive load implications because good procedural knowledge is not used to do the task. This leads to strategies like trial-and-error, rigid exploration or encapsulation in information seeking. It is difficult to rank these strategies according to levels of difficulty for the student, but our results show that if the sequence of actions is 'trial-and-error' and after 'rigid exploration', the student is in less difficulty than when the sequence of actions is 'trial-and-error' and after 'deadlock' state. Thus, deadlock state is a good indicator of a student in great difficulty for prescribed tasks about learning the basic techniques of spreadsheets.

More globally, a student's behaviour, different from the behaviour of the strategy 'systematic exploration', reflects a lack of procedural knowledge, or sometimes a lack of declarative knowledge. A teacher can then provide feedback that is really adapted to the difficulties of the student to help promote meaningful learning (Mayer, 2008). The feedback should be different according to the nature of the specific knowledge which is lacking (declarative knowledge, procedural knowledge) and according to the nature of the strategy used by the student.

On the other hand, the use of spreadsheets by students in a classroom represents a cognitive load (Sweller & van Merriënboer, 2005) which may be higher or lower depending upon the student's knowledge of the spreadsheet tool. This cognitive load will be reduced if the student possesses enough specific knowledge about spreadsheets, and will allow cognitive resources to be called upon to do the task. This is the case for the first student. Student 1 had good knowledge about spreadsheets allowing the student to answer several questions correctly and relatively quickly (questions of tasks 1, 2, 6, 7, 8 and 9). The fact that student 1 could not answer the question related to task 4 is due to a problem with rational numbers (a recurring problem, which a large number of students have at that point in their

schooling). In that case, from a point a view of using spreadsheets, the prescribed task 4 causes a cognitive overload.

A lack of spreadsheet knowledge, especially declarative knowledge, does not allow students to rely upon the software's help. Especially as the help offered by the software and the command comments are very difficult to understand for students at this level of schooling (vocabulary which is inadequately adapted, wording that is too complex and barely representative of the described function).

The lack of declarative knowledge for some tasks is clearly shown by this extract of interviews with the two students:

Student 1: 'I didn't understand... 2/3 and 0.666 at the beginning. Then afterwards when I saw a fraction, I made the link. You can see that from my hesitation in the video... Then I understood that I had got the wrong graph, but it is true to say that we could choose a lot of them in that part For question 11, I'd seen one of the films when I was 15 and I made the link and in the beginning, I hadn't double sorted the data, that's why I had dates that didn't match the film titles...'

Student 2: 'I didn't understand question 4 at all. Division isn't my strong point and I never manage to do formulas, why are there always "#####". Graphs are even worse. I've never understood bar graphs at all in mathematics, so... And for the pictures it was too difficult...'

The use of a spreadsheet tool by students in class requires a clear understanding by teachers about the fact that, the use of this tool, for a beginner student, requires specific knowledge about spreadsheets. Learning this specific knowledge may be long and sometimes difficult for students. Moreover, the extraneous cognitive load imposed by the tool plays an important role in the nature of the student activity (type of HMI, type of help offered by the software). Therefore, the teacher must analyse the prescribed task in terms of work carried out by the student and not only in terms of knowledge to learn/to teach. The student must also have the necessary knowledge concerning the problem posed by the prescribed task (intrinsic cognitive load).

Sometimes, however, the origin of the difficulty does not depend on the tool. For example, most of the students had difficulty with task 4 (using rational numbers with different representations, which is a recurrent difficulty in learning mathematics for students). Indeed, to be able to solve the problem of task 4, the student had to be able to interpret the written symbol '2/3' as being a written fraction (but this idea format is different from what students had already encountered on paper or in the manuals; for example, student 1 needed a certain amount of time before choosing the 'Fraction' option). Furthermore, student 1 had to make the link between the value '0.666' and the written '2/3' which represents the same numerical quantity. However, as the interview shows, student 1 did not seem to know what to do: 'I had difficulty with this question'

(interview with student I). The kinds of types that the spreadsheets offered in the 'Fraction' option were not clear to this student (see the propositions of the software in Figure 3) as was said in the interview: 'I did not understand the size proposed by Excel'.

Many students have difficulty making the connection between a 'division' and a 'fraction'. We can see this effect in the following dialogue with regard to the problem in establishing the link between the written symbol ' $\frac{2}{3}$ ' and the notion of a fraction (student A and student I were placed beside each other):

Student A: And the ' $\frac{2}{3}$ ', what is that called?

Student I: Fractions.

Student A: That's not written down.

Student I: Yes, it is; look 'make a fraction'.

Student A: No, it isn't ' $\frac{2}{3}$ '.

Student I: Are you sure?

Concerning the interpretation of the written '0.666':

Student I: I don't understand what ' $\frac{2}{3}$ ' is.

Student A: '0.666' is the same.

Student I: Oh? Ok.

In summary, we can say that, for spreadsheet activities, 'systematic use' and 'deadlock' are behaviours that are relatively easy to identify during spreadsheet activities as 'using inadequate prior knowledge'.

The behaviour corresponding to 'encapsulation in information seeking' is not inauspicious for spreadsheet activities (very few students had used it) because, in the frame of this course, the spreadsheet activities were not really problem-solving activities but more activities which needed the implementation of procedures. For spreadsheet activities, the student needs to use procedural knowledge and in the case of difficulty the student looks for the procedure. Therefore, when students use this strategy, 'encapsulation in information seeking', the sequence of actions is usually very short and in light of this, difficult to identify. The 'trial-and-error' strategy can be informative in the case of students with good knowledge of spreadsheets (they have more opportunities to try), but not in the case of students in difficulty (they cannot try).

On the other hand, the 'rigid information' strategy is difficult to identify because this strategy is few explicit for spreadsheets activities.

- To conclude, we can try to establish a categorisation of the strategies used by students:
- 'using inadequate prior knowledge': student 'understands' the prescribed task (student is able to elaborate a goal for the task or the subtask), but student has not yet elaborated the good 'procedural knowledge';

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- ‘trial and error’: student has some knowledge of the use of the tool (she/he can ‘try’) but student has some difficulty elaborating an operational sub-goal/goal for the prescribed task;
- ‘rigid exploration’: student lacks knowledge about the prescribed task (failed to retrieve the relevant information about the situation);
- ‘encapsulation in information seeking’: student is not able to elaborate an operational goal for the task or the subtask (lack of declarative knowledge and procedural knowledge about the tool and/or student does not ‘understand’ the prescribed task);
- ‘deadlock’: lack of knowledge about the tool and lack of knowledge about the prescribed task.

If the ‘systematic use’ behaviour is mainly present in the activity of the student, then we can say that the student has probably built up knowledge for doing the prescribed task; the student has learnt. If the student is mainly in ‘deadlock’, then we can say that the student needs to learn the appropriate knowledge (here, ‘spreadsheet knowledge’), and the student is in great difficulty. If the student is able to use strategies like ‘rigid information’ or ‘trial-and-error’, then we can say that the student has some knowledge about the use of spreadsheets.

To analyse the activity of a student in class, a teacher must be able to: identify mental representation construction phases and categorise the sequence of actions following the construction of a mental representation. This analysis of the student’s activity can be facilitated if the students’ computers are networked and if the teacher has a shared screen allowing her/him to visualise the screens of the students.

To sum up, if the way students work with spreadsheet software is not always simple and is often surprising (Tort et al., 2009), it is often due to the fact that students use inappropriate prior knowledge in the spreadsheet situation because students do not have the relevant knowledge (“spreadsheet knowledge”) for the construction of the mental representation of the prescribed task. That is why, in spreadsheet situations, the intrinsic cognitive load will be high (students have still not necessarily automated their knowledge about spreadsheets) and as the extraneous cognitive load is already high (students are not expert with the spreadsheet software, they are in class in order to learn to use it, to learn about the functionalities of the software), the total cognitive load will limit the possibilities of the cognitive system resources of the students. And strategies like trial-and-error, rigid exploration, or action sequence related to deadlock seem to be good indicators of this.

CONCLUSION

When a student uses an IT tool like spreadsheets in a teaching-learning situation, she/he has to complete a double concurrent activity: one of solving a problem and one of using the IT tool (Amadiou & Tricot, 2006). When using spreadsheets, a student needs to know how this kind of tool works, i.e. the specific functions of the tool. With 'copy/paste' for instance, you copy the formula and not the cell content. Therefore, before using spreadsheets to solve problems, a student has to know the spreadsheet functions needed to do the task. The student must have built some 'spreadsheet procedural knowledge'. But she/he does not necessary need to know *all* the functions - only those that are useful in solving the problem will be used.

Furthermore, we saw that the help from the software is not always very useful for the students: the vocabulary and syntax structures need to be adapted for them. Therefore, it is necessary to learn how to use this help, and how to understand it.

In order to perform the prescribed task, students attempt to answer the questions using the knowledge that they have at that moment. If the knowledge needed to accomplish the task is not constructed because the student does not have it in her/his long-term memory the adequate procedural knowledge (in that case, some 'spreadsheet procedural knowledge'), then the student often uses strategies which are frequently unsuccessful.

Steps for reconstructing the mental representation of the problem, the use of inadequate prior knowledge, knowledge learned in previous situations which are not spreadsheet situations, steps where the student is in 'deadlock', steps where the student undoes what he has already done, from our point of view, could be useful 'indicators' for a teacher. A good knowledge of these 'indicators' can allow the teacher to progressively guide the student (Merrill, 2002; Hérold & Ginestié, 2011). However, it is true that identifying these indicators accurately remains a difficult task for the teacher in a class. Nevertheless, we have seen that strategies like 'inadequate prior knowledge', 'systematic exploration' or 'deadlock' are easier to identify. Encouraging teachers to try to identify them can be a good start to go beyond the traditional correct answer/wrong answer pattern and thus to let them try to understand the nature of students' responses and the nature of their actions from a point of view of the students' learning.

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