Analyzing teachers' views on the integration of computer science into mathematics teaching

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This contribution addresses the issue of understanding teachers' difficulties in integrating computer science and programming software into their practices. To do so, we previously used the theoretical concepts of distance/landmarks to analyze the development of such practices and show the importance of the teacher's personal component. We use this lens here to analyze some interviews of teachers' views on this integration. The results show that the barriers of ICT integration situate mostly on the changes that ICT introduce at cognitive and mediative levels. Conversely, institutional, and social components rather seem to play in favor of integration.

Keywords: Teaching practices, computer science, instrumental distance, didactical landmark.

1. Introduction

The last changes in mathematics curricula at French primary and secondary levels strongly bring in computer science into mathematics teaching, in association with several software. Our research question is to understand teacher's difficulties in integrating computer science and programming software into their practices. To do so, our previous work analyzed the practices of teachers, first time using computer-related technologies as Bee-Bot robots, or Scratch (Haspekian & Gélis, 2021). The results concerned the didactic references (Haspekian, 2017) that the teachers built in these new situations in terms of both knowledge and tool use: these teachers built some sessions that allowed them to remain not too distant from what they already knew, while, at the same time, they gain new reference marks (Haspekian & Gélis, 2021). These ideas of *distance/ landmarks*, together with other theoretical concepts of the Instrumental Approach (detailed below), allowed to study the instrumental geneses of the teachers, both personal (to master Scratch or robots) and professional (to teach mathematical knowledge via these instruments). The results lead to reflections on teaching practices: how do teachers develop new didactic references, and how do they use previous situations to manage new ones, as long as these are not *too* distant. In this paper, using these same frames, we are interested this time in the teachers' opinions and representations about these tools and this new teaching. The following sections present the theoretical frames we use, the first results, and a discussion of these.

2. Theoretical frames for the study

Our work integrates 2 frames briefly describe below.

The five components of the Double Approach of Robert & Rogalski (2002)

This frame approaches the teachers' activity through the ideas of constraints and room for action. Indeed, the teachers have some liberty in their didactic choices, as learning goals of each session, tasks given to students (these are part of the *cognitive* component), or still scenarios, class organization, etc. (part of the *mediative* component). These choices are very personal, depending on the teacher's history, vision of what is teaching, learning... (this is the *personal* component). Yet, these choices are made within the limits of some constraints: official instructions, curricula, time duration of the lessons, profile of the students… (the *institutional* and *social* components).

Our work focusses on the personal component and considers the four others *from the teacher's point of view*. Indeed, our previous research used this component to explain teachers' practices, considering that it *contains knowledge on cognitive, mediative, social and institutional ones* themselves (Haspekian, 2017). The daily cognitive/ mediative choices are imprinted of various didactic knowledge, which pre-exist in this personal component. This diversified knowledge, covering these fours dimensions, acts as *didactic landmarks* (*ibid*.) guiding the activity. These are needed to perform new cognitive and mediative choices. The next section presents this tension distance/ landmarks.

The instrumental genesis and instrumental distance of the Instrumental Approach

Since the activity is instrumented by new technological tools, initially, our work is also framed by the Instrumental Approach in didactics (Artigue, 2002; Guin et al., 2005; Lagrange, 2000; Trouche, 2004) with its key issue of *instrumental genesis* (Verillon & Rabardel, 1995). This is the psychological process, through which the subject uses and transforms an artefact so that it becomes an instrument for the activity and, through which, conversely, using the artefact affects the subject's conceptualizations. Applying this concept to the *teacher*, we divided it into two processes: a *professional* instrumental genesis (for the didactic activity of the teacher) and a *personal* one (for the mathematical activity of the teacher) (Haspekian, 2006).

The Instrumental Approach also focusses the attention on how tools affect mathematical concepts. The idea of *instrumental distance* (Haspekian, 2005) has been initially introduced to study this impact of a new artefact on concepts and conceptualizations. For example, the spreadsheet introduces a distance regarding the usual concept of variable in mathematics.

On the teacher's side, this distance affects the teacher's didactic landmarks. For example, teaching algebra with a spreadsheet causes a loss of these marks. Thus, the instrumental distance has been then extended in a more general idea of *distance to practices* and to its usual didactic landmarks (Haspekian, 2017), that is the impact and deviation from the practices produced by the introduction of a new tool, a new domain, or still a new discipline as computer science into mathematics teaching.

A theoretical grid to analyze the didactic distance/ landmarks

To theoretically structure the factors that contribute to didactic distance and landmarks, we used the 5 components described above, isolating more specifically in the personal one the epistemology and representations of teachers (Haspekian, 2017). These elements may play in favor of integration, or in disadvantage because of the distance that they create. For example, teaching algebra with spreadsheet presents a distance at the cognitive, personal, and institutional levels.

The possible new practices that may develop result from an equilibrium between elements of these components that legitimate/ support the integration of the newness, and elements that create some tensions and distance to the pre-existent didactic marks (at institutional, social, cognitive, and mediative levels). Table 1 shows this reading grid for teaching practices in innovative situations.

Table 1: A grid for analyzing teaching practices in innovative situations

	Legitimacy of the "newness"	Tension landmarks-distance
Institutional and social dimensions: - **I**: institutional - **S**: social		
Didactic dimensions: - **C:** cognitive - **M:** mediative		
P: Personal dimension: - **E:** Epistemology of the teacher) - **R:** Representations		

Applying this categorization for analyzing emergent teaching practices with Scratch and robots, we showed that the integration of these novelties depends on two conditions on each one of the 5 components I, S, C, M, P - a condition on legitimacy and a condition on the didactic landmarks:

1. A certain legitimacy must be perceived/conferred by the teacher to this object at the institutional (I, S), didactic (C, M) and personal (E and R) levels
2. This legitimacy alone is not enough, the "newness" should not create (on each components I, C or M) a too distant situation to the teacher's former landmarks, *i.e.* that the integration of new can be done on landmarks close to those already acquired.

Table 2 details the theoretical elements in the different dimensions.

Table 2: The possible positive or negative impacts on practices of a newness at different dimensions

	For a given "novelty"	Positive/ legitimating Elements, (Favoring integration)	Negative Elements (Braking integration)
Institut. and social	- ***Curricula, official instructions: institutional legitimacy***	praxeological changes positively perceived	or negatively perceived
	- ***Social Legitimacy:*** - ***Cultural Legitimacy:***	- social role, professional tools - modernity	- increased workload and more time-consuming - organization complexified
Didactic dimension	***Didactic potentialities due to an impact of the distance***	**Legitimacy at cognitive level:** Benefits for learning and conceptualization	- new landmarks must be created - resulting tension between distance vs landmarks finally resulting in a too big distance
	Mediative dimension (new possibilities) o mediation of the knowledge o scenarios…	**Legitimacy at mediative level:** Benefits for learning and conceptualization	- new landmarks must be created (orchestrations to define…)
Personal dim.	- ***Epistemological legitimacy*** - ***Additional subjective elements:*** o Mental representations about the new object, about teaching and learning… o Beliefs, o Past Experiences, etc	o the role the tool plays in the development of mathematics o the place taken within the field of mathematics	o may create doubts o may not be in congruence with the teacher's representation of mathematics, etc.
	Resulting Balance:	**Integration or not**	

On the **Institutional and Social dimensions**: legitimacy is given by curricula, inspection, assessments, schoolbook; and by societal developments. On counterpart, this requires the creation of new landmarks, even if curricula give some.

On the **Didactic (cognitive and mediative) dimension:** research studies, professional training and literature, legitimize the contributions and benefits to cognitive and mediative levels, but, *a priori*, for an ordinary teacher, the newness introduces a loss of cognitive and mediative marks. Instrumental professional geneses are to develop in terms of orchestration (Trouche, 2004), particularly to manage students' instrumental geneses.

On the **Personal dimension:** the epistemology of the teacher and his/ her representations may legitimate/ foster or hinder the integration, according to teachers. It depends on the person, her very knowledge of the disciplines at stake, her epistemology of the mathematics to be taught, her representation in general on teaching and learning (not specifically disciplinary).

Finally, the distance to usual practices is problematic if too few landmarks remain (I, C, M) (negative factors). This loss is counterbalanced by the perceived/ conferred legitimacies at the levels (S, I, C, M) (positive factors), and by the personal component, particularly the teachers' representation and epistemology in the concerned domain (P: R/ E) (factor positive or negative according to the person).

In IeCare project, we use these theoretical concepts to analyze interviews of primary and secondary school teachers. The collecting of these data is still in progress, we share, here, our first analyzes: the barriers of ICT integration situate mostly on the changes that ICT introduce at cognitive and mediative levels. Conversely, institutional, and social components rather seem to favor integration.

3. Methodology

The data come from the ongoing French National Research Agency project *IeCARE*, where we made some questionnaires and interviewed primary school teachers' feelings, beliefs, or knowledge about these new curricula. In these data, we try to understand the determinants of the activity of the teacher regarding computer science and the integration of new technological artefacts: What contents are identified (mathematics? computer science? instrumental only?)? Through which functionalities and modalities? What goals are assigned to these contents? How will students construct these? What knowledge do they have to integrate these new goals? What resources do they use? What motivates the teachers deep down? Where are their main difficulties?

We used a methodology of semi-directives interviews (De Ketele & Roegiers, 1996, p. 172), that we transcribed then in series of speaking turns. Each round of speech is numbered and coded in the following way: "3.TDP12" means the 12^{th} round of speech, in the interview of Teacher 3. The theoretical grid above provided a lens of reading through which to analyze the transcripts. The analyze consisted of reading, highlighting the salient facts in different colors according to the associated dimension, summarizing them superficially, then in a more exhaustive way in the grid.

The collection, transcription and analyses of these interviews are still ongoing. Up to now, we analyzed three of them and obtained some interesting results: each of the interviews presents on one side, some elements that play *in favor* of integrating computer science in mathematics teaching, on the other side, some deeper elements revealing resistances and playing *against* this integration. These elements are identified according to the dimension they belong to cognitive, mediative, institutional, social, or personal. We thus obtained a picture of how each dimension of the profession weighs. The picture is discussed in the last section; we summarize here the salient facts for the three interviews.

4. Teachers’ opinions about computer science integration within maths curricula

Interview 1 - Salient facts:

- An opposition between openly stated opinions that refers mainly to **institutional and social components**, and a deeper opinion rather conflicting with the first one.
- A **cognitive component** very little present
- A **personal component** opposed to what is openly expressed

Indeed, Teacher 1 clearly expresses a positive attitude at the beginning of the interview:

- She is “for” the integration of computer science in mathematics teaching at primary school levels. The arguments that she gives are situated here at **institutional, mediative and social** levels. There is not any “pro” argument at cognitive level (except very superficially, and not for mathematics, but to evoke the benefits of some word processing software for the teaching and learning of French language, thanks to typing texts and formatting).
- She uses "politically correct" arguments (**institutional**) when she needs to explain why she does not use these software despite the favorable position she stated: lack of training, lack of equipment, lack of quality connection, old school… Resorting to **institutional and social components** (she is in a very particular environment), she admits reticently her “lack of interest"

Cognitive component: in her discourse, the cognitive component is not very present. Basically, she has the following representations: “computer science” means “hardware, computer, tools”, and “teaching computer science” means essentially having an interactive video projector and teaching students to use some tools” (essentially Office tools). Let us note that the word "programming" was used once (to say that the teachers would be interested in it)

Personal component: As the interview progresses, an "opposing" view to the displayed acceptance reveals. We access to what she thinks deeply (which is "not correct" according to her):

- Regarding students: she is against screens, against children always being on them. These opinions conflict with the institution (programs) and what is promoted in society (modern aspects, etc.). Therefore, she has difficulty saying these opinions, even asking “do I have the right to say that?”…
- Regarding her own person: as to her person, she finally admits that she is not "hyper motivated by", that she is not "interested" in these novelties (computer science, Scratch, robots…)
- It is also interesting to note that she explicitly expresses her need of **didactic reference points**: she says that she feels not comfortable with this teaching, that she, would like to ask her colleague, who does it, how she does it, she lacks resources that would help her “at the beginning”. The precision about the “beginning” makes us reasonably think that the didactic reference points are missing. Once acquired, she would be able to go on without help.

Interview 2- Salient facts:

Here, the “political correctness” is present too and refers to **institutional and social** components. The **cognitive** component is much more present than in interview 1 as for mathematics:

- The link here to mathematics teaching goes with a more developed professional instrumental genesis of computer tools. The teacher explicitly exploits ICT to do math sessions.
- Teacher 2 is conscious that “computer science” means also “learning to program”, but he says he is not comfortable in this field.

Regarding the **personal component:** teacher 2 has personal interest in computers. He likes learning about this field; he even mentions quantum computers... The main obstacle here is not his personal opinion. What he feels as an obstacle is the time to solve hardware problems plus the time of the students' instrumental geneses, essentially because of the teacher's usual orchestrations: his practices consist of letting students explore during several sessions. This indicates some needs in training, not at technical level, but at didactic (in particular mediative) level in order to gain different approach and see different orchestrations allowing saving time on the students' instrumental geneses. Besides, he adds that the lack of training on technological abilities is not a hindrance for him.

Interview 3- Salient facts:

Teacher 3 is specialized in the use of digital technology for sports. Related to **institutional and social components**: the "politically correct" is present here again. Regarding the **cognitive component**: Teacher 3 says his sessions always mix aims that are both numerical skills and disciplinary contents: mathematics or French language. The sessions are thus orchestrated in a way that allows the students' instrumental genesis to develop at the same time numerical skills and content knowledge (a point that was difficult for Teacher 2). Besides, he also distinguishes the learning of computer science from the learning of using tool *to serve* other disciplines. Yet, he reduces the place of computer science in the curricula to "digital" aspects, *i.e*. knowing how to use digital tools, particularly how to use a computer.

The **personal component:** compared to Teacher 2, the interview shows more than interest from the part of Teacher 3: he states "I like it. (…) I like to use digital" and repeats this several times.

- His **professional instrumental geneses** with digital technologies seem quite developed. For instance, he is conscious of the need to homogenize the different instrumental geneses of the students, or still the fact that some tools require a smaller personal instrumental genesis (L 151). He also explains that it is necessary to have a minimum of **personal and professional instrumental geneses** before starting in class (3.TDP44, 96). Regarding the **orchestrations**: he never does sessions aiming at "techniques for techniques". However, he mentions the need for a free exploration/discovery session (3.TDP120) if the tool is new, but in the following sessions, afterwards the technical learning is always mixed with other disciplinary aims.
- He also evokes (3.TDP30) the question of the **distance to old practices**, stating that he starts from his usual practices, then sees what and how it is possible to go on (3.TDP96). Some tools are less easy and, as Teacher 2, he explicitly states the lack and need of landmarks in some cases (3.TDP118). For instance, he needs references for the different orchestrations with the robots:

  3.TDP153 there are many people, who would like to start with robots but do not know how, where to start with the students. There are lots of questions" (...) it's difficult to start in front of 25 children without being ready. You can plan a session and it can go in all directions [laughs]. I've been preparing sessions for quite a few years now and there is never a session that goes the way we imagined. So, we must be able to bounce back and that's also what must scare some teachers, they wonder if they'll be able to react to a technical problem, able to answer all the questions… This is a concern of our profession.

5. First results and Discussion

The previous section gives an overview of the kind of analyses that we are undertaking, using the theoretical concepts in the form of the grid of analysis. Reporting the statements in the grid allows showing where the positive and the negative arguments are respectively situated. For example, the Tab.3 shows the grid for the teacher 1.

Analogous pictures are obtained with the teacher 2 and 3. Synthetizing these analyses gives a picture of how these 3 teachers perceive the “newness” and its distance to their usual practices. For questions of space, here we give a summary of the results obtained in this final picture.

Table 3: Use of the grid to analyze the teacher 1 Interview

	Components	Positive arguments	Negative arguments/ barriers to integration
Instit. and social dim. (in the personal comp.)	- Institutional - Social	- 1.TDP8-16-52 - 1.TDP64	- 1.TDP60 - 1.TDP90-92
Didactic dim (in the personal component) *(instrumentation)*	- Cognitive Mediative	*Didactic landmarks:* 1.TDP16-28-52	*Lack of didactic landmarks:* 1.TDP28-30-46 *Needs for equipment:* 1.TDP24-26-68-80 *Needs for training (instrumentation):* 1.TPD24-30
P: Personal dimension (in the personal component)	Among which teachers' reports on their - Representations - Epistemology		*Representations about their own abilities with digital technologies or with computer science):* 1.TPD8-11-12-14-20-21- 26-28-30-36-46-54-58-60-74-78-90-92-54-74 *Representations of what is computer science limited to “material equipment”:* 1.TD32-38-42-50-60-70 Personal interests: 1.TDP74-78-

Some convergences in the teachers' discourses

Regarding these three interviews, the theoretical grid shows some convergences:

It is less the arguments "officially" announced by the teachers (the "political correctness": training, tools, resources...) than personal arguments (vision/conception of the disciplines, of the teaching, of the learning etc.) that play in the teachers' integration of technology and computer science in mathematics teaching.

These 2 "poles" of arguments are sometimes opposed (personal versus institutional component) such as positive and negative arguments clearly draw two separated sets.

The positive arguments are situated mainly on institutional and social components, whereas negative ones pertain to the teacher's personal dimensions: personal representations of their own abilities (in computer science and with technology), personal representation of what is computer science, personal interests, and personal epistemology and ethical considerations about their social and educative role and the meaning of teaching.

Regarding the cognitive and mediative dimensions, they mainly play as barriers: the didactic landmarks are crucial in these innovative situations. These latter move the teachers away from their didactic landmarks formerly built. New marks, guiding the teacher in her action, must be created. If former references are too much disrupted without new ones being considered, the teacher will not integrate the novelty: the teachers clearly express the need for gaining didactic landmarks on cognitive and mediative levels. In some rare cases, they play positively, the teachers mainly seeing the benefit of using ICT to teach transdisciplinary aims (work in pairs, investigating procedures…). We meet here the results of previous research (Haspekian & Gélis, 2021), where we explained that this choice is not fortuitous: choosing transdisciplinary aims provides well-known landmarks, easily transferable to new situations because without underlying disciplinary concepts.

Discussion and perspectives for the research

In conclusion, drawing on the two theoretical frameworks of the Instrumental Approach and the Double Approach, we used concepts such as instrumental geneses, distance/landmarks, or personal component, to understand what is at stake when teachers implement new practices involving digital tools and computer science. This allowed identifying what is critical in this implementation:

- it is less the arguments "officially" announced by the teachers (the "political correctness": training, tools, resources...) than more personal arguments (vision/conception of the disciplines, of their teaching, of learning etc.) that play.
- these 2 "poles" of arguments are sometimes opposed (personal versus institutional component)

These concepts have been used before to analyze the practices observed with robots and Scratch. In both cases, they appear helpful to analyze the data. Yet, in the case of interviews, we access more deeply to the personal component. Therefore, we chose this type of data to explore teachers' personal opinions, which is not accessible if only observing effective practices. Conversely, the cognitive and mediative components are more accessible with observations; they are only indirectly caught (and may present some bias) with interviews.

It could be interesting to compare this approach with others, such as TPACK (Mishra & Koehler, 2006), or the *Mathematics Knowledge for Teaching* (Ball et al., 2008). Some of the concepts used here, as the double instrumental genesis, have already been used to find some connections between the Instrumental approach and TPACK (Tabach & Trgalová, 2019) and we have previously evoked too these connections (Haspekian, 2018, 2020), but this work is still on-going. Yet, some more general reflexions revisiting theories that frame research on teaching mathematics with digital technology can be found in Sinclair et al. (to come).

Lastly, the analyzes should be pursued at a larger scale, interviewing more teachers. The idea would also be to interview different categories and compare the pictures obtained for each category: primary school teachers, secondary mathematics teachers and secondary technology teachers. One could reasonably presume that the pictures will be different, especially in terms of the epistemological component, due to the due to their different professional identities and specific background.

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