TEEN-IMMIGRANTS EXPLORE A MATH MOBILE APP

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We present the pilot phase of the project "Teenagers Experience Empowerment by Numbers" (TEEN), which is funded by Politecnico di Milano through the Polisocial Award 2018 and concerns the development of a mobile app to teach essential mathematics to young immigrants. The project aims at preparing them for living in a conscious, autonomous way in a Western country, increasing their ability to deal with everyday tasks that require some mathematical understanding. We present the app, some materials and an activity with the learners who have interacted with that. The set of tasks, tested in small groups, is rooted in daily activities, such as shopping at the supermarket, choosing a mobile internet plan, planning a trip. Our theoretical background is related to existing research findings on teaching to immigrants, Rabardel's instrumental orchestration and feedback.

Keywords: Immigrants; Intelligent Tutoring Systems; Out-of-school mathematics.

INTRODUCTION

The research project TEEN (Teenagers Experience Empowerment by Numbers http://www.teen.polimi.it) deals with the phenomenon of young immigration, from Africa to Europe, which has received increasing attention in the last years, given the very large number of young immigrants who leave their country (without parents). Once they arrive in Italy, the teen-immigrants are accommodated in communities for minors. Institutional protection plans provide teen-immigrants for their basic needs (accommodation, food, health services and a language course). This turns out to be insufficient to deal with the requirements of the "real world" that they need to face early, considering that the protection guaranteed by the Italian legislation to foreign unaccompanied minors ends on the day of their 18th birthday. The TEEN project aims at promoting basic mathematical literacy as another fundamental right that may significantly increase the level of autonomy of teen-immigrants, helping them to deal with daily needs, such as to manage their monthly budget, to buy a train ticket, to read the pay slip, and even to manage their time. All these activities have a common root, that is: the understanding of elementary mathematics.

The idea that mathematics can play a role in social integration of disadvantaged students has been proven successful in other contexts. Civil (2008) reports a growing attention towards mathematics taught to immigrant students at school, with a special focus on both developing educational methodologies which improve the immigrant students' learning; and exploring and pointing out the social and ethical implications of teaching mathematics to a "minority". Powell and Brantlinger (2008) shed a light on the actual tension between "academic" and "everyday" mathematics, underlying the centrality, for mathematics teachers, to create alternative curricula with the purpose of showing mathematics as an accessible (and useful) discipline. It is crucial that teachers promote a new idea of mathematics as valuable skills and social integration. In Greece, Stathopoulou and Kalabasis (2007) and Chronaki (2005) have provided evidence that Romani students learn better when mathematics is related to their identity and their attitudes. In U.S., Gutstein (2003) shows that if teachers consider the students' language and the way they interact when they design the lesson, the students turn out to be more aware of the role of mathematics, and tend to appreciate the discipline.

Drawing on these research findings, the TEEN project aims at developing a mobile app that can be used by teen-immigrants, outside the context of the classroom and without the interaction with a teacher, to develop their basic mathematical skills. In order to make the discipline more accessible and attractive, the app is designed to deal with everyday mathematics, with non-academic language and, to be inclusive, with the least possible amount of written words. The activities proposed by the app address situations that are familiar for teen-immigrants. In designing the app for teaching mathematics to teen-immigrants, we consider the app both as an artefact and as an instrument, in Rabardel's (1995) sense. In the sequel, we first recall the theoretical framework that informed the design of the app, then we present the results from the pilot phase of the project, which consists of activities carried on with small groups of immigrants organized in the communities where they live.

THEORETICAL FRAMEWORK

Artefact is an object designed with the purpose to achieve a particular goal and embedding a specific knowledge (Rabardel, 1995). Within this view, artefacts can be seen as facilitators of knowledge acquisition, or more generally as extensions of the individual. However, Radford (2012) stresses that artefacts can play a deep cognitive role: artefacts "become part of the way in which we come to think and know" (p.285): in a Vygotskyan perspective, in fact, human cognition is affected by its relationship with social and cultural settings, which are grounded in the use of artefacts. Artefacts are cultural devices that shape, affect and change our cognitive functioning (Radford, 2012). Since artefacts are artificial devices, Radford (2012) argues that "investigating the proper conditions of artifact use in educational settings constitutes an important research problem" (p.283).

Instrument is the artefact jointly with the utilization schemes developed while the individual uses it. This notion of instrument allows us to take into account both the artefact itself and its actual use, namely to distinguish between the intention of the designer, who produces the artefact, and its use. In case of a learner, through a cognitive artefact she is supposed to internalize knowledge embedded in it. In particular, we are interested in the instrumental genesis, a process that underlies the construction and evolution of the instrument (Beguin and Rabardel, 2000) and encompasses two dimensions related to the subject: instrumentalization and instrumentation. Instrumentalization concerns the recognition of the features of the artefact, for instance its potentialities and constraints. In this perspective, the artifact evolves as the learner's activity unfolds. Instrumentation concerns the way(s) the subject interacts with the artefact: utilization schemes are built and enhanced by the learner. The "utilization scheme" (Rabardel, 1995) is intended as an active structure into which past experiences are incorporated and organized. The schemes have a history, they may change and are characterized by private and social dimensions. The social one can be thought of as the transmission of the schemes, in particular those that are embedded by the designers of the artifact, including various type of user aids, for instance manuals and instructions (Béguin & Rabardel, 2000).

An important research imperative, thus, concerns not only a general focus on the conditions under which artifacts are effective in educational settings, as Radford (2012) put it, but in particular on the social dimension of utilization schemes, and even more specifically on the way instruments provide effective feedback to the users. This holds true especially for educational software that offers guided learning support to students engaged in activities like problem solving. The kind of support may range from identifying and correcting errors to promoting mastery learning (Baker, D'Mello, Rodrigo & Graesser, 2009). Feedback is information provided by an agent (e.g., teacher, peer) regarding aspects of one's performance or understanding, and it is seen as "consequence" of performance (Hattie & Timperley, 2007). Also Intelligent Tutoring Systems (ITS) can provide valuable feedback, according to Baker et al. (2009). Hattie and Timperley (2007) argue that feedback should address the goal, the progress and the quality of the performance of a learner, helping her answering three questions: Where

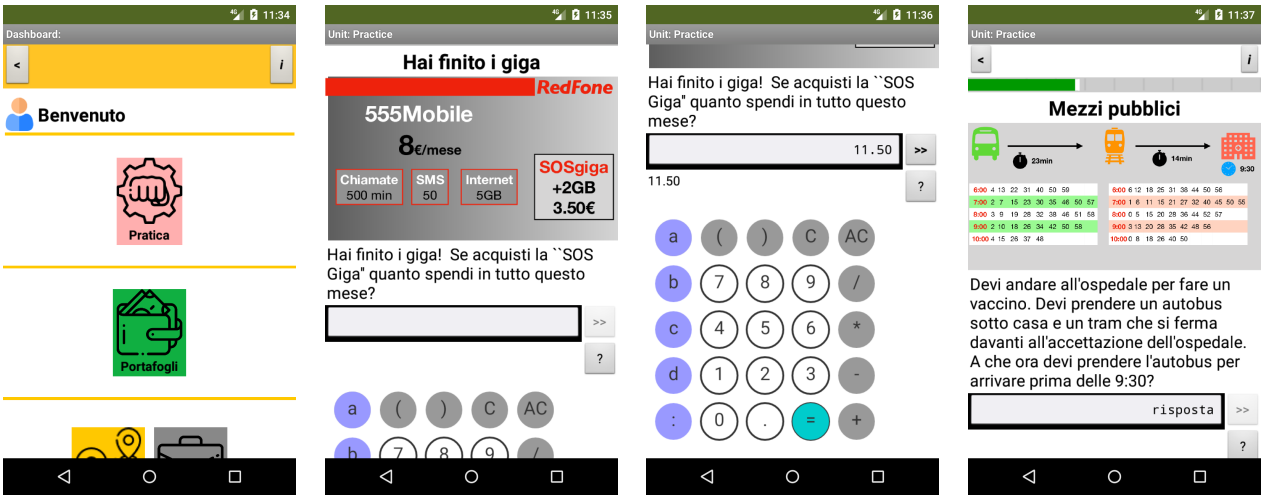
am I going? How am I doing? and Where to next? Moreover, these questions, which correspond to notions of “feed up”, “feed back”, and “feed forward”, work at four levels (Hattie & Timperley, 2007): the one of the task, if they provide information about how well tasks are understood and/or performed; the level of the process; the level of self-regulation, if they concern self-monitoring, directing and regulating of actions; and the level of self, if they point to personal evaluations and positively affect learner’s identities. Hattie and Timperley (2007) also point out that feedback is part of a range of practices that aid the learners’ understanding. Moreover, feedback and instruction become intertwined until the provided aid is not a sole check of correctness (Hattie & Timperley, 2007). In the process of instrumental genesis, thus, the nature of feedback provided by the artefact can be considered as part of its features.

METHODOLOGY

We aim at answering the following research question: which features of the app emerge from immigrant’s interaction with it, that can help us design a proper feedback system? In order to address this question, we report data from an activity that took place on November 2018 in one community for minors that hosts teen-immigrants. It involved two teenagers who come from Africa, which are fictitiously named Drissa and Sedou. Drissa comes from Mali, where he attended elementary school; he has been in Italy for two years and he is attending middle school (grade 6). Sedou comes from Ivory Coast and has been in Italy for 1 year. Sedou has never attended school in Africa and he is attending a language course (level A1). Both of them do not work and live in a large community of 20 people.

This activity is part of a three-months long pilot phase of the project TEEN. The research project follows a design-based research methodology, which focuses on examining a particular intervention by continuous iteration of design, enactment, analysis, and redesign (Cobb *et al.*, 2003). The pilot phase of TEEN consists of meetings with groups of teen-immigrants in different communities, which provided us with important information about the functioning of the app. The goal of the research is, in fact, to produce an app for smartphone that can be used by teenagers outside school, without the aid of any tutor or teacher. Following Powell e Brantlinger (2008), we aim at designing an app that proposes "everyday" mathematical problems, given the importance of showing mathematics as an accessible discipline. Following Stathopoulou & Kalabasis (2007) and Chronaki (2005), the problems presented in the app relate to teen-immigrants’ identities and attitudes. Along this line, following also Gutstein (2003), we consider the teen-immigrants’ language, and in particular we tried to reduced the verbosity of the tasks given their difficulties with the Italian language, supporting the problem statements with graphical content. Four meetings in three different communities took place in the pilot phase. Each meeting lasted between 60 and 90 minutes. We selected the case of Drissa and Sedou, because it illuminates important aspects of the interaction with the app. In some meetings, we observed difficulties mostly related to the Italian language, that were overcame talking in English and Bambara language thank the mediation of a peer who speaks I. In other meetings, the emotional burden provoked by our presence was overwhelming. We agree with Civil (2008) that the difficulties related to data collection within this special sample of teenagers are part of the ethical issues concerning working with a minority.

The app is structured as follows (Figure 1a): it proposes some practice problems, which involve basic mathematical facts, to allow the user to become confident with the instrument. For example, a calculator is embedded in the app and it is activated once the user clicks on the blank space to submit her answer (Figure 1c). After the practice section, the users are engaged in a budgeting activity, in which they have to make their lifestyle compatible with a given salary (as a 18-years-old boy in Italy). Then, more complex scenarios are proposed and problem solving tasks are shown.



a) The dashboard b) Task 1 c) The calculator d) Task 4

Figure 1. Screenshot from the app used for the pilot phase

The practice section represents the most challenging part of the app and it is the focus of this paper. Being the entrance door of the app, it should be engaging, easy to be understood even by teenagers who are not fluent in Italian, intriguing, not boring, and self-explaining given that in the experimental phase of the project TEEN the users would no longer interact with a tutor. In order to monitor all these features of the practice section, we employed Rabardel's notions of intrumentation and instrumentalisation to examine how the app is experienced by teenagers and the utilisation schemes that are prompted. At the same time, we examine the nature of feedback that is provided by the tutor (who was present for the pilot phase).

DATA ANALYSIS

To recall, we now present an excerpt from a meeting with Drissa and Sedou. They are presented for the first time with the app and they have been invited to explore it. The first task they encounter concerns the choice of a fare for the monthly internet plan (Figure 1b). From previous meetings with the educators who work in the community, we know that these boys take into consideration two important features of a monthly fare for mobile phone: one is the possibility to surf the internet the most possible, and the other one is the possibility to call their country of origin (that is even more important), spending the least possible money. The former need is addressed in the first task.

For a long while, Drissa and Sedou remain silent, reading the question on the screen of the smartphone: "You have finished your giga for this month. If you buy the SOS-giga, how much do you spend this month?". The tutor noticed that they are struggling with its meaning and that they are also reading the text embedded in the image (Figure 1b), where it is shown that the monthly fee for internet mobile is 8 euros (which gives 5 giga), and the SOS-giga (which gives 2 extra giga) costs 3.50 euros. The tutor, after some minutes of silence, intervenes: "this is about your mobile phone, do you use it to surf on the web? Do you have 'Giga'? Have you ever finished your giga before the end of the month?" While Drissa replies that he has an internet plan, and adds "but I never ended the giga", Sedou says "I do not have internet". The tutor addresses Drissa, and asks "Really? Have you ever received an SMS proposing SOS internet?" [when the monthly data are going to finish, the company texts customers to offer extra internet data]. And Drissa replies "Oh! Yes, I have! but I wait for the next month, and I use only wifi connection". Then the tutor asks Drissa and Sedou to figure out the problem in this way: "But if you pay 8€ monthly, and you need more data, so you pay further 3.5€ to have extra data, how much do you pay?". Drissa answers: "11.50".

We recall that the app shows a blank space under the question, which is meant to be used as a calculator. However, Drissa makes the computation by heart. We notice that, in terms of instrumentalisation, Drissa is not fully exploiting the potentiality of the app. In terms of the learning trajectory designed for the use of the app, since this task is the simplest one, Drissa is missing the opportunity to practice with the calculator add-on (see Figure 1.c), which becomes essential in more complex tasks (later). In other words, we notice that the process of instrumentation vanishes, and Drissa is not acquiring its basic utilization schemes. We further comment that the nature of the question, and the computations required, are too simple to require the (proper) use of the app as a calculator, and this hinders Drissa's instrumentalisation process. The tutor intervenes two times: the first one, to clarify the task and to connect it to Drissa's and Sedou's sense-making. The second time, given that Drissa and Sedou do not buy extra giga, the tutor invites them to answer to the question anyway.

The interaction among Drissa, Sedou and the tutor goes on. Once Drissa has found the answer, the tutor invites him to write this number in the blank space, and to record his answer on the app. Drissa has difficulties to write the number 11.50 due to the point that indicates the decimal number. Drissa searches for the comma, which in his understanding signals the decimal number. We comment that this difficulty with the writing is mostly related to the representation of decimal numbers (in Italy, differently from English speaking countries, the comma separates the decimals). Another difficulty is related to a feature of the app, that is: once Drissa has written the answer "11.50", he shows difficulties in figuring out how to submit the answer. The command is an equal sign, which does not make sense if one does not insert a computation to be carried out, e.g. 8+3.5. In this case, Drissa aims at writing only the result of the sum: namely, 11.5. In terms of the process of instrumentalisation, we notice that this is a constraint of the app.

Drissa submits the answer and the app provides a positive feedback, that is "right answer", then Drissa and Sedou are exposed to the second task, which concerns the buying of milk at the superstore: "A bottle of milk costs 1.50 euros. How do 12 bottles cost?" They read the task and suddenly they activate the calculator embedded in the app to compute the multiplication. We observe that the time required to make sense of the task is shorter with respect the previous one and, in terms of instrumentation, the utilization scheme concerning the activation of the calculator is surfacing. At this point of the episode a new difficulty is observed: Drissa inserts 1.50 and searches for the multiplication sign, that is expected to be "x", but the calculator presents the symbol "*". Like in the first task, we see a difficulty related to the representation of mathematical objects, which can be read as a constraint in terms of the process of instrumentalization. The tutor has to intervene and shows the symbol for multiplication. Drissa performs the multiplication and clicks on the equal sign. The app provides the results, which is 18, and a positive feedback. A this point the third task shows up, Drissa and Sedou deal with it quickly and not showing difficulties related to the process of instrumental genesis.

Then, a task concerning time to arrive at the hospital with public transport is presented: "You have to go to the hospital for vaccination. There is a bus stop in front of your home. You have to take a bus that stops there, then you have to take a tram which stops in front of the entrance of the hospital. Which time should you take the bus to arrive before 9.30?" Above the text of the problem there is an image (Figure 1d).

Sedou: I have to take the bus at 8:30, because if I take the bus at 9:30 I arrive late.

Drissa: Yes, you have to arrive before 9:30.

Tutor: If you leave at 8:30, which time do you arrive?

Drissa: The bus takes one hour.

The first interactions around the task show that Sedou is making sense of the situation: in the past, someone might have explained that, in order to be punctual for a meeting, one has not to get out from home at the time he has to be there. Drissa believes that the bus takes one hour to bring him to the hospital. Both boys are not taking into consideration the information provided in the image, where the bus and the tram schedules are given. The image contains relevant information to perform the task. The tutor intervenes and, referring to the time schedule, he asks: "Have you ever seen this table?". Drissa and Sedou reply negatively and the tutor explains the meaning of it. At a certain point, Drissa says "I should take the bus at 8:20", and the tutor asks if this time is present on the bus schedule. Drissa replies "We should compute the one that we have to take before we arrive. If you take…" and Sedou "Let's leave at 8:19".

Tutor: If you leave at 8:19, which time do you arrive at the tram stop?

Drissa: 23 minutes

Tutor: To arrive ...where?

Drissa: At the tram stop

Tutor: So, how long does the journey take?

Instead of answering to the tutor's question, Drissa proposes "I should take 8:28 to arrive at 9:30". The tutor follows his line of reasoning: "Is there 8:28 on the bus schedule?", and Drissa replies affirmatively. Then the tutor proposes again "If I take 8:28, which time do I arrive at the tram stop?" This time, Drissa replies: "8:41 no… 8:51", so the tutor asks: "If I arrive at 8:51, I can take the tram at 8:52. Is it clear?". Instead of answering, Drissa tries another time on the bus schedule (8:03). The tutor asks to check the time they arrive at the tram stop in case they take the bus at 8:03, and so which tram they can take. Drissa replies that at 8:42 they arrive at the hospital.

Tutor: 40 minutes behind schedule. Too early. So, what do we do? Do we leave later?

Drissa: Yes, this one [8:38]

We notice that Drissa acts as if he can click on the touchscreen, on the time schedule. He does not only point to the time, but he acts as if an action is expected to be taken by the app after his choice. However, the answer should be written in the blank space, not selected on the touchscreen. In terms of instrumentalisation, this feature of the app can be seen as a constraint on the range of possible actions that can be undertaken.

Drissa: Early. Too early. 9:20 is fine.

Sedou: However, the earlier the better.

Drissa: Let's try with 8:46

Sedou: 8:46 + 23

Drissa: Yes, 9:09

Tutor: So, which tram do you take?

Drissa: 9:13

Tutor: 9:13 + 14, which time do you arrive at the hospital?

Drissa: 9:27. This is ok!

Drissa writes the answer on the app. Drissa and Sedou have proceeded by trial and error, with a significant amount of feedback provided by the tutor. As the episode unfolds, we notice that the

students gradually acquire the utilization schemes regarding the bus and tram schedule: they select a time from the bus schedule, then they compute the time they need to arrive at the tram stop, then the time they need to arrive at the hospital.

Few minutes later, the tutor asks Drissa and Sedou if they have found the activity interesting. They comment that all the tasks were interesting and useful for them, in particular Drissa says: "I think that the time schedule for the public transportation is very useful. Very good. We all arrive at the train station 40 minutes, 30 minutes in advance, because we do not know how to read the time schedule. The Italian people arrive 2 minutes before departure. We need to know how to read the time schedule, and not to arrive so early at the station". This comment arises another interesting theme concerning the app use, that is: the perceived usefulness of the task, and the consequent motivation that may derive. Affective issues related to the use of an app of this sort have been proven important by Andrà, Parolini and Verani (2016), however they are not the focus of this work. Further investigation is, thus, necessary. We can see that one of the features of the app that is related to the process of instrumentalisation is the possibility to start over again, trying different times and see which one is best. Being able to catch teen-immigrants attention for an extended period of time in order to solve a task is one of the features of the app that we aim at developing.

DISCUSSION AND CONCLUSIONS

The goal of our work is to understand the process of instrumental genesis related to the app designed for teen-immigrants, in order to inform a second step of design of the app. To this end, we want to figure out the features of the app that either promote or obstruct the instrumental genesis that supports the acquisition of basic mathematical skills. The episodes relate to different contexts of everyday life: the internet monthly fee for mobile phone, the price of items at the superstore, public transport. In the first and the third cases, Drissa and Sedou show difficulties in understanding the task: in the case of extra giga, neither Drissa and Sedou have used them, so the tutor has to intervene and asks them to solve the problem arithmetically; in the case of the trip to the hospital, they have experience of it, to the point that they say they are frustrated by the time they need to read a bus schedule, and they struggle for completing the task. The reported episodes further allow us to observe that difficulties of different kinds emerge: a difference in the representation of the mathematical objects (e.g., decimal numbers and multiplication), the use of the calculator embedded in the app, the ambiguous meaning of the equal sign, and reading a bus time schedule.

As we observe how teen-immigrants overcome these difficulties, the process of instrumental genesis unfolds. We notice that the process of instrumentation goes on quite straightforwardly, since Drissa and Sedou progressively acquire the utilization schemes that are necessary. In fact, the first time they make a mistake, or they do not know how to proceed, they learn how to deal with an unfamiliar situation and became able to effectively apply what they have learnt in the subsequent tasks. For example, in the first task Drissa faces difficulties with the point for the decimals and equal sign for submitting the answer, but in the second task he immediately writes 1.50 and uses the equal sign appropriately.

With respect to the urgency of redesigning the app so that it promotes teen-immigrants' learning without the support of a tutor, we can conclude that it is necessary to find a way to avoid the difficulties related to differences in the representation of mathematical objects. For example, a tutorial that pops up in the first tasks, or when appropriate, and shows how to proceed. The bus schedule task deserves special attention, given the importance it has for teenagers like Drissa and Sedou. The structure of the feedback to support the understanding of the bus schedule needs to be more complex, and the single task may be subdivided into more tasks. The bus schedule task further shows that immigrants persist on it, since it is relevant for them.

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