The Complexity of Integrating Technology Enhanced Learning in Special Math Education – A Case Study

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Abstract. We present a study of integrating an educational game in special math education, to explore challenges faced during the process. The game promotes an unconventional approach supporting students having math difficulties, through visual representations, learn-by-exploration and learn-by-teaching models. Our conclusion is that integration in special education is more challenging than in the main stream counterpart, due to social vulnerability of the students, learning/teaching challenges in content, motivation and attitude, a non-typical learning situation, and the challenge of matching learning peers.

Keywords: technology enhanced learning, educational game, mathematics, integration, special education.

1 Introduction

Difficulties with mathematics are often rooted in elementary school [11], but may not become apparent until later. Research suggests that mathematical curriculum for student with learning disabilities should focus on a few important concepts (such as the basic operations of arithmetic) to mastery rather than numerous skills superficially [5]. Special education mathematics instruction still continues to focus on computation rather than mathematical understanding [5]. Problems with math may result in low self-esteem, low confidence and lack of interest. Trying to solve problems without understanding the underlying concepts, creates passive learners and may result in learned helplessness [11]. Repeatedly experiencing negative feelings, such as failure, math anxiety or stress, may result in reduced/low motivation [1, 20] and negative self-confirmation [1]. For students with math difficulties, it is recommended to encourage to “talk math” [4], to use motivational practices such as games [4], and to use board games and other manipulatives as well as instructional software [9].

Educational games as learning tools have documented potential for learning and motivation [7, 22, 4, 9]. We have developed a Technology Enhanced Learning game (TEL game) aiming at conceptual understanding of arithmetic, which is suitable for learners with math difficulties [14] and has shown to benefit low-performing students in an ordinary classroom situation [16]. In this study, *we explore which challenges are faced when integrating the TEL game in a practical special education situation*. Before going into the study, we will describe the TEL game.

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2 The Technology Enhanced Learning Game

It is far from evident how to design a game environment which fosters deep mathematical understanding [12]. Our approach is to provide, for the domain arithmetic, 1) a graphical, animated representation, 2) a behavioural model which is explored through game play and 3) an intelligent agent that can be taught to play the game. This yields an engaging game that promotes self-regulation, conceptual understanding and discussions, which is appropriate for learners with difficulties.

The graphical representation is a metaphor for arithmetic: integers are represented as coloured squares and square boxes (Figure 1), where 1's are red squares, 10's are orange square boxes containing 10 red squares, and so forth. Square-boxes are packed and unpacked, to explicitly show carrying and borrowing. Such low-stress algorithms help conceptual understanding [9]. It is a constructive, visually rich representation, which is often essential for learners with difficulties [21]. The metaphor provides a language to talk math, e.g., "*we must unpack the orange square-box, to get more red squares*". The metaphor explains basic arithmetic in an unconventional way, which means that the relation to math can be hidden until the learner is ready for it: particularly important for learners with math anxiety.

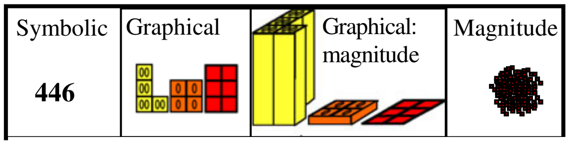

Fig. 1. Representation of positive integers

The graphical representation is used in a simulation model. Mathematical rules are built-in: the model behaves like proper arithmetic. Two-player card and board games are developed on top of the model. Each player act an operation and receives a set of cards with graphical numbers. They take turn choosing a card which is added to a game board, also representing a number. Hence, a game constitutes a sequence of computations, but the task of the players is to choose good cards according to various game goals, such as maximizing number of carryings or number of zeroes. Playing well requires reasoning and anticipating results (i.e., perform mental calculations). Reasoning is fundamental to conceptual understanding and problem solving [6]. Games can be played competitively or collaboratively, but productive strategies are different. Learners can explore how computations behave, how to play strategically, and how to invent solution methods. By inventing methods students learn in a deeper and more lasting way, and should also be allowed for students with difficulties [19].

Guidance and reflection techniques are often required in games to help learners achieve deep understanding [8, 10, 12]. A teachable agent, which is an intelligent agent that can learn [3], can provide both [18]. In our game, students train agents to play the game. The agent learns by observing and asking reflective questions. Teaching the agent is engaging [16], and students are encouraged to reflect on and self-explain their knowledge. The agent's knowledge is determined by the player's playing performance and responses to the questions (for details see [15]). Thus, the agent mirrors the student's knowledge level, but the externalization and disconnection from self makes performance levels easier to accept and talk about (the agent is performing poorly, not the student), which is important for students with low self-esteem and/or confidence.

3 Integration in Special Education – The Case Study

To explore challenges of integrating TEL in practical situations, we conducted a study in special education parallel to a larger study in main stream education. Here, we report results from special education, but use the main stream study as comparison. The study focused on students' attitudes; self-efficacy [2]; and performance in the TEL game compared to conventional math. A special education teacher and six of her students participated: two boys and four girls from 5th to 7th grade. The game play took place under natural circumstances: the teacher instructing students in pairs during regular classes twice a week planned to 40-50 minutes per session. The study involved pre/post-tests, observations, questionnaires and interviews with the teacher.

The pre-test included questions on attitude, self-efficacy, and traditional math problems. The attitude and self-efficacy involved judgments of concentration, subject difficulty, and ability to explain. The math test involved problems on arithmetic operations, the base-10 system, method invention, and negative numbers. The post-test consisted of a combined attitude, self-efficacy and math test, in the two contexts conventional math and the TEL game, in order to make comparisons.

Students played the TEL game for three weeks in class. Each pairs' game playing was observed and video-recorded at three occasions: the first, middle and last session. Recordings were roughly transcribed and analyzed to on students' attitude and ability through verbal statements, facial expressions, gestures and levels of engagement.

The teacher interview concerned her judgment of the students' attitudes and math abilities, and reflections on using the TEL game. Finally, the students' quantitative and qualitative performances in the game were analyzed through game logs.

Results from the pre-test are shown in Table 1: average scores (left part) and generalization to the levels (--,-,0,+,++) for the purpose of overview. Attitudes and self-efficacy were valued on the scale -5 to 5, math results denote percent correct.

Table 1. Results from pre-tests (specific to the left, and levels to the right)

Student/ results	D	M	E	L	N	S	(*)	Student/ levels	D	M	E	L	N	S
attitude	**3,0**	**-3,3**	**-3,6**	**-2,6**	**-0,7**	**2,0**	***-0,3***	attitude	**++**	**- -**	**-**	**-**	**0**	**+**
efficacy	**3,3**	**-1,6**	**-4,5**	**1,3**	**-1,5**	**-0,9**	***1,1***	efficacy	**++**	**-**	**- -**	**+**	**-**	**0**
math	**29%**	**65%**	**37%**	**50%**	**48%**	**24%**	***72%***	math	**--**	**++**	**-**	**+**	**0**	**- -**

(*) As comparison, average results from the same test with 53 5th grade students from the parallel study are included. The math results are as expected generally lower for our subjects, but for instance student M is close to average in performance, whereas attitude and self-efficacy is far below. Attitude and self-efficacy are lower in general. For level generalizations, the scale (--,-,0,+,++) is mapped to {[-5,-3), [-3,-1), [-1,1), [1,3), [3,5)} for attitude and self-efficacy, and to {[20,30), [30,40), [40,50), [50,60), [60,70)} for math performance. Note how different the 6 students' profiles are regarding attitude, self-efficacy and performance, e.g., D and M are each other's opposites. Attitude and self-efficacy are generally on similar levels, whereas self-efficacy (perceived performance) and actual performance differ up to 4 levels.

The post-test results are presented as *the difference* of performance in game and math representations, as shown in Table 2. From the attitude test questions of enjoyment of math, efficacy and enjoyment of explaining are reported, and from the math test problems on base-10, calculations, and negative numbers. “0” denotes same results in both representations, “+” better and “–“ worse in the game.

Table 2. Results from comparative post-tests (attitude left, math right)

Student/ Diff attitude	D	M	E	L	N	S	*avg*	Student/ Diff math	D	M	E	L	N	S
enjoyment	**4,5**	**10**	**6**	**4,8**	**5**	**1,3**	***5,3***	Base-10	**+**	**+**	**0**	**0**	**0**	**+**
efficacy explain	**0**	**5**	**4,8**	**4,3**	**4**	**-4**	***2,3***	calculation	**0**	**0**	**+**	**0**	**0**	**+**
enjoyment explain	**0,5**	**5,5**	**6,3**	**-0,8**	**5,3**	**-1,8**	***2,5***	Negative numbers	**0**	**-**	**0**	**0**	**0**	**0**

All students prefer the game to conventional math, 4 of 6 is much more confident explaining in the game and 3 of 6 enjoy it much more. For the math problems, 3 of 6 performed better for the base-10 problem, 2 of 6 in the calculation problem, whereas in the negative numbers problem 1 performed worse.

According to the teacher, all students regard math as a boring and difficult subject. Strong words as “*hates*” and “*detests*” are used. They seem to like the game, except for student L who has a negative attitude in general. It is hard for the students to reason and reflect in the game, and she believes some are mainly guessing. She tries to help by asking questions. She thinks the agent is good, and that the students like teaching it and watch it play, but the agent’s reflective questions are too frequent. The vague connection to math and the level of guessing worries her: “*they don’t see the numbers being represented*”. She has observed that the students are quiet and don’t help each other when playing competitively, more so when playing collaboratively. The reason might be that the students are not used to collaborate in math.

Being withdrawn from ordinary class is delicate, therefore sometimes refused, and it makes the students socially vulnerable. This reinforces exclusion and is questioned by the teacher. Students’ parents and other teachers have been informed of the study. Parents reactions of the new form of instruction varied from “*anything as long as it helps*” to worries that the student may fall behind even more. Finally, she admits that she is not convinced herself, which may have effected others.

4 Discussion

Several aspects influenced the students’ special instruction sessions: e.g. being withdrawn from ordinary class; taking instruction time to do unconventional math instead of practicing typical problems for tests; being influenced by parents; and the relation to the playing partner as learning companion.

The motivational dilemma and vulnerability when having to leave a movie in class for special math instruction while being called names from classmates, is easy to imagine. Such situations lead to avoidance of help, denial of the teacher among friends, and emotions of shame and distrust in self. Due to such circumstances, one of the students only attended the first observation, and one session only lasted for 6 minutes.

Despite the TEL game's unconventional approach and the students' negative attitude towards math, the teacher frequently pointed out the connection to math. As evident from the video recordings, some students reacted negatively to such instructions, and immediately lost interest or concentration. From this we learn that it is crucial to allow the teachers to become comfortable with the game and learning model prior to instruction, in order to mediate a confident and positive attitude.

While some parents reacted positively to the game, others were stressed by their children playing a game instead of "*doing real math*". They were afraid it would make the student fall behind further, and therefore not supportive of the activity. Parents' attitude is known to have strong influence on their children [17], and similar negative attitudes were shown by their children In fact, one student skipped game playing in favour for doing conventional math tasks difficult even for her peers.

The practice of selecting pairs of students for special instruction based on effective time scheduling, in particular for a pair activity as this game play, is understandable from a practical point of view but not from learning perspective. The relation between play partners can have negative impact on their learning situation: one student's uncertainty was reinforced by the more confident player's occasional lack of certainty. Another student's need for concentration was disturbed by the partner's loud requests for attention and acknowledgement. The mismatch resulted in separating the pair after the first observation. The last pair consisted of one student with a strong behaviour of negative self-confirmation, which may be rooted in a fixed ability belief [13], whereas her partner played intuitively without effort and yet scored a lot. Hence, neither of the pairs was an optimal learning constellation.

A learning situation is affected by the student's social network: the school, teacher, peers and parents. The student's own attitude towards learning, her perception of self, self-efficacy in relation to performance, attitude to the game and special education also influence the learning and motivational effect.

5 Conclusion

Integration of TEL in special education is more challenging than in ordinary classes, due to the social vulnerability of the students; the learning/teaching challenge with respect to content, motivation and attitude; the learning situation, and the challenge of matching learning peers. The latter because of the diversity regarding math level, type of difficulty, attitude and learning needs. Our recommendation is to take time to involve the student's social network, introduce the TEL to the involved teachers until comfortable, and provide support for unconventional approach to mathematics.

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