A teaching methodology focused on the use of a videogame: analysis of the engagement of students with special educational needs

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In this paper we reflect on the effects of a methodology based on the use of a videogame in terms of engagement of students with special educational needs. By referring to theoretical lenses useful to characterize students' in-the-moment engagement, we analyse data collected within a teaching experiment conducted within mixed-abilities lower secondary school classes. The results of our analysis show a general positive trend in the evolution of students' engagement structures.

Keywords: Special educational needs, videogames, inclusion, structures of engagement.

Introduction

The research documented in this paper is part of a wider study on the use of videogames in fostering inclusion in the teaching-learning of mathematics at primary and lower secondary school level. Different studies highlighted the potentialities of the use of videogames in fostering inclusive processes for students with special needs (Durkin et al., 2013), highlighting the key-role of fundamental dynamics that these methodologies trigger, such as identification, gradualness and non-public failure (Gee, 2003). In the case in which the use of videogames supports mathematics teaching, fostering inclusion requires a careful design of the teaching methodologies with the aim of giving to all the students the opportunity to "experience mathematics in ways which make sense to them" (Scherer et al., 2016, p. 641). Research has shown, in particular, the key-role of fostering students' reflections on: (a) the mathematics embedded within the videogame (Jorgensen (Zevenbergen), 2015); (b) the skills they develop when they play (Gros, 2007); (c) their own difficulties and the possible ways to overcome them (Van Eck, 2015).

In tune with these ideas, we designed a teaching methodology which combines the use of a videogame with the activation of reflective practices developed by students at both individual, peer and collective level. In this paper, we reflect on the effects of this methodology in terms of students with special educational needs engagement, by focusing on data from a teaching experiment carried out with mixed-abilities classes of lower secondary school.

Context of the study and teaching methodology

The teaching experiment on which this paper is focused involved 93 students of 5 mixed-abilities lower secondary school classes (grades 6 and 7) and their mathematics teachers. Here, we analyse the case of 25 pupils with special educational needs (in the following, SEN) belonging to these classes.

Before presenting these students, it is important to share some information about the Italian tradition in terms of inclusion. In Italy, differential classes were abolished during the 1970s. The issue of SEN has become central since 2012, when the Ministry of Education introduced a specific regulation that identifies three main categories of students with SEN: (A) students with certified disabilities (sensory, motor or psychic); (B) students with specific developmental disorders (dyslexia, dyscalculia, dysgraphia, dysorthography, attention deficit hyperactivity disorder and limiting or borderline cognitive functioning); and (C) students within a condition of socio-economic, linguistic or cultural disadvantage. The regulation introduces, in particular, a series of benefits for students belonging to these categories, such as the creation of personalized didactical plans that include didactic strategies based on the students' needs and a list of didactic tools to be used to support the students.

21 students, among the 25 on which the study is focused, belong to these three categories: 2 students belong to category (A), 15 students belong to category (B), and 4 students belong to category (C). Other 4 students not belonging to these categories were included within this study, due to their poor performance and the difficulty faced by the teacher in involving them during mathematics lessons.

Table 1: An example of activity that students face within Matematica Superpiatta

Description of the activity "Prime numbers"	Tools provided to students within the activity
The activity is divided into 6 tasks of increasing difficulty. The goal of each task is to complete a sequence of integer numbers by inserting the missing numbers. Each number in the sandbox game is represented as a block that can be searched and picked up, placed, or created (crafted) according to some rules. Students can find only prime numbers in the game field. Not prime numbers have to be crafted as products of prime numbers through the tools provided in the game.	"Inventory": a place when the user can collect objects gathered in the game field. "Crafting table": a table where prime numbers can be inserted to craft other numbers as products of prime numbers. "Pick": when used on a block containing a number, the block disappears from the world, appearing in the user inventory. In case the picked block does not contain a prime number, it is "broken" into blocks containing the prime factors, which appear in the inventory.

As stated above, during the teaching experiment we implemented a teaching methodology that combines the use of a sandbox videogame, Matematica Superpiatta (www.matematicasuperpiatta.it) with the activation of students' reflective practices. Matematica Superpiatta (in the following, MS) was designed with the aim of realizing a learning environment within which students could face challenging mathematical activities by interacting with the different tools at disposal. Table 1 summarizes one of the activities that students face within MS ("Prime numbers"), which is aimed at making them reflect on the decomposition of numbers in prime factors. The teaching methodology combines individual interactions with the MS and collective metacognitive reflections on the strategies implemented during this interaction and on the mathematical knowledge on which these strategies are based.

Table 2: Questions from the reflective worksheet related to the activity "Prime numbers"

Questions from the worksheet	Aims of the questions
(a) Which of these numbers can you find in the field? Why? (list of numbers written under the question: 11, 14, 27, 31, 59, 75) (b) How do you find the useful numbers to be put in the crafting table?	Questions (a) and (b) are aimed at making students reflect on the mathematical knowledge on which the activity is focused and on the strategies that they adopted during the game.
(c) Does the game become easier or harder when you progress through the levels? Why? (d) What did you learn through this activity?	Questions (c) and (d) are aimed at making students reflect on their own experience of learning through the use of the videogame.

The teaching methodology is characterized by this sequence of phases: individual interaction with MS (phase 1); individual (phase 2) and small groups' (phase 3) reflections on the activities faced within MS; and collective discussions aimed at sharing and comparing ideas, enhancing the contribution of each student in the collective construction of meanings (phase 4). Specific reflecting worksheets have been designed to support students' metacognitive reflections during phases 2 and 3. Examples of questions from the reflecting worksheet proposed after students' individual interaction with the activity "Prime numbers" are presented in Table 2.

Research framework and research questions

Motivation plays a fundamental role, especially in the case of students with special needs and learning disabilities (Sideridis, 2009), since it has the potential to direct students' choice of taking part (or not) in mathematics activity. In the last years, research studies on the issue of motivation in mathematics suggested to shift the focus of the research on motivation in mathematics from the study of longer-term attitudes and beliefs toward the study of in-the-moment engagement (Middleton et al., 2017). *Engagement* is a multidimensional construct, which combines three interrelated components (Fredricks et al., 2004): *behavioral engagement*, which draws on the idea of participation; *emotional engagement*, which refers to students' affective reactions in the classroom; *cognitive engagement*, which incorporates "thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills" (Fredricks et al., 2004, p. 60).

To study and understand the specific nature of *mathematical engagement*, Goldin et al. (2011) introduce the term *engagement structure*, defined as:

> an idealization involving a characteristic motivating desire or goal, actions including social behaviors toward fulfilling the desire, supporting beliefs, self-talk, sequences of emotional states, meta-affect, strategies, and possible outcomes – a kind of behavioral/affective/social constellation situated in the person, becoming active in social contexts (Goldin et al., 2011, p. 548).

The key-role played by the design of teaching methodologies in structuring students' engagement have been stressed by Jansen (2019), who states that engagement is structured by the opportunities to do mathematics given to students and by students' way of taking up these opportunities to interact with the teachers and peers about mathematics. Goldin et al. (2011) identified 9 main categories of engagement structures: (1) *Get the job done*, related to students' desire of completing an assigned mathematical task correctly following given instructions; (2) *Look how smart I am*, related to the desire of impressing others or him/herself with his/her mathematical ability; (3) *Check this out*, related to the desire of obtaining a reward; (4) *I'm really into this*, related to the desire of experiencing the very activity of addressing a mathematical task with the need of understanding; (5) *Don't disrespect me*, related to the desire of meeting a perceived challenge to the student's dignity, status, or sense of self-respect; (6) *Stay out of trouble*, related to the desire of avoiding interactions that may lead to conflict or distress; (7) *It's not fair*, related to the desire of redressing a perceived inequity; (8) *Let me teach you*, related to the desire of helping another student; and (9) *Pseudo-engagement*, related to the desire of seeming to be engaged while avoiding genuine participation.

The aim of this paper is to reflect on the potentialities of the teaching methodology implemented during our teaching experiment in structuring students' with SEN engagement by providing them with opportunities to both do mathematics and reflect, with the teacher and their classmates, on their experience. The research questions related to this aim are: (1) How could the students' with SEN engagement, during the teaching experiment, be characterized at the behavioural, social, cognitive and affective level? (2) What are the main characteristics of the teaching methodology that structured this kind of engagement?

Research methodology

Middleton et al. (2017) stress on the importance of focusing on multiple methods to investigate students' engagement, combining different techniques, such as, for example, researcher's observations, students' self-reports and teachers' reports.

In tune with this idea, we collected different kind of data: students' written answers to the questions in the reflecting worksheets; videos of classroom discussions; data about students' individual interactions with the videogame (levels of the game that were faced, number of mistakes, number of attempts, …); students' answers to a questionnaire about their experience within the whole teaching experiment; teachers' answers to two different questionnaires proposed at the middle and at the end of the project; teachers' final interview aimed at making them reflect on their students' experiences.

In order to answer our research questions, we developed a qualitative analysis of the collected data that refer to the students who participated in the teaching experiment. For each student, the results of the analysis of each kind of data have been intertwined with the aim of highlighting clues of his/her engagement. Table 3 summarizes the data analysed to characterize each level of engagement.

Table 3: Data analysed to characterise each level of engagement

Level of engagement	Data that have been analysed
Behavioural engagement	- students' interventions during the classroom discussions that highlight their ways of taking part to the collective work that is developed; - students' ways of interacting with others (tone of their voice, kind of gestures they used…); - students' answers to the final questionnaire, in which they share how they perceive their participation within the classroom activity.
Affective engagement	- students' interventions during the collective discussions, answers to the reflecting worksheets and to the final questionnaire, through which they share their emotions toward mathematics and manifest their perceived competence in doing mathematics.
Cognitive engagement	- students' interventions during the classroom discussions that highlight their willingness of understanding and of contributing to the reflective practice developed at a collective level; - students' answers to the reflecting worksheets, in which they make explicit the mathematical reasons subtended to the strategies adopted during their interaction with the videogame.

The data collected through the questionnaires proposed to the teachers and their final interviews were analysed with the aim of confirming (or not) our interpretation of the other data. In particular, during the final interviews, teachers were explicitly asked to reflect about their students' engagement and about the role played by the methodology adopted during the teaching experiment in structuring students' engagement.

Data Analysis

In this section we present two examples of the analysis we performed. We chose to focus on two opposite cases: the case of Antonia, which testifies a positive evolution of the student's engagement throughout the teaching experiment; and the case of Giorgio, which highlights the role played by the student's difficulties in inhibiting his fruitful participation

Example 1: The case of Antonia

Antonia is a female student diagnosed with severe specific learning disorders (dyslexia and dyscalculia; category (B)). She has a problematic relationship with a very close and competing classmate, Elisabetta, who tends to impose herself on Antonia, blocking her attempts to participate in classroom activities and heightening her sense of insecurity. During the different phases of the educational project, Antonia's participation becomes active lesson by lesson.

This evolution of her engagement has been clearly highlighted at the behavioral level. In fact, during the pair activities and the classroom discussions, the tone of her voice and the gestures used to show her involvement in these activities highlight Antonia's ongoing overcoming of her sense of insecurity in interacting with others. Moreover, in different moments during the classroom discussions, Antonia intervenes without the need of the teacher's solicitation, differently from what usually happened in the past. In the final questionnaire, she declares that she was stimulated to participate in an active way when excerpts from her reflecting worksheets were displayed on the interactive whiteboard. This testifies the role played by the design of the classroom discussion (phase 4) in fostering Antonia's positive attitude toward her participation within the discussion itself. The analysis of classroom discussions has also shown that Antonia has become able to overcome the difficulties due to Elisabetta's presence, since she reacts with confidence to her interferences when she intervenes during the discussions. We hypothesize that playing alone with the videogame (phase 1) contributed to strengthen Antonia's self-esteem and the sense of self-efficacy, thanks to the gradualness of the tasks and to the possibility of managing time in an autonomous way.

It was possible to highlight a positive evolution even at the level of cognitive engagement, since Antonia's interventions during the classroom discussions are productive also in relation to the mathematical content, highlighting that she is able to effectively direct her attention at the issues on which the discussion is focused. Moreover, Antonia is able to autonomously complete all the levels of the videogame that the students were asked to face. In the individual reflection sheets (phase 2) and in the final collective discussion (phase 4) Antonia often refers to the videogame as a real concrete experience talking about "numbers that cannot be multiplied", referring to the crafting table. This testifies that: on one side, individually interacting with the videogame (phase 1) contributed to make Antonia's experience with mathematics less abstract; one the other side, working on the reflecting worksheets enabled Antonia to make the mathematics behind the game more explicit and to reflect on the reasons subtended to the effectiveness of the adopted strategies. These factors allowed Antonia to speak more confidently about mathematics during the classroom discussion.

At the level of affective engagement, Antonia's answers to the questions within the reflecting worksheets display her increased perceived competence, as it is testified by this excerpt, which highlights her self-confidence about the competencies she has developed in facing the different levels of the videogame: “The videogame becomes more difficult (level by level), starting from the easiest (levels) to enable us to learn. Since you get better, the game gets harder".

Our analysis highlights different structures characterizing Antonia’s engagement during the project. Although some of her answers show an engagement in tune with the structure “look how smart I am” (testified by Antonia’s declaration that she was proud that her answers were displayed on the IWB, making her protagonist of classroom discussions), we think that the prevailing structure is “I’m really into this”, since Antonia explicitly addresses the idea of learning in her reflections, displaying satisfaction about her increased mathematical understanding through the different levels of the videogame. Our interpretation of Antonia’s engagement has been confirmed by her teacher, who, during the interview, declares that she was positively impressed by the desire to interact that Antonia, usually very shy and insecure, displayed during classroom activities.

Example 2: The case of Giorgio

Giorgio is a male student diagnosed with severe specific learning disorders (dyslexia and dyscalculia; category (B)). He presents serious short-term working memory problems, logical-cognitive difficulties and a strong sense of frustration that often leads to conflicting relationships with peers, teachers and parents. During the different phases of the teaching experiment, Giorgio’s difficulties are so great that they prevent him from deeply and truly participating in the activity at different levels. At the level of behavioral engagement, Giorgio does not participate in the collective discussions, even when one of his classmates solicits his intervention to share some reflections about the phase of small group work. The inconsistency and lack of meaning that characterize Giorgio’s answers to the reflecting worksheet highlight also the difficulties faced by Giorgio in being engaged at the cognitive level. Moreover, the student declares, in his reflecting worksheet, that he felt lost during the activities, testifying the problems related to his engagement also at the affective level. A little evolution of his engagement could be observed only in the last part of the teaching experiment, when, after a collective discussion, Giorgio shows a better sense of perceived competence when answering to the final questionnaire, declaring that he has understood a little better and that he has overcome, albeit with great difficulty, the problems encountered when interacting with the videogame, displaying a more positive attitude towards the activity performed.

Our analysis highlights a main structure characterizing Giorgio's engagement during the teaching experiment, that is “Pseudo-engagement”. In fact, although Giorgio seemed busy when he individually worked on the reflecting worksheet, a sentence within his answers to the final questionnaire testifies that his aim was to pretend to be actively involved in the activities, rather than really reflecting on the mathematics problems he faced and on the possible strategies to face them: “In the worksheet I had no problems because it was enough to write something”. Our interpretation about Giorgio’s engagement has been confirmed by his teacher who, in both the first and second questionnaires and during the final interview declared to be worried about Giorgio’s situation.

Conclusion

In the previous section, we presented two examples of analysis of the data collected during our teaching experiment. The first example, the case of Antonia, testifies the effectiveness of our methodology in fostering the positive evolution of students’ engagement structures toward a structure characterized by students' desire of being involved in the collective construction of mathematical knowledge and of learning, which Goldin et al. (2011) indicate with "I'm really into this". The analysis of the data collected for most of the 25 students with SEN who participated in our teaching experiment has confirmed the positive trend highlighted in Antonia's case. In particular, we observed that most of the students showed a positive evolution of their engagement structures, even at the level of cognitive engagement. 20 of them, in fact, were able to autonomously complete all the activities within the videogame. Among them, 14 students proposed fruitful interventions during the classroom discussions in relation to the mathematical content under scrutiny and 11 students showed awareness of their progress by explicitly reflecting on the improvement of their cognitive engagement. These interpretations were confirmed by the teachers in the intermediate and final questionnaires and in the interview. In particular, teachers stressed on the greater participation that they observed in the case of the students with SEN involved in the study, declaring that they observed a widespread students' desire to interact positively and a sense of gratification, trust and security manifested by most of these students, together with a reduction of fear of making mistakes and a general fun in doing mathematics.

These results allow us to propose some reflections on the characteristics of the teaching methodology implemented during our teaching experiment that played a key-role in structuring students' engagement. In tune with other studies, the phase of individual interaction with MS (phase 1) favors a positive development of students' sense of self-efficacy. Working (individually and in small groups) on the reflecting worksheets (phases 2 and 3) supports students in making the mathematics behind the videogame explicit and in developing argumentative competences, enabling them to effectively contribute to the classroom discussion. Phase 4, in turns, contribute to the refinement of the reflections developed during phases 2 and 3, supporting students' development of awareness about the teaching-learning processes in which they are involved.

The structure "I'm really into this", the one displayed through the analysis of Antonia's data, emerged only in 4 cases. We think that this result shows that it is necessary to devote more time to the implementation of this kind of methodology (in particular, the phases devoted to the activation of reflective practices) in order to foster an engagement characterized by students' will to address the activities guided by a real need of understanding. Our analysis has also highlighted that in some cases (Giorgio and two other students), students tended to strive not to be noticed, adopting an avoidance behavior, or pretended to be involved even if they did not really address the mathematical content under scrutiny. In these cases, students' experience within the teaching experiment was not effective in fostering a positive evolution of the structures of their engagement. Our hypothesis is that, in the case of students like these, it is necessary to plan a targeted intervention to help them overcome the difficulties that prevent them from becoming deeply engaged in the activities. In the case of Giorgio, a first targeted intervention has been carried out, involving him in meetings with his teacher aimed at triggering and supporting his explicit reflections about his experience with the videogame and the other activities around which our teaching methodology is designed. This approach seems to be promising but further experimentation is needed. As a further step of our study, we will also collect further data, throughout a longer time span, with the aim of investigating if the positive trend highlighted by our analysis could be confirmed.

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