Virtual Reality to improve Metacognition in Special Needs Education

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Abstract
Due to the Covid-19 pandemic, some school-related phenomena, such as dropout rates and the lack of involvement of disadvantaged groups, have consistently increased. Families in socio-cultural disadvantage conditions have faced difficulties in accessing essential services and participating in digital education. On these premises, FOndazione per la RicercasullaMigrazione e IntegrazionedelleTecnologie (FORMIT) developed CLASS, a 12-month project funded by the Italian Ministry of Education, Universities and Research, Directorate General for Research, that started on 6 November 2023 with the aim of comparing three different teaching and learning methods, namely: one that focuses on helping students develop their metacognition; one that involves the use of Virtual Reality (VR) to further strengthen this skill; and finally, the traditional method. Key for the project's success is the collaboration with three state secondary technical and/or professional schools located in the suburbs of Rome, which will participate in the delivery of the teaching and learning activities with a group of students from disadvantaged backgrounds or with cognitive, affective and social needs. The research hypothesis of CLASS is that metacognitive strategies improve the learning process and the engagement of socio-culturally disadvantaged students, and that the use of VR can further enhance the benefits of this type of strategies.

Keywords
Special Needs, BES, Metacognitive learning, Virtual Reality, VR

1. Background information to the project

The definition of the term "Special Educational Needs" (SEN)widely vary across countries depending on each country's legislation.

A student is commonly recognised to have SEN if he or she is not able to benefit from the school education that is generally provided to anystudent of the same age without additional support or adaptations in the content of studies.Therefore, SEN refers to specific educational needs that students may have. In Italy,the equivalent term of SEN, BES (*Bisogni Educativi Speciali*), was introduced by the Italian Ministerial Directive of December 27, 2012, entitled "*Strumenti di intervento per alunni con Bisogni Educativi Speciali e organizzazione territoriale per l'inclusione scolastica*" (lit. "Intervention mechanisms for students with Special Educational Needs and local organisation for school inclusion").

These needs can involve cognitive, emotional, and social aspects. In the former case, they are considered permanent needs, while in the latter case, they are referred to as transient needs(1).Within the realm of SEN, there are also students facing challenges related to social, economic, emotional distress, or difficulties arising from a lack of knowledge of the Italian language. Amongst various teaching models, the metacognitive approach seems to be particularly effective to address the learning and inclusion challenges of students from disadvantaged backgrounds (2, 3).Metacognitive teaching aims at developing both the "cold" metacognitive aspects

(more specifically cognitive aspects such as working memory, attention, abstraction, problem-solving, etc.) and the "hot" aspects (which include mentalisation and cross-cutting skills) (4). Specifically, the ability of mentalisation allows individuals to perceive and interpret human behaviours in terms of intentional mental states such as emotions, goals, or desires. These abilities arise from any interaction with the environment and other factors, promoting various motivational aspects that regulate the learning process (5). Transversal skills, or soft skills, refer to a set of positive personal attributes and competencies that enhance interpersonal relationships, work performance, and the social value of the individual (6). In the Italian school system, strategic for the support and development of students' soft skills are the "Pathways for soft skills and guidance" (PCTO), which were established by the Italian Legislative Decree of April 15, 2005, No. 77. In 2020, the Covid-19 pandemic caused a slowdown and, in some cases, the impossibility to activate such training pathways, resulting in a disadvantage for students. For this reason, providing students with tools that help optimise their learning process, as well as regulate their external responses and develop transversal skills is very useful, especially in the case of socio-cultural disadvantage. Moreover, quarantine and physical distancing policies amid the Covid-19 pandemic prevented us from having social interactions and led us to reconsider new technologies. Therefore, it is crucial to be able to support metacognitive teaching through technological tools such as Virtual Reality (VR). Thanks to their immersive and interactive nature, VR environments have a strong potential in educational contexts as they can be customised to allow learners to leverage their strengths, enhancing task mastery through virtual experiential support (7). Due to the Covid-19 pandemic, families in socio-cultural disadvantage conditions had to face multiple difficulties, both in accessing essential services and in participating in digital education. In fact, students from families with lower economic resources have encountered challenges accessing digital education due to the lack of appropriate tools and effective internet connection. However, the opportunity to work with technological tools, already experimented with in the educational context, could support disadvantaged students by enhancing the metacognitive aspects of their learning process. In light of these considerations, as a non-profit research organisation with solid know-how in education and training, FOndazione per la RicercasullaMigrazione e IntegrazionedelleTecnologie (FORMIT)developed"CLASS", a 12-month project funded by the Italian Ministry of Education, Universities and Research, Directorate General for Research through the Fund for Research in the Economic and Social Field. Started on 6 November 2023, CLASS aims at studying, using, and evaluating an effective educational model tailored to students with socio-cultural disadvantages enrolled in three state secondary technical and/or professional schools located in the suburbs of Rome.In particular, three teaching and learning methods will be compared: one involving the implementation of procedures aimed at enhancing metacognitive aspects; another enhancing metacognitive aspects through the use of Virtual Reality (VR); and finally, the traditional method. The research hypothesis of CLASS is that metacognitive teaching improves the learning and engagement of socio-culturally disadvantaged students, and that the use of VR can further enhance the benefits of this type of teaching.

2. The project's objectives and endpoints

The CLASS project aims to achieve the following objectives: (a) comparing the effectiveness of traditional metacognitive teaching strategies with metacognitive teaching enhanced through immersive VR; (b) developing a VR application to improving students' transversal skills and mentalisation abilities.

3. The project's main phases

The study timeline covers a period of one year and consists of six phases. Phase 1 consists of students sampling.Itwas scheduled for November 2023/January 2024. Phase 2 –Students' entry assessmentis expected to be run from January to February 2024.Phase 3 aims at

developing a novel VR app from January to March 2024. Phase 4will be the core of the project, as it is related to the teachers' training and the teaching activities involving the students sampling, which will be delivered from February to May 2024. Phase 5will take place in May and June 2024, to assess the students' learning outcomes upon the completion of the teaching and training activities. Finally, Phase 6will cover the period ranging from June to early November 2024, to develop the project's statistical analysis and come up with the final research results, which will be thus communicated and disseminated.

Figure 1 The project's phases

3.1. Phase 1

Started in November 2023, Phase 1 represents the official kick-off of the CLASS project, aiming to identify the students sampling with socio-cultural disadvantage to be involved in the teaching and training activities. Three state secondary technical and/or professional schools located in the suburbs of Rome were chosen and asked for collaborationconsidering their favourable environment for detecting socio-cultural distress situations. To achieve the expected, the research team has developed a tailored study protocol employing Raven's Matrices (excluding students with IQ < 90), as well as SES to identify students with socio-cultural disadvantage. Additionally, K-SADS has been used to exclude other psychiatric disorders. For each school, three classes of 12 students will participate to the three teaching programmes that will be part of the experimental study. Two out of the three groups will be the experimental groups working on procedures to enhance metacognitive aspects with and without the use of VR, whereas the third one will be the control group that will work with a traditional teaching model.

3.2. Phase 2

Once the students sampling is identified, the CLASS project will enter Phase 2, to assess the initial skills of the students. A protocol including the following tests will be thereforeimplemented: (a) the RF-Q8 will be used to assess students' transversal skills and mentalisation processes; (b) a post-evaluation questionnaireassessing students' proficiency in the teaching programme that was part of the previous quarter will be designed by the teachers that will participate in the experimental study. AMOS will be used to evaluate students' metacognitive skills and motivation. The results stemming from this evaluation will used as a baseline to evaluate the students' increase in their academic learning upon completion of the experimental study.

3.3. Phase 3

Phase 3will be instrumental for the delivery of one of the three teaching programmes that are part of the experimental study, namely the use of VR to enhance students' metacognitive aspects. A novel VR application will be thus developed, to use gaming mechanisms to enhance students' cross-cutting skills to increase their employment opportunities on the job market.The app will be developed in compliance with ISO/IEC/IEEE 12207:2017 –"Systems and software engineering", that involve an initial phase of planning (i.e., analysis of the requirements and architectural design), a second phase of design, coding and mock-up, and finally a third phase of release. Phases 2 and 3 will be repeated at least three times for incremental optimisation.A compatibility test will be performed before releasing the app in its final version.

3.4. Phase 4

Phase 4 will be the core of the CLASS project, as it is related to the teachers' training and the teaching activities involving the students sampling, which will be delivered from February to May 2024. Teachers working in the three schools with which the research team collaborates will be invited to join a one-month training programme focused on metacognitive strategies, as well as the use of VR to enhance students' mentalisation and metacognitive skills.The training aims to provide teachers with a general overview of the project, as well as with the theory at the base of metacognition and mentalisation, and the models and strategies to be implemented for teaching and learning purposes at school. Subsequently, a3-month piloting involving the students sampling will be initiated to deliver the three teaching programmes that are part of the experimental study. In this regard, each school will participate with three classes having students of the same age, who will be provided with the following: a) a teaching programme involving the implementation of procedures aimed at enhancing metacognitive aspects (experimental group 1); b) a teaching programme aiming to enhance metacognitive aspects and improve transversal skills through the use of VR (experimental group 2); c) a teaching programme delivered by using traditional teaching methods (control group).

3.5. Phase 5

Once the teaching and training activities are over, the research team will enter Phase 5, to assess the students'final learning outcomes to compare them with the initial assessment carried out in Phase 2. To achieve the expected, the same protocol used in Phase 2 will be applied.

3.6. Phase 6

The assessment carried out in Phases 2 and 5 will be finally elaborated through statistical analysis in Phase 6, which represents the final evaluation of the experimental study. In this regard, the most effective teaching methods will be verified and an internal validation of the implemented protocols will be carried out. This analysis will be instrumental to develop tailored lessons learnt and best practices stemming from the project activities, which will be useful to identify areas for improvement of the proposed model and deliver *ad hoc* recommendations to be implemented to replicate it.The identification process will start with a set of brainstorming sessions that the project team will hold using the Delphi method, where a rating (on a scale from 1 to 9) will be given to the relevance of each proposed recommendation, to come up with a final ranking. The selected recommendations will be developed to address different categories of stakeholders, which have been primarily identified in schools and policy makers.

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