

# Augmented reality environments for teaching innovation

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## Abstract

*This contribution presents the results of research on teaching practices supported by augmented reality conducted in school contexts in the three-year period 2015–2017. With reference to the objectives of the National Plan for Digital Education relating to the realisation of innovative learning pathways to promote critical thinking, reflection and creativity, attention is addressed here to the digital environments and in particular to the augmented reality environments for school education.*

*Specifically, the article aims to reflect on the impact of augmented reality in learning for secondary school students, in relation to the co-constructive and participative approach of knowledge and to the expressive re-elaboration. For this purpose, the analysis of the data of a questionnaire is proposed, administered to secondary school teachers from various Italian regions, in regard to heritage education developed by means of augmented reality. Both the strengths, with particular reference to the elements of teaching innovation, and the critical aspects have been examined to identify the elements/processes capable of making innovative learning practices sustainable.*

**Keywords:** *augmented reality; digital environments; learning; teaching*

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## 1. Introduction

In line with the indications of the National Plan for Digital Education (2015)<sup>1</sup>, in the last few years, digital environments have been tested and/or are still undergoing testing, in respect to which students of any type of school show a high degree of familiarity. Indeed, computers, tablets, smartphones and other mobile devices are widely present in the socio-relational and cultural practices of the young generations. In particular, as shown by a study on adolescents conducted in 2015, “the smartphone is identified as the polyfunctional instrument par excellence, the support and the accomplice of all their activities”<sup>1</sup>. For Bachmair (2014, p. 10), the mobile devices are configured as “bridges towards daily life” for young people, on which the school finds itself necessarily having to reflect. The spread of applications that are simple to create, install and use on smartphones and tablets had indeed led to augmented reality in the classroom, fostering the design and the realisation of new educational experiences that provide significant elements for a pedagogical reflection.

This contribution thus aims to focus attention on the use and the potential of the augmented reality environments in learning for secondary school students. Specifically, I will examine the digital environments not as spaces already predisposed to foster the acquisition of abstract concepts, but rather as spaces to be created in which the students themselves can construct artefacts accessible in augmented reality. After an initial reflection on studies and research that define the theoretical and methodological framework within which are positioned the development of augmented reality, the results of research conducted in the national school contexts that have tested new teaching practices via the “augmented” methods will be analysed. In particular, the analysis of the data of a questionnaire administered to the teachers of secondary schools in various Italian regions will be proposed, in regard to projects for education on the heritage realised via augmented reality. The strengths will be examined, with particular reference to the elements of teaching innovation, as well as the critical aspects emerging in the experiences realised in augmented reality environments. Within the scope of a more general reflection on the future directions of the research, the reading of the responses of the questionnaire will allow us to identify the elements capable of guaranteeing the feasibility of the cognitive processes and consequently the sustainability of an innovative teaching practice.

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<sup>1</sup> This is a survey carried out by the Permanent Youth Publishers Observatory, in collaboration with the independent research institute GFK-Eurisco. The survey involved 2,200,000 secondary school students, as regard their use of the web and mobile devices. “Young people and information: 2015” from <http://www.osservatorionline.it/page/242989/giovani-e-informazione-2015>.

## 2. Theoretical background

The design and realisation of learning experiences by means of augmented reality represents one of the themes of greatest interest in the current debate, especially in the past 10 years (Bacca et al. 2014; Billingham, Duenser, 2012; Bower, 2014; Brown 2015; Chen et al. 2017; Dunleavy, Dede, 2013; Diegmann et al. 2015; Echeverría, Gil, Nussbaum, 2016; Herrington, Crompton, 2016; Salmi et al., 2016). The application of augmented reality to teaching fields is indeed an innovative area of research whose testing hark back in particular to *mobile learning* understood literally as learning that avails itself of *mobile devices*. This form of learning draws on the affordances proper to the mobile devices: portability and flexibility, ubiquity and ease of access, multimediality, multi-touch and personal ownership (FitzGerald et al. 2013; Ranieri, Pieri, 2014). These characteristics determine the development of “educational experiences based on learning systems centred upon blended and/or augmented realities with a view to enriching the activity of meaning building by the student, allowing him/her to take part in a rich media-based environment, distinguished by the combination of real and virtual objects, by the use of sensorial inputs and by the possibility to position the virtual learning objects in the real world and to interact virtually with a hybridized world” (Bonaiuti, Calvani, Ranieri, 2016, p. 134). We are thus witnessing the “transition from Mobile Learning to Augmented Reality Mobile Learning” (Petrucco, Agostini 2016, p. 2), where “Augmented Reality Learning is a further development and extension of Mobile Learning” (*ibidem*).

In particular, augmented reality learning refers to a *situated learning*. Indeed, augmented reality, based on the binomial augmented contents-georeferencing, allows for just-in-time and just-in-place access to the digital contents in respect to the real perceptive experience. Virtual and real objects coexist in a new space that does not substitute the physical world but overlaps it. Augmented reality increments the perception of real space with images taken from the virtual space with the result that real and virtual objects seem to coexist, like two indistinguishable entities. According to the taxonomy proposed by Milgram, Kishino (1994), the *Reality-Virtual Continuum* (fig. 1), augmented reality and the virtual one are connected while the real world and the virtual environments represent two extreme conditions.

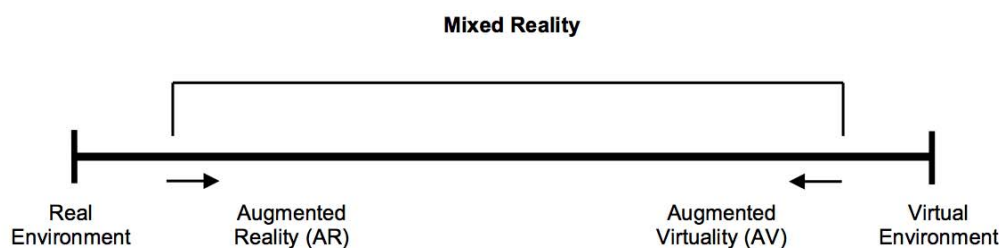


Fig. 1. Reality-Virtuality (VR) Continuum. Source: Milgram, Kishino, 1994.

In particular, in the scale of Milgram and Kishino, augmented reality is positioned to the left close to the real environment, precisely because in it the real-world results to be predominant in respect to the digital data. “Augmented Reality acts within a *continuum with two polarities*: The Real Environment and the Virtual Environment. The areas which lie between these two poles are part of a so-called ‘Mixed’ Reality. AR acts within the Mixed Reality interval which is closer to the Real Environment, whilst Augmented Virtuality is closer to the Virtual Environment” (Petrucco, Agostini 2016).

Augmented reality thus places the user in what Rossi calls *third space*: a space in which virtual and real objects cohabit through a process of digital addition; a hybridised space in which the reality perceived through the senses is superimposed by digital data (images, video, objects, 3D writings, virtual characters, etc. ) to access localised information (Rossi 2013). This third space is also a *space of flows* in that the technologies of augmented reality connect different places through the subjective practices of individuals who relate with one another (Castells et al. 2006; 2008), but it is also an “*intelligent distributed space* in which it becomes ever more difficult to distinguish between real and virtual and where the mobile technologies mediate the experience of a new sense of space, which we can call augmented” (Ranieri 2014, p. 22).

This emerges the possibility to design educational activities within the scope of an innovative teaching system that inserts augmented reality among its strategies as a function of new approaches to knowledge and to knowledge-building.

## 3. Research questions

The present research aims to explore from a learning standpoint and according to a qualitative approach the theme of augmented reality in school contexts. Indeed, the testing that some pilot schools have undertaken in the past few years

can provide important elements for a meaningful reflection on the designing of learning pathways, with particular reference to the cultural heritage, in line with the main educational objectives laid down in law no. 107/2015: “enhancement of skills in the musical practice and culture, in art and in the history of art, in cinema, in the techniques and media of production and diffusion of images and sounds, also by means of the involvement of museums and other public and private institutes operating in such sectors; the development of skills on the subject of active and democratic citizenship via the valorisation of intercultural education; literacy in art, in the techniques and the media of production and diffusion of images; development of the students’ digital skills; valorisation of school understood as active community, open to the territory and capable of developing and increasing the interaction with families and with the local community” (art. 1, comma 7).

### 3.1 Research phases and tools

The research, conducted in the three-year school period 2015–2016, 2016–2017 and 2017–2018, was developed according to the following plan:

1. the *first* phase of the research was dedicated to the identification, study and analysis of the scientific literature on themes of augmented reality (Panciroli, Macauda, Russo 2018; Macauda 2018);
2. in the *second* phase, an explorative investigation was performed on a qualitative and quantitative nature that has examined 30 augmented reality projects already realised or in the process of being realised, in the school years 2015–2016, 2016–2017 and 2017–2018, in some Italian schools, both primary and secondary, representative of many Italian regions. The investigation has made it possible to identify the main disciplinary fields of application of an active teaching supported by augmented reality with reference to heritage education experiences (Macauda, 2018);
3. the *third* phase envisaged the analysis of three case studies, focusing on the re-elaboration of the heritage by the students in relation to the production of artefacts in augmented reality. The three case studies referred to three projects that won the tender in 2017–2018, one of which international and two national, aimed at promoting the cultural heritage via the digital (Competition: “crowdreaming: the young co-create the digital culture”, Global Junior Challenge, Future present) (Panciroli, Macauda, Corazza 2019);
4. in the *fourth* phase that is presented here, a questionnaire was prepared to survey the most significant elements in respect to the realisation of learning activities in augmented reality environments. The questionnaire was administered to 15 secondary school teachers at the end of the school year 2017–2018.

### 3.2 Survey

Taking account of the fact that the learning projects in augmented reality examined involve schools in several regions, the administration of an online questionnaire is considered to be the most suitable instrument for gathering the data (fig. 2). The questionnaire was sent to the referent teachers of 15 lower and upper secondary school projects, taken into consideration during the explorative second phase investigation. As compared with this investigation, primary schools were not taken into consideration. The projects developed by these schools are mainly based on the use of augmented reality environments already constructed that enrich the student’s experience only in terms of interaction with the objects of the physical space.

SURVEY “Educational experiences with heritage through augmented reality”	
<b>Section A</b>	
1. Name of the school	
2. School level	
• Lower secondary school; Upper secondary school	
3. If the secondary school is an upper level, specify the type:	
• Lyceum (specify whether it is classics, sciences, arts, etc. )	
• Professional Institute (specify specialisation) _____	
• Technical institute (specify specialisation)	
4. City	
5. Province	
6. Region	
7. Title of the project/experience	
8. Referent/s of the project	
9. E-mail	
10. Class/es involved	
• I, II, III, IV, V	
11. Number of students involved	
12. School year when the project was realised	
• 2014–2015, 2015–2016, 2016–2017, 2017–2018	
13. The experience with augmented reality was:	
• Disciplinary (specify the discipline) _____	
• Interdisciplinary (specify the disciplines)	

<p>14. Which technological resources were used? <i>Choose one or more options</i></p> <ul style="list-style-type: none"><li>• Smartphone; Tablet; Visors; Notebook; PC; LIM; Altro</li></ul> <p><b>Section B</b></p> <p>1. Short description of the project (objectives and articulation in phases)</p> <p>2. The experience realised with augmented reality can be referred to which type of mobile learning? <i>Choose one or more options</i></p> <ul style="list-style-type: none"><li>• Receptive (delivery of contents)</li><li>• Directive (delivery of structured and interactive contents)</li><li>• Guided discovery (partially structured contents with progressive revealing)</li><li>• Collaborative (unstructured contents or open and generated through interaction with others)</li><li>• Explorative (unstructured or open contents and generated through interaction with the environment)</li></ul> <p>3. In respect to the intellectual dimension of the learning, the experience with the heritage realised through augmented reality envisages the acquisition of which level/s of knowledge: <i>Choose one or more options</i></p> <ul style="list-style-type: none"><li>• Basic knowledge (primary literacy)</li><li>• In-depth study (analysis of the context/logical construction of knowledge/practice or exploration)</li><li>• Re-elaboration (expressive and original construction of knowledge)</li></ul> <p>4. To what extent have the technologies of augmented reality modified the experience of the students with the heritage? <i>Choose just one of the following options</i></p> <ul style="list-style-type: none"><li>• Not at all, Not much, Quite a lot, A great deal</li></ul> <p>5. In respect to the socio-relational dimension of learning, the experience with the heritage realised through augmented reality envisaged the acquisition of what level/s of socialisation: <i>Choose one of more options</i></p> <ul style="list-style-type: none"><li>• Autonomy (acquisition and individual elaboration of the contents/creation of a product autonomously)</li><li>• Collaboration (activity of comparison and sharing skills as a function of the realisation of the project)</li><li>• Cooperation (elaboration of a project in which each student played a role and developed a specific part).</li></ul> <p>6. What was the level of participation/involvement of the students in respect to the use of the augmented reality technologies in the classroom and at home? <i>Choose just one of the following options</i></p> <ul style="list-style-type: none"><li>• Not at all, Not much, Quite a lot, A great deal</li></ul> <p>7. Did the augmented reality experience lead to the realisation of final products? <i>Choose only one of the following options</i></p> <ul style="list-style-type: none"><li>• Yes, No</li></ul> <p>8. If so, which products were realised?</p> <ul style="list-style-type: none"><li>• Exhibition, Website, Video, Altro</li></ul> <p>9. In regard to the use of augmented reality, what was the main strength of the project?</p> <p>10. In regard to the use of augmented reality, what was the main critical issue of the project?</p> <p>11. In your opinion, in regard to the use of augmented reality technologies, what were the main elements of teaching innovation in the design and the realisation of educational heritage experiences?</p>
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Fig. 2. Survey

The questionnaire is articulated in 25 open-ended and closed-ended questions, distributed over two sections: section A “registration-identification” and section B “pedagogic”. Section A allowed for the collection of preliminary information about the school (name, type, geographical position, etc.) and the project (title, referent teacher, classes involved, the year/s of realisation, the technological resources, etc.). In section B, information was collected concerning the structure and the phases of the project, the learning architecture of reference, the strengths, the critical issues and the elements of teaching innovation. Specifically, the questionnaire was built taking into consideration some dimensions deriving both from the analysis of the scientific literature and from the explorative investigation of the first research phase: the dimension of the *learning architecture* (receptive, directive, guided discovery, collaborative, explorative); the *intellectual* dimension of learning (acquisition of basic knowledge, in-depth study, re-elaboration); the *socio-relational* dimension of learning (autonomy, collaboration, cooperation) and the *participative* dimension (involvement and participation of the students).

### 3. Data analysis and findings

The questionnaire was administered to 15 lower secondary (20%) and upper secondary (80%) school teachers<sup>2</sup> who took part in the explorative investigation of the second phase. The projects are representative of the following Italian regions: Basilicata (Potenza), Emilia-Romagna (Fiorenzuola d'Arda, Parma), Piemonte (Asti), Puglia (Bari), Sardinia (Cagliari) and Umbria (Deruta).

The data that concern the school years when the projects were realised show that 12% of the sample is placed in 2015–2016, 76% is shared between 2016–2017 and 2017–2018, while the remaining 12% envisages a further

<sup>2</sup> The software used for the collection of the quantitative data is Google Moduli.

development in 2018–2019. With reference to the upper secondary schools (fig. 3), the 15 projects were realised by the lyceums 45% (scientific, human sciences, artistic, musical, sports), 30% by technical institutes (specialised in administration, finance and marketing, mechanics, mechatronics and energy, electronics and electro-technics, constructions, environment and territory) and 25% by professional institutes (specialised in maintenance and technical servicing, artisanal and industrial productions, socio-health services).

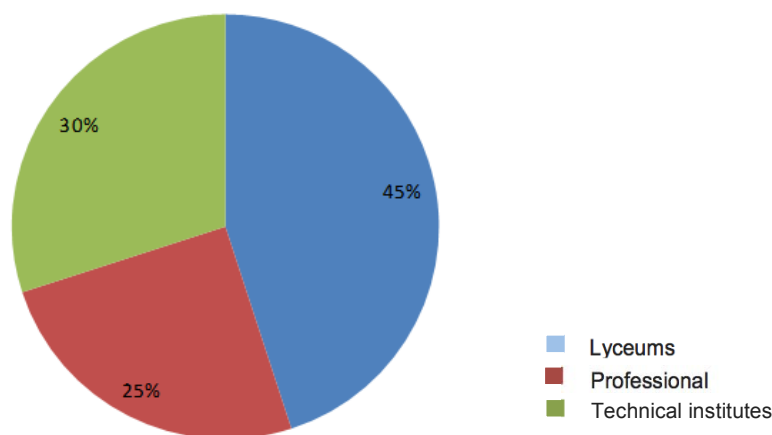


Fig. 3. Upper secondary schools

In relation to the disciplinary/interdisciplinary nature (A, 13), the responses position the experiences developed with augmented reality for 90.9% in interdisciplinarity. This aspect is mostly confirmed by the descriptions of the projects (B, 1), some significant passages of which are reported here:

- the project involved several classes of the institute and several disciplinary areas;
- the augmented reality facilitated the integration between different disciplinary environments;
- the project connected philosophy and other disciplines via an involving technology with a high potential of internal and external interaction;
- through the augmented reality technologies, the students have acquired disciplinary skills in the environmental, naturalist, territorial, urban, architectural, artistic, historical-literary, chemical, physical-mathematical, musical fields, etc. and transversal skills of an organisational, social, ethical-civil kind;
- the project has provided the chance to understand interdisciplinarity, operatively, with AR.

In regard to the design and realisation of augmented reality experiences of an interdisciplinary nature, the remaining 9.1% of the answers reveal critical issues of an organisational kind, above all in relation to the school schedule:

- in the realisation of the project, the practical difficulty emerged in the organisation of multidisciplinary projects during the normal performance of the school activities.

Referring to the technological dimension (A, 14), the smartphone comes within the most utilised devices (96%), followed by the tablet, the notebook and the LIM. This fact is immediately confirmed in the responses that reveal the strengths of the project in regard to the use of augmented reality (B, 9):

- the teaching activity has represented an opportunity to insert tablets and smartphones as teaching tools enabled in daily practice, an added value in the learning phases when the objectives and the aims of use are clear, with the student at the centre of his/her own learning and the teacher who monitors and supervises;
- the applications like Quiver or HP Reveal are easy to install and use on different mobile devices and guarantee the creation and enjoyment of experiences in augmented reality environments;
- adding multimedia contents manageable via smartphone, “basic tool” and always present in youths’ daily lives, allows for more simplified and immediate elaborations in respect to any other technological support of larger size.

The description of the projects (Section B, 1), in relation to the objectives and the articulation in phases, allowed us to survey a shared structure. Indeed, starting from an asset/object or from a theme/argument acting as “stimulus”, presented by the teacher or by an external expert, the projects develop according to three phases:

1. search, collection, selection and organisation of contents so as to elaborate augmented texts with particular attention addressed to the reliability of the sources and the resources available online;
2. search for images on sharing sites and/or realisation of personal photographic images;
3. construction of different digital artefacts accessible in augmented reality like conceptual maps, digital posters, videos and websites.

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The experience with augmented reality was: Choose just one of the following options	• Disciplinary	9.1%
	• Interdisciplinary	90.9%
Which technological resources were used? Choose one of more options	• Smartphone	96%
	Tablet	35%
	Visors	0%
	Notebook	7%
	PC	0%
The experience realised with augmented reality can be referred to which type of mobile learning? Choose one of more options	LIM	21%
	Receptive	40%
	Directive	5%
	Guided discovery	8%
	Collaborative	95%
In respect to the intellectual dimension of the learning, the experience with the heritage realised through augmented reality envisages the acquisition of which level/s of knowledge Choose one of more options	Explorative	100%
	Basic knowledge	16%
	In-depth study	80%
	Re-elaboration	67%
To what extent have the technologies of augmented reality modified the experience of the students with the heritage? Choose just one of the following options	Not at all	0%
	Not much	0%
	Quite a lot	25%
In respect to the socio-relational dimension of learning, the experience with the heritage realised through augmented reality envisaged the acquisition of what level/s of socialisation Choose one of more options	A great deal	75%
	Autonomy	35%
	Collaboration	92%
	Cooperation	70%
What was the level of participation/involvement of the students in respect to the use of the augmented reality technologies in the classroom and at home? Choose just one of the following options	Not at all	0%
	Not much	0%
	Quite a lot	18,2%
	A great deal	81,8%

Among the main teaching architectures (Clark 2000; Ranieri 2005; Ranieri, Pieri 2014), all the lecturers have recognised in the *explorative* form and in the *collaborative* one, the two types of mobile learning that best describe the experience developed through augmented reality (B, 2). Indeed, on the grounds of a learning architecture of an *explorative* type, the students were able to control and manage the learning process in the real and digital environments actively, and worked on the unstructured contents, indeed generated by the interaction with the environment. In regard to the *collaborative* architecture, the projects based on *cooperative learning* envisaged peer learning and peer tutoring activities, and an orientation to project work. The students worked on unstructured contents, generated from the interaction with others. In this regard, the following responses can be mentioned (B, 1):

- the students, pioneers of AR were the technological coaches for their schoolmates, supporting them in the realisation phases of the augmented contents;
- some students needed the support of their companions to bring their project to fruition according schedule.

In respect to the intellectual dimension of learning (B, 3), all the lecturers acknowledged in the analysis and re-elaboration the two levels most of all involved in the used of augmented reality. Here, we report some significant responses in regard to the strengths of the projects (B, 9):

- augmented reality allows for the stimulation of the in-depth analysis of subjects and topics;

- to construct, via augmented reality, clear and synthetic information, it was necessary to investigate the topics rigorously;
- augmented reality is a go-between by means of which to analysis disciplinary contents;
- augmented reality has allowed us to promote critical and creative capacities;
- the objects have acquired new life and new meanings thanks to the use of augmented reality;
- augmented reality has helped to compose a story of the monument encompassing the different works of the students according to a unitary project;
- the students came into contact with tangible and intangible goods of the cultural heritage of the city after which they were re-elaborated from their point of view, both by means of manual techniques and by means of digital applications.

The “socio-relational dimension” of learning (B, 4) (fig. 4) is recognised by all the teachers in terms of collaboration and cooperation. These two levels of socialisation are referred to in the questionnaire responses (B, 1, 9):

- in the classroom, many opportunities arose for discussions and to compare ideas with the idea of “triggering” the social construction of knowledge and the active search for answers and solutions to the questions posed;
- even the least studious manage to identify a field in which to apply themselves, to share with the workgroup first and with the class group later, and to compare the study issues. We can add to this that the pupils are aware that the product to be realised can be of help to the other students as well;
- the collaboration between students has allowed for the construction of stimulating work groups in respect to the new teaching tools and has stimulated an approach based on problem-solving before a delivery of reality, thanks to discussion and respect.

In quantitative terms, 81.8% of the responses showed a high level of participation of the students *vis-à-vis* the use of augmented reality technologies (fig. 4).

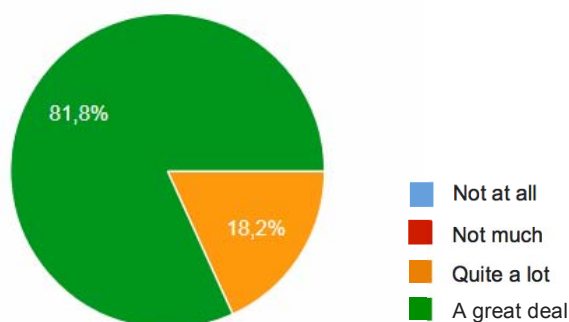


Fig. 4. Level of participation

Such a high level of participation is related by the teachers to the growing motivation on the part of the students who also thanks to the encounters with experts and territorial bodies have been able to develop new skills in relation to the technologies and the heritage. We report here a summary of the responses (B, 9, 11):

- the chance to create and/or search for contents to overlap upon the real objects has greatly stimulated the motivation to analyse the issues dealt with;
- the realisation of a final concrete result has motivated the students;
- the students are motivated to learn how to realise something they like;
- precisely because the augmented reality technologies involve the visual dimension they make the learning experience for the students highly involving;
- involvement of the students demotivated by traditional teaching methods;
- shift from passive use of technology to a more conscious and constructive use;
- development of skills of active citizenship in relation to the care for common heritage assets;
- augmented reality has fostered the exploration of the territory;
- conscious use of applications that have enabled the sharing of the work with the whole city in the perspective of the enjoyment of a diffuse and involving cultural heritage.

In regard to the critical issues, some difficulties were detected in regard to the *infrastructures/technologies* and to the management of *time* (B, 10):

- lack of a good Wi-Fi connection in that the use of augmented reality applications calls for a large amount of data traffic;
- scarce versatility of the open source apps, not always efficient in respect to the selected environments;

- scarce reliability of the open-source apps, owing to inappropriate updates that blocked the use of the environment and disrupted/slowed down the work;
- little time available to test all the potential of the augmented reality applications;
- difficulty in matching the students extra-curricular work with their traditional school commitments, also in the light of the different study pathways of the participants;
- long realisation times for the contents which call for a lot of work from the students and the teachers who act as reviewers of the works. This aspect is not always understood by the families of the students and scares many colleagues;
- great commitment and a long of hours' work that at time led to moments of demotivation when faced with unexpected situations and/or technical problems with the platform.

## Conclusions

The results of the questionnaires have shown that the testing realised in the school realities taken into examination attest to a high degree of awareness in respect to the potential of augmented reality in the didactic environment.

In this regard, what emerges is that the designing of learning pathways through augmented reality is positioned within a constructivist and problematic perspective of the learning process.

Through augmented reality, the students learned to explore, search for and construct new knowledge via creative means; they structured and re-elaborated the information and the data collected, constructing accessible digital pathways/narratives above all within the scope of exhibition events. Augmented reality indeed allowed them to know, discover, reinterpret, each one according to his or her own vision, a cultural asset or a place, transforming the physical spaces into scenarios of a person imaginary to be shared both with the school community and with the community of the territory of belonging. In so doing, the augmented reality produced an involving learning on the motivational level, with a significant impact on cognitive maturity and on the imagination.

However, it is important to underline that the data collected in the questionnaire also show how these school realities proceed with different methods and speeds. This depends on some factors that intervene in the design:

- the level of collaboration between the teachers with reference to the interdisciplinary design;
- the level of diffusion among the teachers of skills connected to the learning use of the augmented reality technologies;
- the management of the relationship with the bodies of the territory/heritage;
- the management of the relationship with the families in terms of communication and participation in the projects;
- the upgrading of the schools' technological infrastructures.

Faced with these issues, the schools are nonetheless moving in the direction of an active teaching realised both within and through the new environments of augmented reality. However, and the questionnaire highlights this, these environments offer concrete potential only if developed with reference to a precise educational project that constitutes the fundamental premise for supporting the learning process of students in terms of further analysis and creative re-elaboration of the knowledge and within spaces of collaboration and cooperation.

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