AR as a Tool for Teaching to Architecture Students

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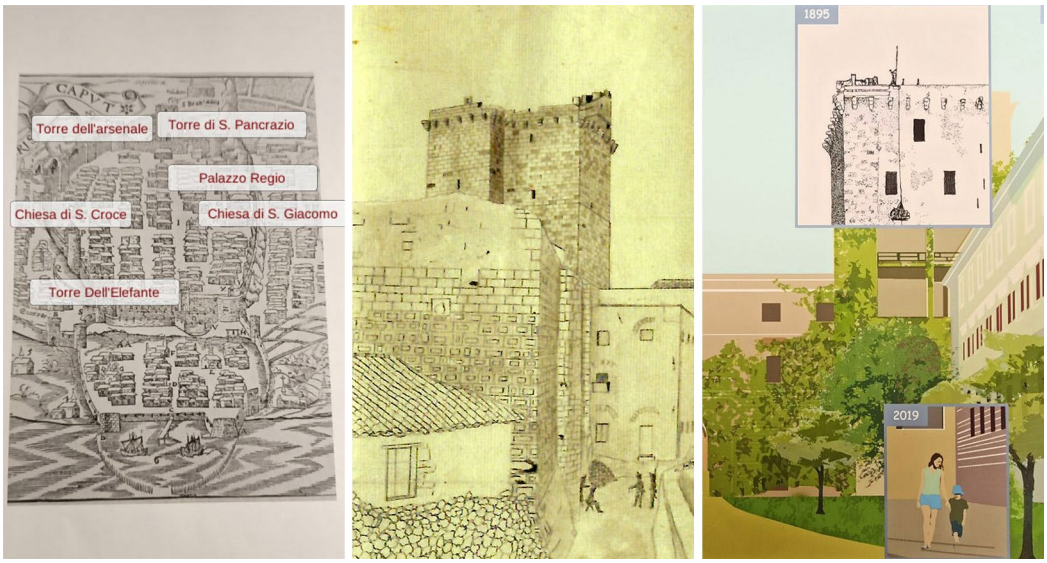
Abstract

Information and communication technology (ICT) are nowadays an integral part of daily life. Training and educational activities are among the different areas that widely profit from the use of these technologies.
The proposed contribution aims to develop an augmented reality application for accessing documentary sources used in the teaching of drawing disciplines in architecture courses at the University of Cagliari. Much information is produced and collected in drawing classes, primarily in the form of representations, which are either adopted by the professors year after year or elaborated by the students during the classes.
This collection of materials represents a significant legacy that is typically used to enhance instruction, despite certain obstacles in disseminating it among students.
As a result, it was decided to use some of the publications from the core bibliography for a student studying the Castello district and its architecture as an "access point" to the knowledge.

Keywords
AR, education, Cagliari, drawing disciplines, communication.



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Introduction

Information communication technologies (ICT) today play a central role in everyday activities. Among the various sectors that benefit from the use of these technologies there is undoubtedly that of training and educational activities; in fact, there are frequent studies that demonstrate how the application of technologies such as virtual world modelling, augmented or mixed reality, can facilitate the learning process and expand accessibility to information [Mortara, Catalano 2018].
The proposed contribution presents the first stages of an experimentation that aims to create an access application, in augmented reality [Quintero et al. 2019], to documentary sources used within the teaching activities of the disciplines of Drawing in the Architecture courses at the University of Cagliari. In the drawing courses a large amount of information is produced and collected, mostly in the form of representations such as drawings and photographic images, adopted by the teachers themselves from year to year or elaborated by the students in the development of the assigned themes. This "archive of drawings and graphic elaborations" defines an important patrimony normally used to support teaching itself with not a few difficulties of dissemination among students. This information can be easily catalogued and managed thanks to the use of a relational database that can contain the information of individual documents and, if necessary, offer advanced search tools based on links between names, dates, representation techniques, etc. [Chiavoni 2014].
The choice of augmented reality, relying on the database, focuses more on the problems related to access modes; while it is true that the database can be interrogated through forms suitably structured to be used by certain categories of users, such as students, this type of tool lacks a "narrative" of the information that can accompany the student in the discovery. It should be remembered, in fact, that querying the database returns as a result a series of information and documents that, although filterable according to the user's preferences, are not "linked" by an ordered logical thread.
For this reason, it was decided to use, as an "access point" to the information, some of the texts belonging to the fundamental bibliography for a student who is going to study the Castello district and its architecture [Spallone, Palma 2020]; in particular, it was decided to start the experimentation with the text *Forma Karalis* by Dionigi Scano [Scano 1934].
The intention is therefore to "enrich" the paper support with multimedia information, offering the student information and references related to maps, drawings and photographs represented within a certain volume, while preserving the narrative order. For each image of particular interest, framed by means of a mobile device, a series of labels are displayed on the screen that identify the object and, if tapped, open a tab containing additional information on the object.
This is particularly useful when, in the analysed image, objects are not represented in their current state. Typical cases can be photos or historical drawings, where the element is shown in a very different state than it is today, or transformations that have taken place on the urban scale when looking at a historical map; another interesting case is when the represented element no longer exists, such as in the case of demolitions and reconstructions during urban redevelopment or following wartime events. Immediate access to a series of subsidiary or supplementary information via an app facilitates a mode of use that is now consolidated among the youngest, allowing on the one hand a streamlined use of the adopted text and suggesting to students further possible insights and study ideas.

AR Applications for Education

Educational content can be accessed through many types of media. Traditional dissertation involves students to learn interacting and discussing with teachers and colleagues, and using textbooks or non-interactive media. In recent decades, digital media have assumed an increasingly important role in educational environments, providing students with the opportunity to learn through interactive tools. To make this possible, classrooms are equipped

with desktop computers and interactive whiteboards, and more learning experiences are accessible by students using modern portable devices. In parallel with new ways of access, new ways of interacting with learning experiences have also developed; keyboards and mice used to interact with content on the screen are being joined by tools that allow learners to use their whole bodies to interact with educational content that appears to exist in the physical world, thanks to augmented reality technology.
There are several researches illustrating the different possibilities offered by augmented reality (AR), which have led it to be one of the emerging technologies rapidly incorporated in the educational sphere [Akçayır, Akçayır 2017; Johnson et al. 2016]. Precisely, the ease of access to information offered by this tool is, among others, one of the most interesting; this is partly due to recent technological developments that have led to more frequent use of mobile devices in the educational sphere, in the presence of subjects with disabilities or different educational needs [Lin et al. 2016]. Through the combination of the physical and digital environment, AR makes it possible to generate a new reality [Hernández et al. 2015].
However, it should be kept in mind that augmented information can go beyond the sense of sight alone, applying to all senses, such as hearing, smell and touch [Azuma et al. 2001]. Due to this, AR is to be considered extremely promising for facilitating and encouraging processes of educational inclusion [Sheehy et al. 2014]; this technology in fact envisages the support of multiple means of representation, action and the involvement of students in different ways in the learning process [Meyer et al. 2014]. In this regard, Hrishikesh and Nair [2016], in their studies, found that AR facilitates children with disabilities to understand concepts more effectively and quickly. In 2014, Mohd Yusof et al. also demonstrated how AR is able to capture the attention of students with special needs, providing them with educational tools that are fun and enjoyable to use.
Moreover, AR has been shown to have a positive impact on students' educational experience, increasing their trust, level of involvement and interest [Fombona et al. 2017]; it can promote self-learning [Akçayır, Akçayır 2017], but also cooperative learning [Phon et al. 2014], as well as improving the sense of satisfaction and thus motivation in students [Bacca et al. 2018].
However, there are possible negative implications that can be derived from the use of AR systems compared to non-AR systems, which must be taken into account, such as the so-called Attention tunnelling.
Indeed, there are experiments in which students perceived the demand for more attention using AR systems. As a consequence of this, students tend to ignore important parts of the experience or feel inadequate to the demands of the assigned tasks. Furthermore, as observed by Tang et al. [2003] when performing object assembly tasks using AR, users had a greater tendency to ignore previous errors than users performing the same tasks on paper.
Attention tunneling can be a source of danger on certain occasions, which is why it is important to study how the system channels users' attention.

Drawing and Representation Llaboratory Materials

The teaching of Drawing is based on both the use and production of works that synthesise and represent physical reality.
From the earliest years, students are taught the techniques and rules for reading and representing architecture and landscape; this is done with the help of images, whether photos, videos or drawings, as well as models, sculptural elements etc., which are the result of the typical activities of a Drawing course (Fig. 1). In response, the students, while carrying out their study activities, produce new works that become part of the Laboratory's materials.
Over the years, therefore, a seemingly vast collection of materials has been created, which are both an aid and a result of teaching and research; furthermore, this collection has become an invaluable heritage in that it represents and bears witness to how the teaching of Drawing has evolved over the years and how it is still carried out today.

Fig. 1. Some examples of materials belonging to a Drawing Laboratory.

These materials, as already mentioned, are of the most varied natures, from historical cartography to landscape drawing, from study models to plaster casts, from old photographic plates to digital photographs and slides. The study of historical cartography leads to the compilation of new cartography, lightened or enriched with details as needed, just as photographic images are synthesised by redrawing a view during a landscape study or the elevation of a building.
The physical models, which are themselves material reproductions of project drawings, are reproduced or placed side by side digitally by means of 3D models, which offer new keys to interpretation or alternative representations. The drawings or photos produced decades earlier are digitised in order to be preserved; similarly, plaster elements, which were common until the middle of the last century for studying the design of architectural details, now constitute a veritable heritage whose memory can be preserved using modern laser scanning or photogrammetry techniques. To this must be added all the scientific production for the study and interpretation of materials and the subjects represented in them; scientific production that today is practically only digital but increasingly abundant and articulated.
It is clear and undeniable the value that these materials have had and still have in the didactics of Drawing, as well as the support that students can draw from them, if access to this knowledge takes place in a reasoned and structured way.
However, a collection such as the one described involves the problem that it is all the more valuable and difficult to manage and communicate the larger and more heterogeneous it is. Older materials have to be handled with care, thus placing limits on the number and type of users who can be granted access to them; on the other hand, digital materials are often of such a number and nature that effective dissemination is difficult. Cause these problems and taking into account the richness represented by these materials, there is an increasing number of digitised archives of materials related to the discipline of Drawing.

Forma Karalis

Dionigi Scano was an undoubtedly important figure in the architecture and town planning of Cagliari at the turn of the 19th and 20th centuries. Graduated in civil engineering in the Regia Scuola d'Applicazione in Turin, Filippo Vivanet called him back to Sardinia to become his collaborator in the regional office for the conservation of monuments.
Besides having been responsible of the restoration of several important monuments, including the Tower of San Pancrazio in Cagliari, Scano was also very active as an architect, completing buildings of some importance such as the National Archaeological Museum.
In addition to his role as a politician and architect, Scano is also known for numerous essays on medieval architecture in Sardinia and on a variety of other topics.

Of particular importance is his 1934 work Forma Kalaris, already published in previous years with the subtitle '*Stradario storico della città e dei sobborghi di Cagliari dal XIII al XIX secolo*'.
The work illustrates the evolution of the city thanks to photos and numerous maps, which tell the story of its development over the centuries, and provides a valuable description of how it looked at the beginning of the last century. Scano describes the historical quarters as well as the continuous expansion, particularly towards Via Roma in the early 20th century. The wealth of information and images present in Forma Karalis have made it one of the essential texts for any student wishing to approach the study of the city of Cagliari; this is precisely the main reason why Scano's text was chosen as the first object of the presented experiment.

Design of the Database Structure and App Features

Once the types of materials to be made accessible and the channel through which access is guaranteed have been established, it is necessary to proceed with the design of the database and the app; this chapter presents the basic characteristics that the future prototype must have, also proposing some mockups. In order for the designed App to guarantee easy access to information and materials, it is essential that a database containing the main information about the materials to be consulted be developed and populated beforehand. It is therefore necessary to make an initial census of the materials in order to identify the type (paper images, digital files, physical objects, etc.) and the main characteristics; some of the characteristics will have semantics common to all types, such as the name of the author, the date and so on, while other characteristics may be specific to a given type, such as the resolution for a digital image or the type of technique used for a drawing on paper. In addition to the metadata of each type, for which there are precise references to international standards, each object must be accompanied by a series of "tags" that determine its positioning in certain groupings; these tags will then be the basis for the collection and navigation within the app. Some of these tags may include the name of the course during which a particular paper was produced, or its physical location; this will allow the user to view all the materials belonging to the individual course or collected in the same place, useful for example for possible future consultation of the originals.
Another type of tag that is fundamental for effective consultation is the one that concerns the contents of the coursework and what is represented in it; the tags relating to the contents allow for navigation unrelated to the type of coursework and are fundamental for research relating to a single element, be it architecture, an urban space, a district or a person. It is evident that the structure just described for a database is typical of a relational database; this type of database allows an intuitive structuring of the data relating to the individual objects, organised in tables and correlated with each other by means of relations established beforehand, with the possibility of expanding the database at any time by inserting new characteristics or new objects.
Once the characteristics to be attributed to the individual objects and the tags to be used have been established, the objects are inserted into the database. At the same time, the texts to be used as access points to the information are identified (Fig. 2).
This step also includes the study of the works contained in the chosen texts and the attribution of the tags from which to trigger the process of consulting the database. This phase

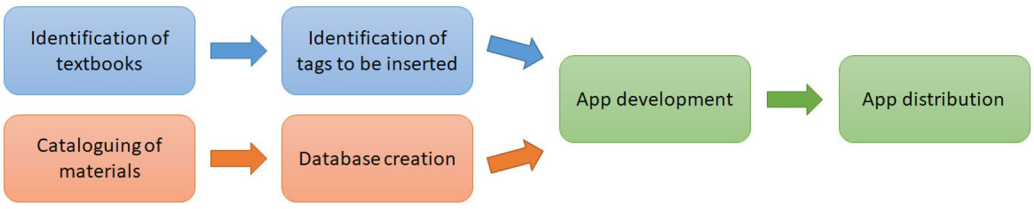

Fig. 2. Workflow proposed.

is of particular importance since the assignment of the tags can have a decisive influence on what information is immediately provided to the user; it is therefore necessary to study and calibrate the tag system according to the type of user and his level of knowledge.
In fact, if tagging a precise element can lead the user to the information targeted on the object of his search, using instead a tag for example of the district, can make the search more articulated but offering more information of the context.
Once the reference texts have been identified, appropriately tagged, and the objects inserted in the database, the next step is the development of the AR consultation App. It is possible to imagine this app as an AR visualiser of the tags on the images present in the reference texts, which, at each tap on one of the tags, triggers a query based on the tag itself. A possible suitable software is the Unity game engine for the development and coding of the application, and its extension Vuforia, designed specifically for the implementation of AR mechanics. In particular, Unity is used to develop the user interface and the database access mechanisms, using simple MySQL code for example; Vuforia is used to create the 'targets', i.e. the images to which the interactive objects representing the tags in the original image are attached.
Once the consultation has started, the user is free to navigate through the digital works, for each of which it's possible to find information on the single object/process, but also other tags to continue the exploration of the contents. At the moment there are three types of element to which specific views correspond: person, object, work. A person is obviously any subject who can be identified as the author of works or the protagonist of events of interest, and is associated with a bibliographic sheet, a works sheet and a bibliographic sheet. Objects, on the other hand, include physical entities such as architecture, an urban space, or a single artefact; they are associated with a descriptive sheet containing the main information, such as author, materials, dating, bibliographic information, etc., a sheet containing the historical materials related to the object, and finally the related works present in the Drawing laboratory. Finally, the elaborate category, which is closely linked to the previous one, includes any catalogued digital product, including photos, graphic works, 3D models, articles and so on; this type is associated with the information sheet containing information on the individual elaborate, i.e. author, dating, techniques used, etc., a sheet containing other elaborates with the same subject or topic, for example. The last sheet relating to the works is that relating to the occasion during which the work was produced, i.e. a course, a research project, a thesis and the like; from this last sheet it is possible to access information regarding, for example, the specific course, with an indication of the teacher name, the course objectives or the reference bibliography.

An Example of Consultation

The logic behind the consultation flow is quite simple and can be schematised as shown in Fig. 03a. Once the user decides which text to consult, if this is among the "augmented" texts, she can use the app for each image in the text or decide to proceed with a standard consultation. If the user decides to use the app, the tags related to the framed image are displayed, allowing access to additional information; for each element displayed, be it a person, a monument or an elaboration, related information is provided and the possibility of moving on to a new element or stopping the augmented consultation. If the user decides to interrupt the consultation, the app goes into standby while the user resumes the classic consultation. At any time, it is possible to resume the augmented consultation following the same procedure.
To better clarify the flow of consultation, an example of access to information is proposed (Fig. 3b). The user decides to consult the text Forma Karalis by Scano and arrives at the map of Cagliari of 1558 attributed to Sigismondo Arquer; she then decides to get more information and frames the map with the app. The app shows her a series of tags linked to some of the main monuments recognisable on the map and, among these, the user decides to click on the tag relating to the tower of San Pancrazio; a tab is then opened

with a brief description of the tower. From here the user can view a second tab containing some historical documents related to the tower of San Pancrazio or a third tab with works produced by the Drawing laboratory; in this last screen the user selects a work related to an experiment on the use of time windows for the narration of urban spaces. A new tab is then displayed, providing information on the selected work, such as the name of the authors, the year in which it was created or the reference course. With regard to the course, the user can open the relevant tab and access the information compiled by the teacher for the course in question, including the course objectives. Finally, on a third tab the user can view further works on the same subject; once she is satisfied with the information received, she can close the enhanced consultation and resume reading the book.

Conclusions

The contribution deals with the difficulties that can arise when the access to a wide collection of materials inherent to the teaching of the discipline of Drawing must be garanted to students. In order to do this, it was decided to design an AR app using as an "access point" the texts that are most frequently consulted by a student of Architecture who is about to study the city of Cagliari. The workflow proposed, easily applicable to a relatively large

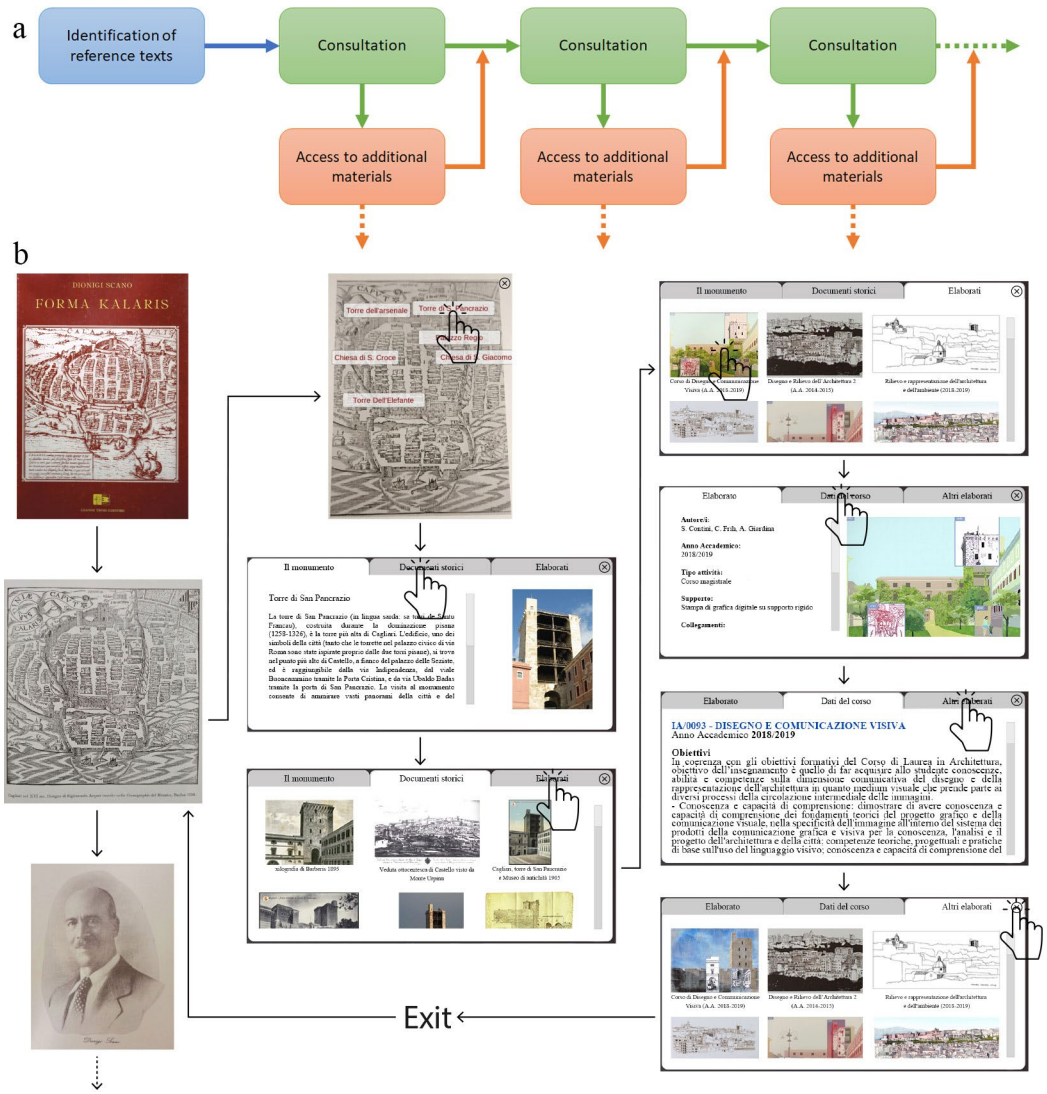

Fig. 3. Consultation flow (a) and a summarized example (b).

number of texts and expandable over time, offers the possibility of structuring a path of learning and discovery of the materials in the possession of the laboratory of Drawing, leaving the text itself to guide the user.
In the future, the research develope a working prototype, extending the range of both "augmented" books and materials that can be consulted. It is also considered necessary to investigate some problematic aspects, such as the attribution of a scale of potential interest for the various materials available for consultation, and to calibrate this scale and the paths of exploration according to the characteristics of the user.

References

Akçayır Murat, Akçayır Gökçe (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. In *Educationl Research Review*, 20, 2017, pp. 1-11.

Azuma Ronald, Baillot Yohan, Behringer Reinhold, Feiner Steven, Julier Simon, MacIntyre Blair (2001). Recent advances in augmented reality. In *IEEE computer graphics and applications*, 21 (6), 2001, pp. 34-47.

Bacca Jorge, Baldiris Silvia, Fabregat Ramon (2018). Insights into the factors influencing student motivation in augmented reality learning experiences in vocational education and training. In *Frontiers in psychology*, 9, 2018, 1486, pp. 1-13.

Chiavoni Emanuela (2014). Drawings on paper. Digital historical archives of the former Radaar Department at the University Sapienza School of Architecture in Rome. In *SCIRES-IT – SCIentific RESearch and Information Technology*, 4 (2), 2014, pp. 117-126.

Fombona Javier, Pascual-Sevillana Ángeles, Gonzalez-Videgaray MariCarmen (2017). M-learning and augmented reality: A review of the scientific literature on the WoS Repository. In *Comunicar. Media Education Research Journal*, XXV (2), 2017, pp. 63-71.

Hernández Maricela Morales, Quecha Claribel Benitez, Martínez Dalia Silva, Cabrera Marisol Altamirano, Gómez Héctor Manuel Mendoza (2015). Aplicación móvil para el aprendizaje del inglés utilizando realidad aumentada. In *Revista Iberoamericana de Producción Académica y Gestión Educativa*, 2 (3), 2015, pp. 22-31.

Hrishikesh N., Nair Jyothisha (2016). Interactive learning system for the hearing impaired and the vocally challenged. In Wu Jinsong, Martinez Perez Gregorio, Thampi Sabu M., Atiquzzaman Mohammed, Berretti Stefano, Rodrigues Joel, Tomar Raghuvir, Prakash Gorthi Ravi, Siarry Patrick, Khan Pathan Al-Sakib, Li Jie, Bedi Punam, Mehta Sameep, Kammoun Mohamed Habib, Jain Vivek (eds.). *2016 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*. Piscataway: IEEE, pp. 1079-1083.

Johnson Larry, Becker Samantha Adams, Cummins Michele, Estrada Victoria, Freeman Alex, Hall Courtney (2016). *NMC horizon report: 2016 higher education edition*. Austin: The New Media Consortium.

Lin Chien-Yu, Chai Hua-Chen, Wang Jui-ying, Chen Chien-Jung, Liu Yu-Hung, Chen Ching-Wen, Lin Cheng-Wei, Huang Yu-Mei (2016). Augmented reality in educational activities for children with disabilities. In *Displays*, 42, 2016, pp. 51-54.

Meyer Anne, Rose David Howard, Gordon David T. (2014). *Universal design for learning: Theory and practice*. Wakefield: CAST.

Mohd Yusof Anuar, Daniel Esther Gnanamalar Sarojini, Low Wah Yun and Ab. Aziz Kamarulzaman (2014). Teachers' perception of mobile edutainment for special needs learners: the Malaysian case. In *International Journal of Inclusive Educatio*n, 18 (12), 2014, pp. 1237-1246.

Mortara Michela, Catalano Chiara (2018). 3D Virtual environments as effective learning contexts for cultural heritage. In *Italian Journal of Educational Technology*, 26 (2), 2018, pp. 5-21.

Phon Danakorn Nincarean Eh, Ali Mohamad Bilal, Abd Halim Noor Dayana (2014). Collaborative augmented reality in education: A review. In Phon Danakorn Nincarean Eh, Ali Mohamad Bilal, Abd Halim Noor Dayana (eds.). *2014 International Conference on Teaching and Learning in Computing and Engineering*. Los Alamitos: IEEE, pp. 78-83.

Quintero Jairo, Baldiris Silvia, Rubira Rainer, Cerón Jhoni, Velez Gloria (2019). Augmented Reality in educational inclusion. A systematic review on the last decade. In *Frontiers in Psychology*, 10, 2019, 1835.

Scano Dionigi (1934). *Forma Karalis*. Cagliari: Edizioni La Zattera.

Spallone Roberta, Palma Valerio (2020). Intelligenza artificiale e realtà aumentata per la condivisione del patrimonio culturale. In *Bollettino della Società Italiana di Fotogrammetria e Topografia*, 1, 2020, pp. 19-26.

Tang Arthur, Owen Charles, Biocca Frank, Mou Weimin (2003). Comparative effectiveness of augmented reality in object assembly. In Tang Arthur, Owen Charles, Biocca Frank, Mou Weimin (eds.). *CHI '03: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. New Tork: ACM, pp. 73-80.

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