AUGMENTED DIDACTIC: WOW EFFECT FOR LEARNING. USE OF AUGMENTED REALITY THROUGH A QR CODE TO ENHANCE LEARNING PROCESSES IN UNDERGRADUATES

DIDATTICA AUMENTATA: EFFETTO WOW PER L'APPRENDIMENTO. L'USO DELLA REALTÀ AUMENTATA ATTRAVERSO I QR-CODE PER MIGLIORARE I PROCESSI DI APPRENDIMENTO NEGLI STUDENTI UNIVERSITARI

Luna Lembo
Niccolò Cusano University
luna.lembo@unicusano.it

Elèna Cipollone
Niccolò Cusano University
elena.cipollone@unicusano.it

Pietro Oliva
Niccolò Cusano University
pietro.oliva@unicusano.it

Salvatore Monteleone
Niccolò Cusano University
salvatore.monteleone@unicusano.it

Double Blind Peer Review

Citation

Lembo L., Cipollone E., Oliva P., Monteleone S., (2023) Augmented didactic: wow effect for learning. Use of augmented reality through a qr code to enhance learning processes in undergraduates, Giornale Italiano di Educazione alla Salute, Sport e Didattica Inclusiva - Italian Journal of Health Education, Sports and Inclusive Didactics. Anno 7, V 2. Edizioni Universitarie Romane

Doi: https://doi.org/10.32043/gsd.v7i2.893

gsdjournal.it
ISSN: 2532-3296
ISBN: 978-88-6022-470-5

ABSTRACT

AUGMENTED DIDACTC: wow effect for learning. Use of Augmented Reality through a QR-code to enhance learning processes in undergraduates.

Studies show that AR has many advantages when used in educational contexts (Cheng, 2013), as it helps students understand the study content, facilitating learning (Tambunan, 2014), increasing attention, motivation and participation (Yildirn, 2018). This quantitative experimental research uses AR through a QR-code to support didactics for undergraduates, through use of QR-code favouring the acquisition of abstract and difficult notions.

DIDATTICA AUMENTATA: effetto wow per l'apprendimento. L'uso della realtà aumentata attraverso QR-code per migliorare i processi di apprendimento negli studenti universitari.

Gli studi dimostrano che la realtà aumentata (AR) presenta numerosi vantaggi quando utilizzata in contesti educativi (Cheng, 2013), poiché aiuta gli studenti a comprendere i contenuti di studio facilitando l'apprendimento (Tambunan, 2014), aumentando l'attenzione, la motivazione e la partecipazione (Yildirn, 2018). Questa ricerca sperimentale quantitativa utilizza la realtà aumentata tramite un QR-code per supportare la didattica degli studenti universitari, agevolando l'acquisizione di nozioni astratte e complesse

KEYWORDS
University, memorization, smartphone, qr code, data analysis
Università, memorizzazione, smartphone, qr code, analisi dati

Received 20/05/2023
Accepted 20/05/2023
Published 20/05/2023

Introduction[1]

Considering the change and evolution of learning scenarios in the era of technology, attention is focused on the need to reconsider teaching methodologies in a way that takes into account students' digital nativity. Digital technology permeates education in order to facilitate the learning process. This aims to respond to the learners' new attitudes, which increasingly lean towards a greater use of technologies that can serve as support or distraction during the knowledge acquisition phase. The student's citizenship becomes digital citizenship, which indispensably requires a reinterpretation of the educational experience based on the pervasive and transversal use of new technologies. In this analytical context, augmented reality used in an educational context emerges as an innovative research area, insofar as the resulting outcomes can provide significant elements for pedagogical reflection. The goal is therefore to establish and evaluate the effectiveness of educational pathways developed through the use of this technology (Rivoltella, 2010). Based on this premise, the impact of augmented reality on teaching methodology and learning processes is investigated, leveraging the "wow" effect to improve performance and at the same time reconsidering the role of smartphones as a means of supporting education, as they allow for easier and immediate access to technology, specifically in terms of augmented reality.

"When we talk about Augmented Reality, we refer to a layer of information connected to an image or representation of the world, in order to offer users the possibility of accessing localized information in an extremely intuitive manner" (Rossi, 2013).

1. Smartphones in didactics

The digital nativity of students leads to the assumption of a deep-rooted tendency among them to act, think, and acquire knowledge in a way that is dependent on

[1] Luna Lembo: author of Introduction, paragraphs 1, 2, 2.1
Elèna Cipollone: author of paragraphs 4, 4.1, 4.2, 4.3, 4.4 and conclusion
Pietro Oliva: author of paragraphs 2, 3
Salvatore Monteleone: Technician

the tools through which they interact with the world. This necessitates a rethinking of the purely instrumental conception of technological devices, as it precludes a proper analysis of the complexity of the relationship with technology and consequently hinders the understanding of the potential dynamics underlying the creation of a new form of knowledge (Ferri, 2017).

In this perspective, it becomes evident how the technological revolution is so pervasive that it would be limiting not to consider it as a cultural turning point. Hence, there is a need to respond to what is identified as a new era in the fields of education, learning, and teaching. Even today, there is still a dichotomy between progress towards digital evolution and the anchoring to exclusively analog tools for teaching. This dichotomy, in the face of the evident change in the experiential and relational modes of students, characterized by constant interaction with touch screens, becomes a limitation not only to progress but also to the ability to embrace the new languages of the students themselves, which are fundamental in the construction of effective teaching methodologies.

Considering the constant use that people make of smartphones today, the potential of this tool has been harnessed for educational purposes. Young people are confirmed as the most avid users of the internet, with over 90% of 15-24 year-olds (Istat, 2019). By overcoming the demonization surrounding the idea of smartphones in the classroom, they become useful for immediate access to augmented reality as an enhancement of education itself, thus giving smartphones a new role in student education. Research shows that this tool significantly changes the educational process. It eliminates routine phases and facilitates research activities. It is a modality that can be used across the board to integrate traditional and digital teaching approaches (Slipukhina, 2020).

Assuming that smartphone usage among young people is extensive, there should be greater awareness of the potential of this tool. In fact, not all smartphone users who use it for conventional purposes such as making calls, sending messages, or using social networks are aware of its real capabilities. Many are unaware that smartphones often possess more power than the equipment found in their school's scientific laboratories, especially when access to internal sensors is available for educational use (Parolin, 2013, Staacks, 2018). Research conducted on the use of smartphones in education highlights positive aspects in terms of inclusion and innovation, as it enables active student participation, which is a fundamental dimension of learning (Maurizio, 2018). Therefore, through smartphones, it is intended to redirect the learning experience towards enhancement. The possibility of maintaining contact with reality and the affordability of the means required for basic use of this technology, such as smartphones, make it particularly interesting for potential applications in educational settings (Guglielmi, 2017).

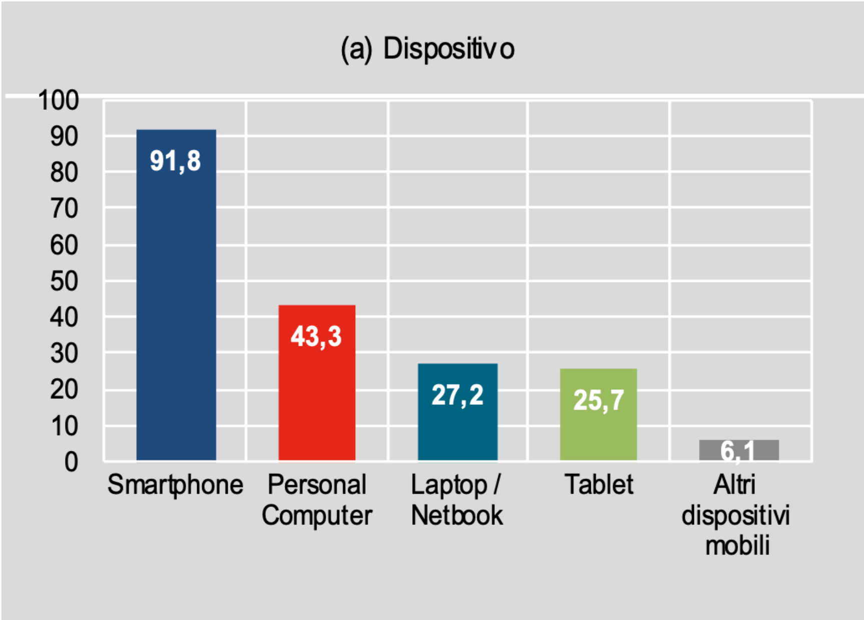


Fig.1 Access to the Internet through a device, Istat 2019

Dataset:Internet: accesso e tipo di utilizzo

Sesso	totale												
Seleziona periodo	2022												
Classe di età	6-10 anni	11-14 anni	15-17 anni	18-19 anni	20-24 anni	25-34 anni	35-44 anni	45-54 anni	55-59 anni	60-64 anni	65-74 anni	75 anni e più	6 anni e più
Tipo dato													
leggere o scaricare giornali, informazioni, riviste online	0	0	0	0	0	0	0	0	0	0	0	0	0
consultare un wiki (per ottenere informazioni su qualsiasi argomento)	0	0	0	0	0	0	0	0	0	0	0	0	0
caricare contenuti di propria creazione sui siti web per condividerli	0	0	0	0	0	0	0	0	0	0	0	0	0
scaricare software diversi dai giochi	0	0	0	0	0	0	0	0	0	0	0	0	0
usare servizi di archiviazione su Internet per salvare documenti, immagini, video o altri file	0	0	0	0	0	0	0	0	0	0	0	0	0
usare servizi relativi a viaggi o soggiorni	0	0	0	0	0	0	0	0	0	0	0	0	0
partecipare a consultazioni online su temi sociali o politici (es. pianificazione urbana, firmare una petrizione)	1,5	4	11,6	14,4	16,4	16,1	12,7	11	9,9	10,7	8,8	7,6	11,2
vendere merci o servizi (es. aste online, eBay)	0	3,1	9,7	16,3	24,4	24,2	22,9	16,2	11,6	9,9	6,7	3,2	14,9
cercare lavoro o mandare una richiesta di lavoro	0	0	4	18,7	30,4	28,9	19,8	13,5	7,8	4,2	1,4	0,9	13,3
esprimere opinioni su temi sociali o politici attraverso siti web	6,3	17,4	30,8	37,9	33	34,4	31,3	27	21,2	21,6	17,1	14	25,7
fare un corso online	7,7	13,4	30,2	36,2	40,8	28,5	23,3	20,2	18,2	13,1	6,2	2,2	20,4
cercare informazioni sanitarie	2,3	10,5	31,1	46	54,8	61	63,5	65,2	65,5	64,1	61,1	57,4	55,4
usare servizi bancari	0	0	5,5	32,8	54,9	65,4	66,2	60,4	57,1	54,3	45,2	38	49,9
giocare o scaricare giochi, immagini, film, musica	73,2	80,9	74	63,3	57,4	42,2	34,1	26,1	20,7	19	17,3	14,5	37,2
leggere giornali, informazioni, riviste online	6,2	21,3	39,8	51,3	61,7	66,7	67,4	63,2	63,8	64,3	60,7	59,5	57,9
cercare informazioni su merci e servizi	6,2	15,8	41,1	58,9	64,6	69,1	69,1	64	61,9	59,8	50,7	43,5	56,8
partecipare a social network (es. creare un proflo utente, postare messaggi o altro su Facebook, Twitter ecc.)	8,5	49,2	84	87,2	82,1	79,5	70,5	58	48,6	44,4	35,2	26,1	58,2
spedire o ricevere e-mail	11,5	47,8	75,1	86,8	88,9	89,5	87,9	82,2	79,9	75,8	67,9	61	76,4
persone di 6 anni e più che hanno usato internet negli ultimi 3 mesi per attività svolta	..	..	..	..	..	..	..	..	..	..	..	..	..

Table 1. Internet access and type of usage, Istat 2019

In light of this, there is a shift towards rethinking the role of the smartphone, recognizing that new technologies can facilitate teaching methodologies based on a constructivist approach. In this perspective, both the role of the learner and the role of the teacher change: the student is no longer seen as a mere receptacle to be filled, and the teacher's lesson is not passively listened to. Instead, students actively collaborate with the teacher, using their own technological device.

The teacher, in this way, becomes not only the primary source of information but also a facilitator and mediator of knowledge. When students use their smartphones for educational purposes, they become more actively involved in their own learning process, contributing to the construction of meaningful learning experiences (De Marco, 2019).

2. Augmented Reality for didactics: Augmented Didactic

Augmented reality (AR) in educational settings is defined by the potential it offers, as it allows students to experience augmented experiences that enable a high level of interaction with the knowledge they want to acquire at that moment (Tomassoni, 2021). The recent applications of augmented reality in the use of textbooks, which enhance their capabilities (Cino, 2017; Filomia, 2019), suggest reflecting on the psycho-pedagogical potential that digital contributions could offer in educational contexts (Diegmann, 2015; Niewint, 2019; Pancioroli & Macauda, 2018).

Consider how augmented reality makes the presentation of content more effective by requiring greater interaction and engagement from students. Augmented reality allows us to overcome the limitations imposed by current teaching aids such as slides, images, or video files, making the learning experience much more exciting and engaging (Tomassoni, 2021). It is precisely the possibility of interacting with the concept to be acquired that led us to rethink the teaching method, based on the dual need to find on one hand an anchoring with the new predispositions and attitudes of students, who now operate in the digital sphere, and on the other hand to harness the intrinsic potential of an Embodied Cognition approach that sees the body as the most natural aspect of learning (Paloma-Gomez, 2016).

The potential of accessing and even manipulating the concept to be acquired in the learning context, becoming aware of a manageable overall reality according to specific needs, was considered to enhance the learning processes. Improving the learning processes involves a more active participation from the student and a greater and renewed awareness of what is being learned, an awareness that is much more effectively conveyed through augmented reality compared to a mere two-dimensional image. Furthermore, the potential of augmented reality lies in its ability to engage multiple senses simultaneously, turning the learning experience into a holistic knowledge acquisition process that involves the entire body. In this way, AR functionally responds not only to the specific and individual learning styles that are increasingly heterogeneous among students but also to the educational needs of students with disabilities (Di Martino & Longo, 2019).

2.1 Augmented Reality and learning processes

Augmented reality (AR) in educational contexts represents a significant technological advancement that allows students to engage in enhanced learning experiences, going beyond theoretical knowledge. AR provides visual, manipulable, and highly interactive learning opportunities that enrich the real world by overlaying digital data and simulating dynamic processes. The potential of AR lies in its ability to incorporate informational content into objects, which, when captured by a device, can respond by displaying text, images, or videos for presentation and further exploration. In a physical context, the objects presented to students tend to be inanimate, static, and silent. However, through AR, these objects come to life on the mobile device screen, enriched with elements that enhance comprehension (Panciroli, 2018).

The use of AR in educational settings is primarily based on the approach of mobile learning, where learning is supported by the use of smartphones or mobile devices in general. This approach aligns with the concept of affordance, as the affordances inherent to these devices, such as ease of access, portability, versatility, and multifunctionality, make them highly valuable tools for integration into teaching methodologies and active participation in the teaching and learning processes of today's students (Bonaiuti, Calvani & Ranieri, 2016).

The use of AR promotes greater accessibility to information related to the concept being learned, allowing students to experience the concept not only visually but also through manipulation. AR provides an augmented image that students can explore from within, zooming in or out, rotating, and moving their fingers on the screen to grasp its overall relationships, enhancing and facilitating understanding through a more realistic and engaging approach. Layered information is provided to enable further exploration of additional meanings (Panciroli, 2018).

Scientific evidence shows that one of the dimensions significantly enhanced by AR is interactivity, which is crucial for fostering meaningful learning processes. Unlike traditional teaching aids, the objects presented through AR are not static but can move and respond to user actions. The meaningfulness of the resulting learning comes from the improved memory retention of knowledge acquired through AR (Dünser, 2012). Furthermore, the scientific community agrees that integrating AR into teaching methodologies improves exploratory skills, facilitates the absorption of new knowledge, and increases student motivation and emotional impact (Liu, 2009). By harnessing the students' habitual use of smartphones, the aim is to provide an educational approach, encouraging them to use their devices during study sessions, thus creating highly interactive and engaging learning experiences that leverage the power of technology and the internet for more dynamic content transmission (Bidoia, 2016).

3. From 3D model to AR model

In the field of creating three-dimensional models for educational purposes, it is advisable to refer to the main development tools currently used, preferably open-source. For the models of choice, we used .GLTF files, which contain a 3D model saved in the GL Transmission Format (glTF). The advantage of this format is the ability to include a complete description of the scene in JSON format within the file, including node hierarchy, cameras, materials, as well as descriptive information about animations and meshes. Once the 3D models are loaded into the repository, they are called by a JavaScript script that associates them with ArUco markers. These markers can then be used in web pages, presentations, PDFs, and any other digital or printed documents. The advantage of these markers is that they can be easily detected by smartphone cameras, even when captured at high angles or rotated relative to the vertical position of the device used. Furthermore, their binary encoding makes them particularly robust, allowing for error correction in detection and decoding. For example, Figure 2 shows the original model in the left frame, from which the .GLTF file is exported and then associated with a specific marker in the right image. The model displayed to the user on their smartphone can be manipulated using touchscreen commands. The effect of viewing a three-dimensional model against the backdrop of the immediate reality accessible to the student serves to amplify the focus on an augmented reality that exists within the space and time of the study session. These markers are most suitable for students' use due to their robustness in terms of rotation, trapezoidal or perspective distortion. Furthermore, ArUco markers are particularly effective even in conditions of low lighting, making augmented reality accessible anywhere and at any time, aligning with the research objective of ease of use. Consider the position that the student assumes during the lesson, where the perpendicularity between the device and the physical support is not always guaranteed. In light of this, the choice of these markers resolves any difficulties and adequately fulfills the project's objectives. The embodied approach supports the overcoming of the Cartesian mind-body dualism, giving the latter a new dignity and centrality in the learning processes. This implies the need to make the use of augmented reality globally experiential by equipping the models with features of scalability and rotatability, through touchscreen gestures that leverage the coordination between action and perception, and the execution of gestural motor actions that contribute to the development of conceptual knowledge from an embodied cognition perspective. This was made possible thanks to the use of the Aframe framework, a library that allows for model manipulation. The overlay of the 3D model onto the student's physical reality is closely related to greater involvement of the student, who becomes the protagonist of a highly emotionally impactful learning experience, positively influencing the internalization of concepts that find an anchoring with the reality in which the subject is immersed (Tomassoni, 2021).

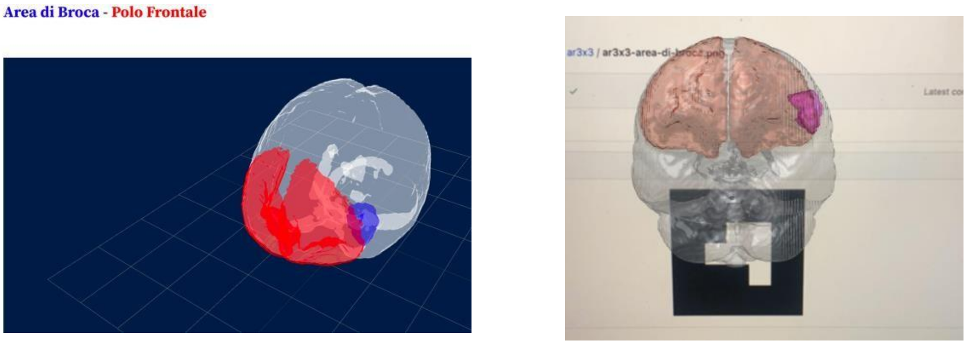


Fig. 2 3D Brain Model with Broca and Frontal lobe areas highlighted, linked toArUco marker via html

Fig. 3 By scanning the QR code on the left, the camera of the smartphone is activated, and you enter the context of augmented reality. Scanning the marker onthe right will display the model that indicates the activation of areas associated with movement.

4. Research Project

4.1 Research Hypothesis and sample

The research hypothesis aims to determine if AR, conveyed through qr code, can implement the learning of abstract and difficult notions in undergraduates. The sample consists of 90 students from the Educational Department of Niccolò Cusano University in Rome.

4.2 Method and Material

The sample was randomly divided into two groups, an experimental group of 51 subjects and a control group of 39 subjects. The proposed teaching activity included a traditional didactics lesson, with frontal explanation and with multimedia support, such as slides and videos. In addition to this, the experimental group benefited from the use of AR. Specifically, AR was presented through qr code which, as in figure 3, allowed to view and manipulate the notions presented in class. AR was therefore used both during the lesson, during the explanation phase, and during learning at home.

Figure 4. AR, by qr code, on smarthpone

The topics developed in the AR concerned concrete but difficult to understand concepts. This choice was linked to a preliminary analysis which showed that this type of information is the most difficult to learn from the reference population.

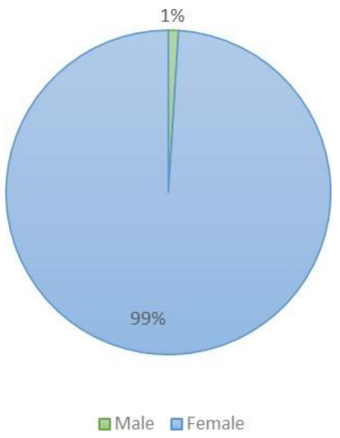
Specifically, it was chosen to treat the neural bases of some cognitive functions, i.e. memory, emotions, movement and languages and of each of these, it was analyzed the level of memorization of the areas underlying the cognitive function, the specific functioning of the area and the mechanism of functioning of the cognitive process.

At an early stage of the trial, we administered the Rey Auditory Verbal Learning test (RAVLT), a mnemonic test used to exclude the presence of memory disorders within the sample. No one had mnemonic disease so the sample taken into account was composed by 90 students.

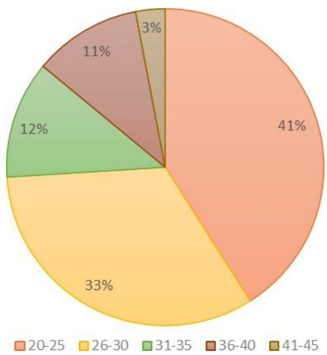
Afterwards, the proposed didactics activity was carried out, inside the laboratories of Special Pedagogy, during which, in the experimental group, the Qr codes for the RA were provided.

Then, at the end of the proposed teaching activity, we administered, both to the experimental group and to the control group, a spontaneous recall questionnaire aimed at investigating the level of memorization of the concepts explained.

4.3 Results and Data Analysis

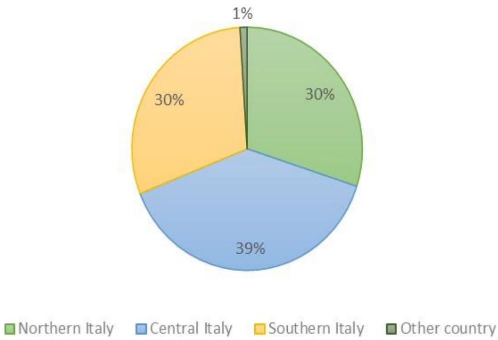


Graph 1. Sample gender

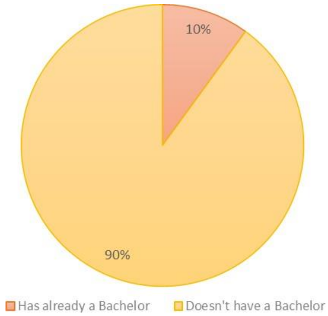


Graph 2. Sample age range

The sample, made of 90 students from the Education Department is composed of 99% females and 1% males. The age is quite heterogeneous, from 20 years to 45 years, with an average age of 26 years.

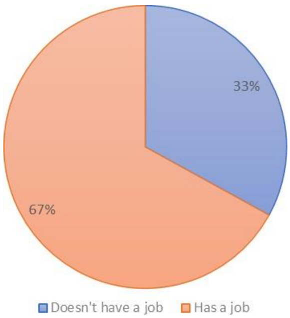


Graph 3. Sample origin

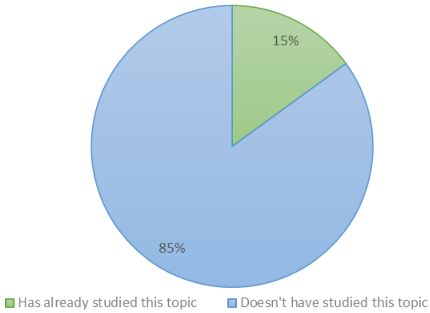


Graph 4. Sample Bachelor

The sample composed of students of Education Department of Niccolò Cusano University of Rome, has a heterogeneous origin from both the north, central and southern Italy and only the 10% has already a Bachelor.

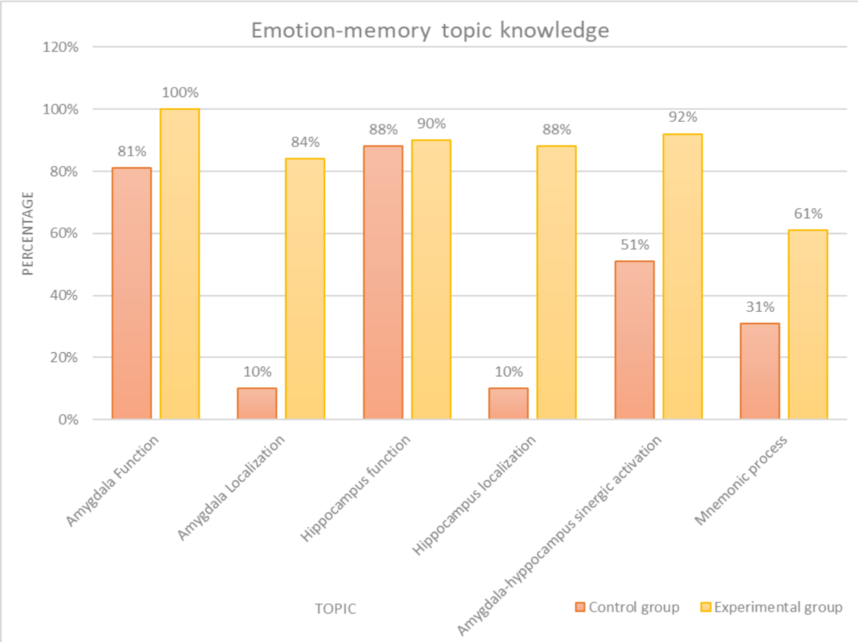


Graph 5. Sample job



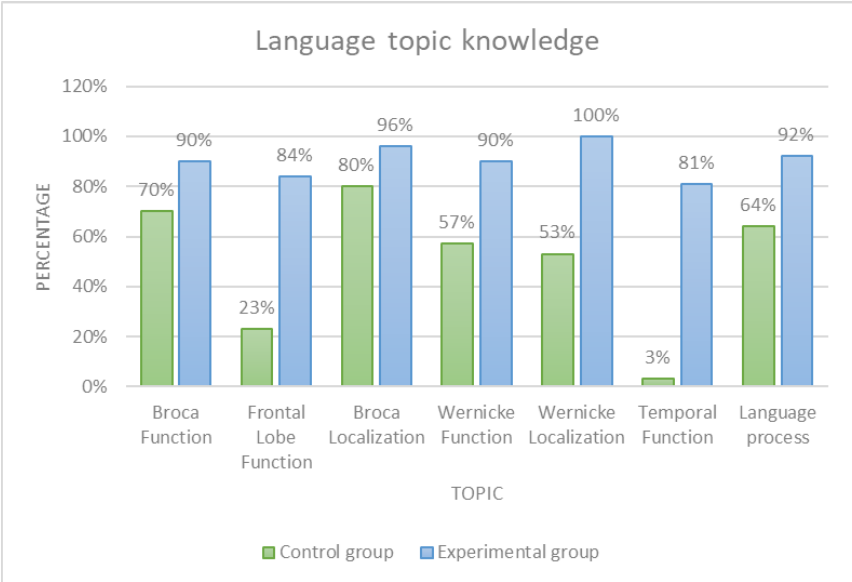
Graph 6. Sample knowledge of the topic

Niccolò Cusano University is also a telematic university and this is the reason why the 33% of the sample has already a job. Regarding to the previous knowledge about the topic proposed, only the 15% of the sample has it.



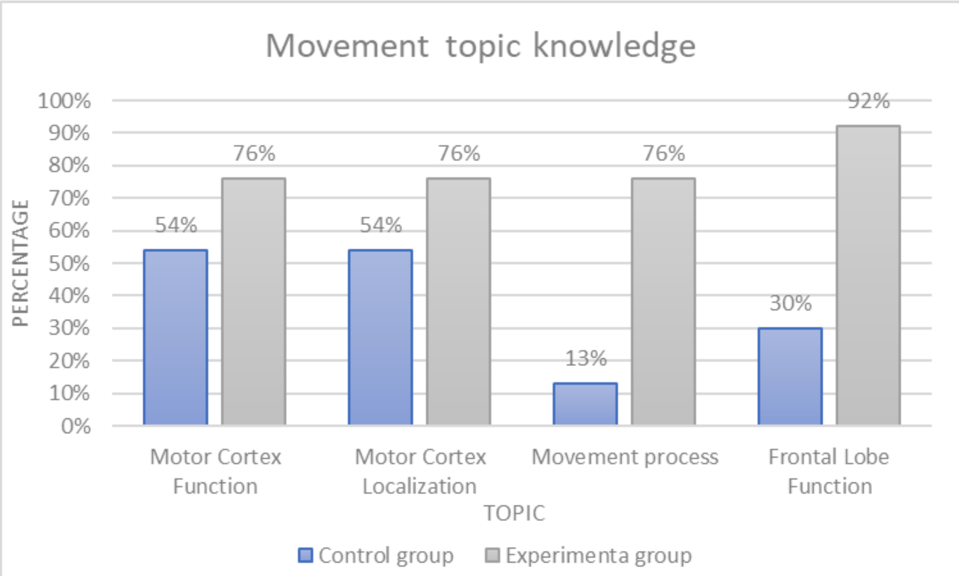
Graph 7. Sample knowledge of the topic emotion-memory

In Graph 7, there are the percentage of correct answers given by the two groups on the topic of emotion and memory: as we can see, the experimental one take advantages of using AR, so the level of memorization in always over 60%, with average of 86%. The area in which there are greater advantage is the area of localization: in both there is an improvement of 70%.



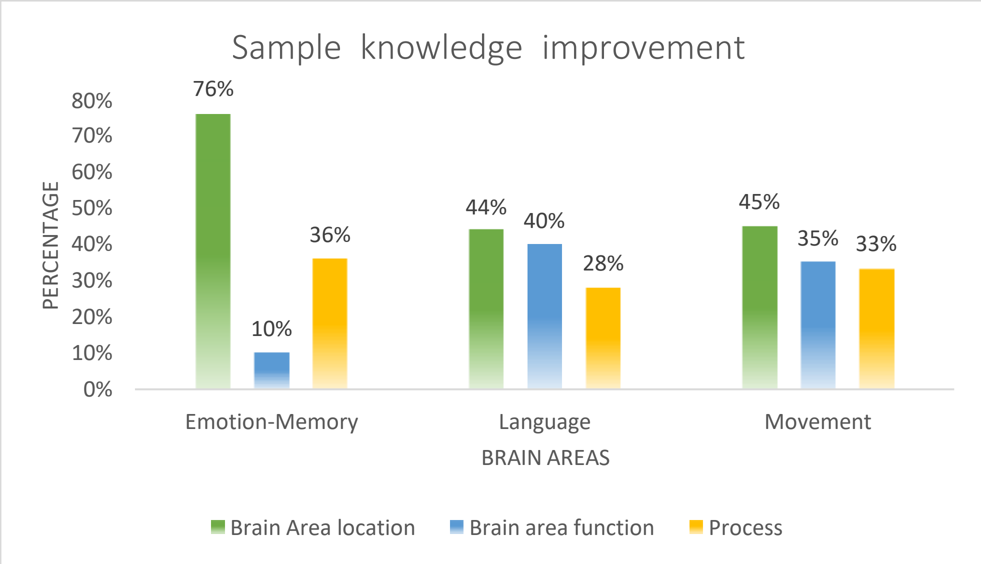
Graph 8. Sample knowledge of the topic language

In Graph 8 there are the percentage of correct answers given by the two groups on the topic of language: also in this are we can see a huge improvement in memorization due to the AR. In this area, the percentage of correct answer for the experimental group is over 80%, with an average of 90%. In this case, there a major advantage on the topic of “function”, with an improvement of 78% in “Temporal Lobe Function” and 61% in “Frontal Lobe Function”.



Graph 9. Sample knowledge of the topic movement

In Graph 9 there are the percentage of correct answers given by the two groups on the topic of movement: also in this are we can see a major improvement in memorization due to the AR. In this area, the percentage of correct answer for the experimental group is over 76%, with an average of 80%. In this case, there a major advantage on the topic of “process”, with an improvement of 63% in “Movement process”.



Graph 10. Sample knowledge of the topic language

In this graph, it is shown the percentage of knowledge improvement of the experimental group, in each area and each topic. As it clearly indicates, the level of knowledge is improved in each and every cognitive function, with a greater emphasis on the "brain area location" and also in "Process".

In the Graph 11, it is reported the independent sample t test. The results show a difference in the averages between the two samples of 11.2 points and the p value less than 0.001. The effect size, through Cohen's d, is 2.86.

Independent sample t test

		Statistic	DoF	p value	Average difference	SD difference	Effect size	
A	t di Student	13.4	88	< .001	12.6	0.935	Cohen's d	2.86

Note. H_a $\mu_{\text{Augmented Didactic}} \neq \mu_{\text{Traditional Didactics}}$

Graph 11. Independent sample t test

4.4 Discussion

The research hypothesis aimed to understand if there is an improvement in learning, of concrete but complex topic, due to the use of AR on the smartphone. From the data analysis, it is evident that there is an huge improvement on the memorization of the topic selected, with a percentage of 39%.

At first, it is important to note that the memorization level of the control group is low, and this underline a need to find a more functional way of teach and learning them.

As the graphs show there are some differences between the level of memorization of the different topic and this is linked to the nature of the topics.
For example, the study of the location of brain areas, in the Education Department, is usually carried out with the use of two-dimensional images of the dissected brain, which do not always help the student to understand the three-dimensionality of the brain. Therefore, in this case, the use of AR, thanks to the possibility of seeing the brain in 3D and thanks to the possibility of manipulating the brain, has favored the acquisition of the localization of the areas of interest, leading to an improvement of 55% of the performance. Another important aspect concerns the improvement in the area of the cognitive process. Understanding how a cognitive process is concretized, and therefore the synergic activation of different brain areas, the connections between them and the co-participation in the elaboration of information, turns out to be a complex subject if the overall visual picture is missing. Visually seeing the areas that are activated in the realization of a cognitive function, helps the student to understand the logic behind the mechanism and thus facilitates the memorization of the same. As the graph shows, in fact, the sample showed an improvement of 32% in the storage of the proposed processes.
It is also important to note that there was two different professor in the lessons carried out, with different teaching style: however, this variable don't influenced the effectiveness of Augmented Didactic. This could suggest that the improvement given by the Augmented Didactic is not linked to this variable.
At this point, it becomes central to understand the actual validity of the experimentation presented. We therefore performed an independent sample t test to check if our hypothesis is null, i.e. that the averages between the two experimental groups were equal, could be confirmed or rejected. The results show a difference in the averages between the two samples of 11.2 points and the p value, less than 0.001, affirms that this difference is statistically significant, which is why we can reject the null hypothesis and confirm the alternative one, i.e. there are statistically significant differences between the two samples.
The fact that the difference is statistically significant, however, is not necessarily associated with the fact that the effect is large enough to have any practical interest. To get this information we used the analysis of the effect size, through the Cohen's d. This index reveals the percentage of overlap between the two distributions, according to an effect that can be small, medium, large or very large. The Cohen's d resulting from our research turned out to be greater than 1.5, so the size of the effect ranks as very large, representing a 25% overlap between the two distributions.

Conclusion

In light of what emerged, the research hypothesis can be defined as confirmed because the use of AR in didactics, conveyed through Qr code, has led to a statistically significant improvement in learning notion concrete but complex. Clearly this is just a pilot study, carried out in order to understand if there are the bases of this new method. Now, it is necessary to continue the investigations that involve the use of AR, declining the latter in the fields of education. It is therefore planned to expand the investigations on the subject by considering the different factors that support learning beyond motivation and in light of this bring the focus on the processes of memorization, perception and emotion, which in a synergistic way contribute overall to determine the cognitive process of learning. The future steps are carried out this research on other Department and other topic, in order to understand whether this effect can be realised in other contexts.

References

Bidoia C. (2016). *Erbario in movimento, la realtà aumentata*. Bricks. SIe-L - Società Italiana di e-Learning, 1.

Bonaiuti G., Calvani A., Ranieri M. (2016). *Fondamenti di didattica. Teoria e prassi dei dispositivi formativi*. Roma: Carocci.

Cheng, K.H., &Tsai, C.C. (2013). Affordances of augmented reality in science learning: Suggestions for future research. *Journal of Science Education and Technology*, 22(4), 449–462.

Cino L. (2017). *Realtà aumentata nell'aula di lettere*. Bricks, 7(1), 51-57.

De Marco L. (2019), The didactic experience «body philosophy & history»: how to use successfully the smartphone at school. *Media Education Good Practice*, 10(1).

Di Martino V., & Longo L. (2019). Augmented reality to promote inclusive learning. *Form@re - Open Journal per la formazione in rete*, 19(1), 179- 194.

Diegmann P., Schmidt-Kraepelin M., Van den Eynden S., & Basten D. (2015). *Benefits of Augmented Reality in Educational Environments - A Systematic Literature Review*. Wirtschaftsinformatik Proceedings 2015/103, 1542-1556.

Dünser A., Walker L., Horner H., Bentall D. (2012). *Creating Interactive Physics EducationBooks with Augmented Reality.* In Proceedings of the 24th Australian Computer-Human Interaction Conference.

Ferri P., Moriggi S. (2017), *L'aula digitalmente aumentata.* Formazione su misura. Rizzoli Education.

Filomia M. (2019). Augmented reality and textbooks: systematic review*. Form@re - Open Journal per la formazione in rete*, 19(1), 165-178.

Gugliemi G. (2017). Il Legionario "Aumentato" - Un esercizio di lessico latino in "realtà aumentata", *Bricks,* 7(1), 40-50.

Liu T.Y., Tan T.H., Chu Y.L. (2009). Outdoor Natural Science Learning with an RFID-Supported Immersive Upiquitous Learning Environment*,Educational Technology and Society,* 12.

Maurizio C. (2018), Tecnologie digitali, smartphone per l'apprendimento della lingua. Il progetto BYOD*, Epale Journal,* 4.

Niewint J., Mori S., Naldini M., Benassi A., & Guasti L. (2019). IDeAL: A methodology for constructing artefacts and promoting transversal skills in the classroom. *Form@re - Open Journal Per La Formazione in Rete*, 19(1), 117-132.

Yildirim, S(2018), The effect of educational videos used in history education on academic success, *Journal of Education an e-learning Research*, 5(3).

Panciroli C., & Macauda A. (2018). Educazione al patrimonio e realtà aumentata: quali prospettive. *Italian journal of educational research*, 11(20), 47-62.

Parolin S.O., Pezzi G., (2013) Smartphone-aided measurements of the speed of sound in different gaseous mixtures, *The Physics teacher*, 51.

Staacks S., Hütz S., Heinke H., Stampfer C., (2018) Advanced tools for smartphone-based experiments: phyphox, *IOP Publishing Physics Education,* 4(53).

Rivoltella P.C. (2010*). Oltre il virtuale: la nostra è una "realtà aumentata". Vita e Pensiero*, 5, 102-108.

Rossi P.G. (2013). *Realtà aumentata e mediazione didattica*. Pedagogia nell'era digitale (pp. 73-76). OrtonaMenabò.

Slipukhina I., Chernetckiy I., Kurylenko N., Mieniailov S., Podlasov S. (2020), Applied Aspects of Instrumental Digital Didactics: M-learning with the Use of Smartphone Sensors. *Ceur-ws,* 2740.

Tambunan, T.D., & Nugroho, H. (2014). Marker textbooks for augmented reality on mobile learning. *Journal of Theoretical and Applied Information Technology*, 63(1), 69–73.

Tomassoni R. (2021), The instrumental function of “augmented reality” in the processes of representation, transmission and construction of knowledge*. MeTis. Mondi educativi. Temi, indagini, suggestion*, 11(1).