A.T.E.N.A.: Augmented Tools for Enhancement of Neural Activation. Variety of teaching styles and consistent effectiveness of augmented reality in didactics

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Abstract

A.T.E.N.A. is a research project launched in January 2023, aimed at exploring the impact of augmented reality (AR) in didactic by harnessing the synergy between human potential and the generative artificial potential that enabled its creation. A.T.E.N.A. is grounded in a solid theoretical framework that integrates the principles of constructivism and Embodied Cognition. The use of AR through smartphones makes the method particularly effective for engaging digital natives, creating learning conditions anchored to their reality. Additionally, manipulating AR models stimulates motor cortex activation, fostering a more immersive and interactive learning experience. Following the positive results of the A.T.E.N.A. methodology on learning processes, the influence of the teacher's teaching style on outcomes was investigated. The data revealed that, despite varying teaching styles, student performance was not negatively affected, with a 40% improvement in memory tests compared to the control group. Thus, A.T.E.N.A.'s approach has proven to be effective regardless of the teaching style adopted by the instructor, enabling students to improve their performance.

Key words: digital innovations, didactic innovations, artificial intelligence

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1. Introduction

Given the changing and evolving nature of learning environments in the digital age, there is a growing emphasis on the need to rethink teaching methodologies to align with students' status as digital natives. Digital technology increasingly integrates into education, aiming to enhance the learning process. The goal is to address learners' evolving preferences, which tend to favor greater reliance on technologies that can act as both tools for support and potential distractions during the process of acquiring knowledge.

Within this analytical framework, the use of Augmented Reality (AR) in education stands out as a cutting-edge field of research, offering valuable insights for pedagogical considerations. The primary objective is to design and assess the effectiveness of educational approaches that leverage this technology (Rivoltella, 2010).

A.T.E.N.A. (Augmented Tools for Enhancement of Neural Activation) is an innovative research project launched in January 2023, aimed at investigating the impact of AR in education, responding to the ongoing digital evolution. This research project materialises through the synergy of artificial intelligence (AI), which allows the project to adapt to the analysis of specific variables that come into play in teaching, and human potential, which enables A.T.E.N.A. to enter classrooms and benefit students.

Previous studies have shown that integrating AR into education can significantly improve learning processes, with positive effects on memory, emotional intelligence, and learning motivation, leading to enhanced academic performance (Lembo et al., 2023; Lembo et al., 2024; Cipollone et al., 2023; Cipollone et al., 2024).

Throughout the various phases of research, a key factor emerged that sets A.T.E.N.A. apart in its educational application: its independence from teachers' teaching styles. The AR technology developed in the project has been designed to effectively adapt to any teaching approach, making it a valuable resource that can be integrated into diverse educational methodologies. This adaptability overcomes the limitations associated with differences in teaching styles and ensures A.T.E.N.A.'s effectiveness across a broad range of educational contexts. This feature represents a crucial competitive advantage in the implementation of AR in schools, as it offers the flexibility to personalise learning on a large scale.

As a result, A.T.E.N.A.'s scalable nature allows it to meet not only the individual needs of students but also those of teachers, each of whom brings their own distinct teaching methods.

2. Theoretical Framework

Based on a robust theoretical framework, A.T.E.N.A. is grounded in the core principles of constructivism and Embodied Cognition (EC), two approaches that emphasise the importance of active interaction and direct experience in learning processes.

Constructivism, a learning theory rooted in the works of Jean Piaget (1970) and Lev Vygotsky (1978), posits that students actively construct their knowledge through interaction with their environment and experiences. This concept highlights the role of experiential learning, where knowledge is not simply transmitted but built by the individual. In the modern context, AR offers a powerful tool for creating learning experiences anchored in the student's reality, allowing them to manipulate and interact with digital content in an immersive and meaningful way. The ability to visualise abstract concepts through three-dimensional models fosters a deeper learning process, creating a direct connection between theoretical concepts and practical applications, as suggested by contemporary authors like Kirschner et al. (2006).

Digital natives, accustomed to interacting with advanced technologies, find AR a natural tool for learning as it allows them to transfer skills already acquired in technological environments to their studies. In this sense, A.T.E.N.A. leverages AR technologies to meet the cognitive needs of younger generations, optimising learning and improving motivation and active participation in class. Recent studies (Cipollone et al., 2023) have shown that AR can indeed enhance teaching effectiveness, helping to bridge the gap between theory and practice.

In addition to constructivism, the concept of EC plays a crucial role in A.T.E.N.A.'s structure. EC, as explained by authors such as Lakoff and Johnson (1999), asserts that cognition is not separate from the body but is deeply rooted in physical experiences and interaction with the surrounding world. This paradigm postulates that the learning process is influenced not only by internal cognitive processes but also by the physical environment and bodily actions. The integration of AR within A.T.E.N.A. allows students to physically interact with digital models, stimulating the motor cortex and encouraging greater neural activation, as evidenced by recent neuroscientific studies (Macrine et al., 2021). This activation leads to the strengthening of synaptic connections, thus improving memory and long-term learning (Gomez-Paloma et al., 2017).

Moreover, the dual-coding theory (Paivio, 1986) is embedded in A.T.E.N.A.'s methodology, further enhancing learning. According to this theory, learning is more effective when information is presented through multiple sensory channels, such as visual, verbal, and motor. In A.T.E.N.A., the use of AR enables students to internalise information through multiple channels, thereby improving recall and understanding of content. Shams et al. (2008) emphasise how multisensory interaction contributes to creating a richer and longer-lasting learning experience, supporting the development of complex skills.

AI allows A.T.E.N.A. to be versatile in addressing complex educational variables, ensuring that the methodology can be effectively integrated into a wide range of pedagogical approaches. In this way, AR becomes a complementary tool that does not replace the teacher but supports and enriches the educational process, creating personalised and engaging learning environments. This combination of technology and pedagogical flexibility helps to overcome the challenges posed by the diversity of teaching styles, ensuring that students benefit from an optimal learning experience, regardless of the approach adopted by the teacher.

2.1 AI and AR in didactics

The exponential growth in studies on AR in education reveals a significant trend in the adoption of this technology as an innovative educational tool, responding to digital innovation and the educational and instructional needs of digital-native students. During the initial phase (1996-2009), research experienced slow growth due to technological limitations and high costs. However, since 2010, the introduction of mobile AR applications has marked a crucial shift, making the technology more accessible and versatile for a wide range of users (Madden, 2011; Dey et al., 2018). This development has triggered a new era of AR adoption, enabling its integration into various disciplines, from engineering to natural science education, revolutionising how students interact with educational content.

The second generation of AR (2010-2019) focused on the use of mobile devices, reducing costs and increasing the technology's reach. Thanks to the availability of platforms such as game engines and AR development tools, integrating AR has become simpler and more accessible. However, challenges remain in terms of usability and educational effectiveness, particularly in ensuring that AR meets the pedagogical needs of students with different learning styles (Garzón et al., 2019).

With the third generation, beginning in 2020, AR has further evolved through the introduction of more advanced technologies, enriched by artificial intelligence. The integration of AI has allowed the technology to become even more adaptable to different educational contexts (Liu et al., 2017).

A.T.E.N.A. sits at the intersection of the second and third generations, leveraging the potential of mobile devices, which make it more accessible to students and teachers, allowing them to benefit from it easily and in any context, without the need for additional equipment that could limit its use. On the other hand, the integration of AI has made A.T.E.N.A. a highly adaptable methodology, decoupled from the specificities of teaching styles.

Beyond technological aspects, pedagogical considerations are essential to ensure the success of AR applications in education. It's not just about introducing new technologies; it's about designing educational experiences tailored to the specific needs of each educational context and every student.

The rapid evolution of AR, supported by AI and technological advancements, represents a radical transformation in education. However, to maximise the impact of these innovations, it is crucial to continue exploring the optimal ways of integrating them into different educational contexts, taking into account the particularities of teaching styles and the specific needs of students.

In this regard, recent research (Chen et al., 2020) highlights how AI has been successfully applied in educational institutions, improving various aspects of teaching and learning. AI has enabled the creation of dynamic and adaptable curriculum content, optimised to meet the needs of students through tools such as AR, virtual reality, robotics, and 3D technologies, transforming learning into a more engaging and immersive experience (Tahiru, 2021). This approach has significantly improved teacher effectiveness, allowing for the personalisation of educational pathways based on students' abilities and the optimisation of the learning experience (Murphy, 2019).

AI also plays a crucial role in monitoring learning, allowing real-time adaptation of educational content to students' abilities and progress. Intelligent systems use data collected during the educational process to optimise learning pathways, working on students' motivation and personal predispositions, improving content assimilation and retention (Pokrivcakova et al., 2019).

The use of AI has facilitated the development of personalised educational content and intelligent learning systems that respond to the specific needs of each student, thus enhancing the effectiveness of simulated teaching and virtual reality in education. These immersive virtual environments offer practical and experiential learning opportunities that increase the quality of education, improve information retention, and positively influence academic outcomes (Dignum, 2021).

In conclusion, AI)is profoundly influencing the educational landscape, contributing to making teaching more efficient and inclusive. A.T.E.N.A. applies the principles of constructivist theories and Embodied Cognition to integrate AI into teaching, offering a methodology designed to meet the individual needs of both students and teachers. This approach represents an effort to balance tradition and innovation, leveraging solid theoretical foundations to develop adaptive and effective educational practices.

2.2 Teaching styles in didactics

Each teacher naturally tends to reproduce their own learning and cognitive style in their teaching approach (Grasha, 1994; Zhang, 2004). In the effort to counteract this automatic inclination and to ensure that every student's learning style has space to develop, A.T.E.N.A. emerges as an effective solution, being versatile and adaptable to every teaching style, as it is detached from, and thus independent of, any specific one. Teaching aims to promote meaningful learning, which must be intentional, recognising the student as an active constructor of knowledge; collaborative, by leveraging cooperative learning in the classroom; constructive, by integrating new information with prior knowledge; and reflective, by encouraging metacognition and awareness of cognitive processes. As explained earlier, A.T.E.N.A. enables students to experience teaching in line with the natural predispositions of digital natives, operating within a constructivist framework, while also emphasising the role of the body, believing that both the body and mind actively participate in knowledge acquisition and construction processes.

University teachers' teaching styles are the focus of much research today, as teacher education is crucial for improving teaching quality and promoting students' academic success (Doulik et al., 2017). As noted, teaching styles often reflect teachers' personal learning and cognitive styles, which strongly influence the teaching approach adopted in the classroom. According to research, teachers naturally tend to replicate their own learning style, but to ensure effective teaching, it is necessary to diversify educational strategies. Some evidence shows that teachers who are open to varied teaching methods, based on collaborative, reflective, and constructive approaches, achieve better results than those who adhere to a more traditional model (Kathibi et al., 2016; Williamson et al., 2007, 2006). Additionally, teacher training programmes encourage more flexible teaching, supported by emerging technologies and innovative practices that better meet the needs of students with different learning styles (Vijaya Kumari, 2014; Gafoor et al., 2012).

Therefore, recognising and being aware of one's own teaching style and the ability to adapt to the diverse needs of students are key elements in creating an effective and inclusive learning environment. A.T.E.N.A. fits perfectly within the broader discourse on teachers' teaching styles. This methodology supports flexible and adaptable teaching that accommodates different teaching and learning styles, overcoming the natural tendency of teachers to replicate their own cognitive style. A.T.E.N.A. promotes a constructivist approach, offering tools that stimulate active interaction and experiential learning, making the teaching process more inclusive, personalised, and capable of meeting the diverse needs of students. By integrating emerging technologies such as AR, A.T.E.N.A., empowered by AI, allows teachers to adopt an approach that is unaffected by their teaching style, thereby improving the effectiveness of teaching with a focus on inclusion and adaptation to different learning styles.

3. The A.T.E.N.A. project

A.T.E.N.A. is a research project aimed at integrating AR to enhance the learning processes of university students. Launched in January 2023, this project has already analysed various variables involved in teaching and learning, including different memory systems, emotional intelligence, the impact of goal-directed gestures, and even the effects of this methodology across different faculties. The results obtained so far, from a sample of 344 students, have been very promising, revealing a clear improvement in academic performance through the use of the A.T.E.N.A. methodology.

In this study, we aimed to investigate whether the teaching style of the lecturer could affect the effectiveness of the teaching methodology.

3.1 Research Hypothesis

Based on the needs highlighted above, the research hypothesis posits that the use of AR in didactics enhances the memory retention process of students, regardless of the teaching style adopted by the lecturer.

3.2 Sample

The sample was randomly selected from students of the Educational Department and Psychological Department attending Niccolò Cusano University. Participation, which was voluntary, involved 107 subjects who were randomly divided into an experimental group (N = 67) and a control group (N = 40). Therefore, the didactic activity was carried out in collaboration with teachers who conducted laboratory activities.

The lectures covered the neural correlates underlying four cognitive domains. Lecturer A dealt with the neural correlates of language and movement, lecturer B with those of emotions and memory. The whole sample took part in the lessons of both lecturers.

3.3 Methods and Materials

The proposed teaching activity for the control group comprised a conventional didactic session featuring frontal explanations and multimedia support, including slides and videos. Furthermore, the experimental group received an additional advantage through the incorporation of AR. To be more precise, AR content was intro-duced using QR codes, as illustrated in Figure 1, enabling the visualization of class concepts in 3D. Therefore, unlike the control group, the experimental group was able to view and interact with neural correlates during the explanation through their smartphones.

Fig. 1 - AR, through qr code, on smartphone

In the initial phase, we administered the Rey Auditory Verbal Learning Test (RAVLT) to rule out memory disorders and collected personal data through a questionnaire. All 107 students were confirmed to have no memory impairments. At the end of the activity, both groups completed a spontaneous recall questionnaire with 41 open-ended questions, delivered via Google Forms through a QR code. Designed as a free recall test, it assessed concept memorization without external aids.

In order to analyse the teacher's teaching style, two tests were administered retrospectively.

The Staffordshire Evaluation of Teaching Style (SETS) (Davies and Ferguson, 1997) is a tool designed to assess teachers' instructional methods and their classroom effectiveness. It consists of 49 items that cover various dimensions of teaching, such as student engagement, information delivery, and classroom management. The SETS uses a 5-point Likert scale.

The Teaching Style Survey (Grasha, 1996) is a self-assessment tool designed to help educators identify their dominant teaching style. It consists of 44 items that categorize teaching methods into styles like facilitator, demonstrator, or lecturer. Each item is rated on a 7-point Likert scale, providing detailed insights into the teacher's strengths and areas for improvement.

This test analyzes five dimensions of the teacher:

- Expert: focuses on sharing in-depth knowledge and challenging students to improve their competence.
- Formal Authority: emphasizes clear expectations and structured approaches to learning.

- Personal Model: teaches by example, encouraging students to follow a role model.
- Facilitator: prioritizes personal interactions and aims to develop student independence and responsibility.
- Delegator: focuses on developing student autonomy by encouraging independent work and teamwork.

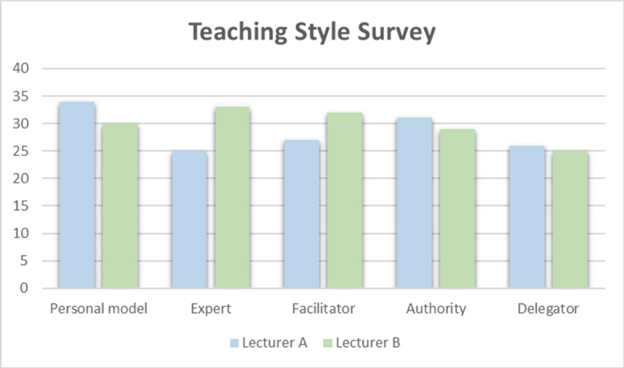
In order to perform the statistical analyses, JAMOVI software (version 2.3.28) was used. The two-way ANOVA was chosen because it allows for the simultaneous examination of the effects of two independent variables (in this case, the lecturer and the group, experimental or control) on students' scores, as well as the evaluation of any interaction between the two variables.

3.4 Results

The administration of the SETS was used to identify the dominant teaching style of the two lecturers. The test scoring revealed that Lecturer A uses Style 1, while Lecturer B uses Style 2. Style 1 refers to the all-around flexible and adaptable teacher, identifying a lecturer who can use a variety of different skills, can teach both peers and juniors, and is highly aware of the overall teaching and learning environment.

Style 2, on the other hand, refers to the student-centred, sensitive teacher. This kind of teacher is very student-focused, teaches in small groups, emphasises emotions, uses role play and drama, and is uncomfortable with straightforward presentations.

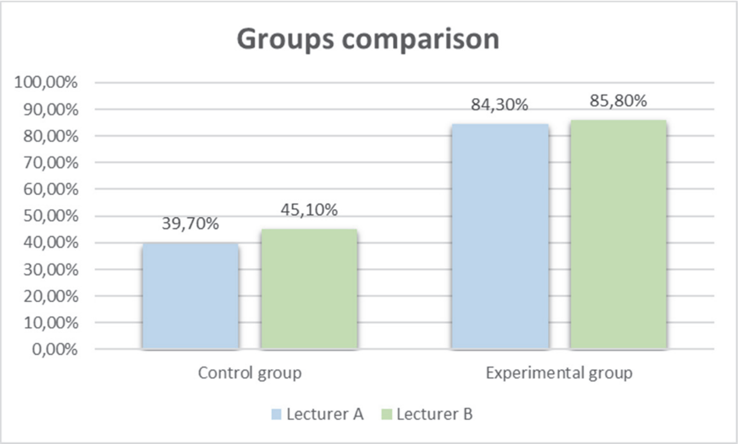
The administration of the Teaching Style Survey also highlighted differing approaches between the lecturers.



Graph. 1 – Teaching Style Survey

As it emerges from Graph 1, Lecturer A, with high scores in the Personal Model and Authority dimensions, is an educator who favours teaching by personal example, establishing themselves as a role model for students. They also emphasise providing a clear structure and specific rules for learning, maintaining an authoritative role.

Lecturer B, with high scores in the Expert and Facilitator dimensions, is an educator who possesses deep subject knowledge and uses it to intellectually challenge students, encouraging them to improve.



Graph. 2 – Groups comparison

Graph. 2 shows the scores, in percentage, from the results obtained in the memorization questionnaire. As can be seen, in the control group, there are differences in the scores obtained in the lessons taught by the two lecturers, while these differences disappear in the experimental group.

3.5 Data Analysis

Based on the highlighted needs, the research hypothesis states that the use of AR in education enhances students' memorization processes regardless of the teaching style adopted by the instructor.

Tab. 1 - Homogeneity of Variances Test (Levene's)

	F	*p*
Results	*6.832*	*0.391*

Note. A low p-value suggests a violation of the assumption of equal variances

Tab. 2 – Normality of Distribution (Shapiro-Wilk)

	W	*p*
Experimental Group	*0.918*	*0.272*
Control Group	*0.885*	*0.102*

Note. A low p-value suggests a violation of assumption of distribution's normality.

As shown in Table 1 and 2, the verification of the assumptions revealed the normality of the distibuition and the homogeneity of the variances, which is why one can proceed with the two-way ANOVA.

Tab. 3 – Two way ANOVA.

	Sum of squares	**F**	**p-value**
Lecturer	6.00	0.009	0.9214
Group	9680.17	16.103	0.007
Lecturer*Group	1.50	0.00250	0.9607
Residual	12022.33		

The two-way ANOVA analysis, conducted to evaluate the effect of the lecturer and the group (experimental vs. control) on student scores, revealed significant results for the group but not for the lecturer or the interaction between the two variables.

In particular, the main effect of the lecturer was not significant ($F(1,20) = 0.01$, $p = 0.921$), suggesting that the students' scores were not substantially influenced by the lecturer. On the contrary, the main effect of the group was highly significant ($F(1,20) = 16.10$, $p < 0.001$), indicating that students in the experimental group scored significantly higher than those in the control group.

Finally, the interaction between lecturer and group was not significant ($F(1,20) = 0.002$, $p = 0.961$), implying that the effect of the group does not vary based on the lecturer. In other words, the impact of being in the experimental or control group on student scores is independent of the specific lecturer.

These results suggest that the primary factor influencing student performance is the membership in the experimental or control group rather than the lecturer, and that the effectiveness of the experimental methodology is consistent regardless of the teacher.

3.6 Discussion

A.T.E.N.A., due to its intrinsic characteristics, addresses the need to integrate both human and digital dimensions within the educational context, respecting the roles, spaces, and timing of both components.

Starting from the excellent results observed in the previous phases, there is a need to understand how effective this methodology could be regardless of the teaching styles of the lecturers, in order to assess its absolute applicability.

To evaluate teaching styles, two tests were administered to the instructors conducting lessons in AR and non-AR settings. Lecturer A demonstrated adaptability, engagement skills, and a focus on structure and guidance, serving as a role model. Lecturer B emphasized student-centered learning, using techniques like role play to evoke emotions and foster independence, critical thinking, and initiative through close connections.Thus, the two lecturers displayed two different teaching profiles, utilizing differentiated pedagogical approaches. In light of these differences, it was essential to understand whether these differences impacted the methodology or the academic performance of the students.

As the data revealed, in the control group, which did not utilize AR, scores varied between the lessons taught by Lecturer A and by Lecturer B, while this difference was not present in the experimental group. This data suggests that, although differences stem from teaching styles, the A.T.E.N.A. methodology could reduce these variations. In the experimental group, the use of AR may have made the learning process less dependent on individual teaching methods, providing structured support that balances the differences between instructors. This suggests that the A.T.E.N.A. approach helps standardize teaching effectiveness, reducing the impact of variations in teaching style.

The two-way ANOVA results confirm that the teacher's main effect is not significant for student scores in the experimental group, whereas differences are evident in the control group. In the experimental group, students consistently outperformed those in the control group, regardless of the teacher. This suggests that AR serves as a compensatory tool, standardizing learning experiences. These findings highlight AR's potential to enhance overall performance while reducing disparities caused by differing teaching approaches.

Despite the positive results, some limitations should be acknowledged. Firstly, the teacher taken into account are only two, and this limited sample size may restrict the generalisability of the findings to other populations. It will be relevant to analyse different teaching styles and teacher from different faculty.

Furthermore, in this phase of the project, we focused solely on analyzing short-term memorization, without delving into long-term memory retention. In subsequent stages, it will be crucial to assess the long-term effects of AR on learning and memory. Additionally, it would be interesting to compare findings across other disciplines and explore additional variables, such as emotional engagement or the impact of students' familiarity with AR technology. This could help determine the extent to which prior knowledge of this technology influences performance outcomes.

4. Conclusion

A.T.E.N.A. represents a highly innovative and versatile teaching methodology designed to significantly enhance academic performance through the integration of AR in educational processes. The results emerging from the data analysis further consolidate the consistent effectiveness of this approach, demonstrating that the positive impact of the methodology is maintained regardless of the teaching style adopted by individual instructors. This implies that A.T.E.N.A. acts as an extremely powerful pedagogical tool, capable of uniformly improving student performance while mitigating the influence of variations in teaching style.

The application of the A.T.E.N.A. methodology in the experimental group highlighted a marked improvement compared to the control group, indicating that AR can not only increase student engagement and participation but also standardize learning processes. This translates into a reduction of disparities related to different teaching methods, fostering a more structured, immersive, and accessible learning experience for all students, regardless of the lecturer (Grasha, 1996; Garzón et al., 2019).

In conclusion, the integration of emerging technologies such as AR, supported by artificial intelligence, represents a revolution in the educational landscape. A.T.E.N.A. proves to be an innovative methodology capable of effectively addressing the challenges of modern teaching, optimizing the learning process in diverse educational contexts.

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