Original article

Augmented Reality in Internal Combustion Engine Teaching: An Experience with Ecuadorian University Students

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ABSTRACT

The article proposes the use of the reality increased like an effective strategy for the teaching of the internal combustion engines exploring. Provide an overview of the foundations of the enlarged reality, you highlight the potential benefits of his implementation in the educational context and a proposal of structure to design an experience of learning shows inmersiva and it cashes on the internal combustion engines. The harmonizing of qualitative and quantitative methods like the bibliographic revision, the analysis and synthesis and the opinion poll managed a mixed focus of descriptive intervening type itself.

Keywords: Augmented Reality; Internal Combustion Engines; Teaching Strategy; Virtual Elements; Learning Experience.

Introduction

In today's society, internal combustion engines play a crucial role in various areas of our daily lives. From ground transportation, with the widespread presence of automobiles and cargo vehicles, to power generation in industrial plants, internal combustion engines are fundamental in driving the development and functioning of our society.

The importance of understanding the operation of internal combustion engines lies in their practical application in multiple fields. These engines are highly efficient in transforming chemical energy into mechanical energy, making them the preferred

choice for various applications. However, effectively teaching the principles and concepts behind internal combustion engines can be a considerable challenge.

In teaching internal combustion engines, educators face obstacles such as the complexity of the internal processes, the difficulty in visualizing and understanding the components at work, and the need for hands-on interaction for more meaningful learning. In addition, traditional teaching based on manuals and two-dimensional diagrams can be abstract and unattractive to students, which hinders their engagement and deep understanding of the subject, it is pertinent, then, to proceed by taking into consideration the need for vocational students, as is the case we are considering, to be instructed in a practical way on this subject.

It is in the context described above that Augmented Reality (hereafter AR) emerges as a promising technology to address these challenges in teaching internal combustion engines. AR combines the real world with virtual elements, allowing the superimposition of digital information over the physical environment. This integration creates an immersive experience that enhances understanding and facilitates visualization of the complex processes that occur within an internal combustion engine.

By using AR as an educational tool, teachers can present interactive 3D models of internal combustion engines, allowing students to explore and manipulate the virtual components in real time. This provides them with a tangible, hands-on experience, facilitating understanding of the principles and mechanisms involved, as AR provides them with access to rich, varied and meaningful multimedia content and provides them with a relevant and immediately interactive context. This immediate and personalized feedback offered by AR allows students to learn from their mistakes and improve their understanding in real time.

Based on the above, the work developed was proposed as an objective the evaluative analysis of the effectiveness of augmented reality as a teaching strategy to improve the learning of internal combustion engines in students.

Development

AR is a technology that combines the real world with virtual elements, generating an experience in which digital objects are superimposed and integrated into the physical

environment. Through devices such as smartphones, tablets or special glasses, users can perceive and manipulate digital information in real time while interacting with the real world. AR enhances sensory perception and provides an additional layer of visual, audio or tactile information that enriches the experience and expands the possibilities for interaction with the environment.

It is in the 1990s, when AR appears in the scientific world, at that time the technology was focused on fast processing computers, real-time graphics rendering and portable precision tracking systems, which allowed combining computer-generated images with the vision of the real world (Basogain; Olabe; Espinosa and Rouèche, 2010).

In the 1980s, cinematic environments implemented basic concepts of AR through effects and texts superimposed on the environment, seen from the scans made by the protagonists (Gómez; Rodríguez and Marín, 2020). However, it was from the 1990s that systems began to use the current conception of AR.

In the educational field AR is very relevant due to its numerous benefits and potential to improve the teaching and learning experience, this is how (Blázquez, 2017) states that the multiple uses of AR in the educational space are vast and varied and cover the different levels of education applying to the needs of teachers and students, it is essential to focus on the objectives to be achieved when using this technology. AR should be considered as a resource to improve the teaching-learning process.

AR is a strategy capable of providing a more immersive learning experience than traditional teaching. By allowing students to interact with virtual objects and scenarios in their real environment, AR offers a sense of immersion and active participation in learning that fosters a complete and immersive learning experience, based on the idea of learning in a participatory way, through direct interaction with the content and the promotion of a deeper and lasting understanding, in this context of AR, immersive learning involves the use of this technology to create educational environments, where you can explore, experiment and solve problems in a practical and contextualized way.

In this order of things AR as a didactic tool that favors the improvement of the learning experience involves human-machine interaction by involving communication and information exchange between the student and the virtual elements generated by the technology. This may include gestures, movements, voice commands or tactile interactions that allow the student to interact and control the digital objects superimposed on the teaching-learning environment, this implies a fluid and intuitive interaction between the student and the technology is fundamental for an effective and

satisfactory AR experience that can enable exchanges such as the one described by (Nájera, 2009) when he refers to "a prehistoric experience where fossils are exhibited or children's books showing three-dimensional scenes instead of photographs and flat drawings or classroom conversations with characters "virtually brought" from the past" (p. 11).

These key concepts - AR, immersive learning and human-machine interaction - are fundamental to understanding how AR can transform the educational process by providing more engaging, practical and meaningful learning experiences. By combining virtual elements with the real world, AR expands the possibilities for interaction and enriches the way students explore and understand complex concepts, such as internal combustion engines, thus generating a positive impact on their education.

The literature reviewed on the use of AR in education has recognized its transformative potential and its ability to improve the quality and effectiveness of the educational process. Worldwide, numerous studies and academic publications support the use of AR as an innovative pedagogical tool. Some of the key findings and approaches that have been identified connote the improvement of motivation and engagement as AR has proven to be highly motivating for students as it creates an engaging and immersive learning experience. The integration of virtual elements into the real environment arouses curiosity and interest, leading to greater student engagement and participation in the learning process (Marín; Cabero, & Gallego, 2018).

There is research on the role of AR in the formative process in general and teaching-learning in particular that has been able to verify that students' class notes that are enriched with AR objects significantly awaken students' motivation, both generally and in terms of attention, confidence, relevance and satisfaction (Marín; Cabero and Gallego, 2018).

Another important aspect is that this tool facilitates the understanding of abstract concepts and allows visualizing and manipulating virtual objects in the real world. By being able to interact with three-dimensional models and observe processes in real time, students can acquire a deeper and more meaningful understanding of the topics studied.

AR offers the possibility of creating collaborative learning environments, where students can work together, share information and solve problems together. This social interaction promotes the collective construction of knowledge and strengthens teamwork skills, in this regard it is relevant the idea defended by authors such as (Cabero, 2018) when he states that the challenge for universities, lies among other

things, in redesigning their formative matrices with the purpose of "the progressive increase in the teaching activity of the use of electronic educational resources that combine different approaches more creative and collaborative"(p. 2)

Regarding the specific context of Ecuador, although the specific literature on the use of AR in education in this country may be limited, there have been initiatives and some projects that explore the potential of this technology, In the Ecuadorian context, there has been a growing interest in adopting innovative technological tools in education, and AR has been recognized as a promising alternative to improve the quality of teaching and learning (Castillo and Quimbita, 2023).

The development of emerging technologies in the educational sphere is generating a significant evolution in the way of teaching in this sense in the Ecuadorian context AR is a technology that effectively contributes to improve the understanding of curricular content, so it is necessary to implement measures that include the provision of digital resources in schools and adequate training for teachers to implement their use (Aguirre; Guevara; Erazo and García, 2020).

It is important to note that exploration in the field of AR in education continues to evolve, and more empirical research is required to fully understand its impact and effectiveness in different educational contexts, including Ecuador. However, the general approaches of the existing literature support the feasibility and potential benefits of AR as a pedagogical strategy.

Aguirre; Guevara; Erazo and García, 2020, confirm in their study "AR and education in Ecuador" that the analysis and systematization of the literature in this context yields about 101,000 results and documents on the Internet about AR in education" (p. 431).

At the international level, it stands out, for example the study, "Augmented Reality-Based Interactive Learning Environment for Internal Combustion Engines" (Hongye, 2019) which proposed an AR-based interactive learning environment to teach the concepts and processes of internal combustion engines. An AR application was developed that allows students to explore and manipulate virtual components of an engine in real time, providing additional information and 3D visualization to facilitate understanding.

Similarly, an investigation entitled "Design and Evaluation of a Mobile Augmented Reality Application for Automotive Engine Learning" was carried out, which focused on the design and evaluation of an AR application for mobile devices that taught the principles of internal combustion engines. The application facilitates students to

visualize and manipulate virtual models of engines and access to additional information and interactive animations to promote understanding (Martin, 2022).

The study "The significance of AR on student motivation. A systematic review and meta-analysis" examined the scientific literature and made it clear that the use of AR in classrooms improves student motivation. The results showed a positive impact in the experimental groups, suggesting that the incorporation of AR in the classroom motivates students (Gómez; Rodríguez and Marín, 2020).

The research "Virtual Reality, Immersive Learning and AR: Case Studies in Engineering Careers" comprehensively examined the state of the art and implementation of virtual reality, immersive levels and AR, focusing specifically on the teaching-learning processes of undergraduate engineering students. The findings of this study show the existence of multiple opportunities to take advantage of open access resources and platforms, in the context of subjects that focus on intensive practices.

This research has explored the use of AR in the teaching of internal combustion engines. The field of AR applied to education is dynamic and constantly evolving.

Methodology for the development of the study.

The methodology employed is based on a mixed descriptive approach that is justified by the complete and holistic understanding of the benefits and effectiveness of AR as a didactic strategy for teaching internal combustion engines. By combining qualitative and quantitative methods, we sought to complement and enrich the findings obtained, achieving a broader and deeper vision of the study phenomenon.

The qualitative approach is justified by its ability to explore and understand in depth the experiences, perceptions and opinions of the participants. Through it, it was possible to obtain detailed information on how students interact with AR and how it influences their understanding of internal combustion engines. In addition, this approach allowed us to capture nuances and contextual factors in addressing the results.

The quantitative approach was evidenced in the analysis of numerical data to make generalizations and establish statistical relationships. Through a questionnaire survey, data were obtained on students' performance, their level of comprehension and their satisfaction with AR as a didactic strategy. This provided a solid basis for evaluating the effectiveness of the intervention and establishing the necessary correlations.

By combining both approaches, a triangulation of the data was achieved, which increased the validity and reliability of the results, by addressing the complexity of the study phenomenon from multiple perspectives and having a more complete

understanding of the effects of AR on the teaching of internal combustion engines. This is especially relevant for educational decision-making and improvement of pedagogical practices.

Instrument design

For data collection, a questionnaire with multiple-choice questions was designed to evaluate aspects such as the level of understanding, motivation and satisfaction of the students' perception of AR as a didactic strategy for teaching internal combustion engines. The response scale is nominal and, where 1 corresponds to very low and 5 to very high.

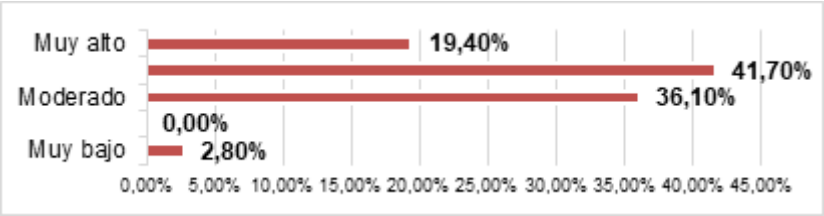
The main purpose of the research was to design a didactic strategy for the implementation of AR in the teaching of internal combustion engines.

Population and sample

The starting population for this study was the 40 students enrolled in the Maintenance and Repair of Diesel and Gasoline Engines program at the Higher University Institute Cotopaxi; in this case, the population and sample coincide, which means that a census research approach was used, that is, information was collected from all members of the population instead of selecting a representative sample.

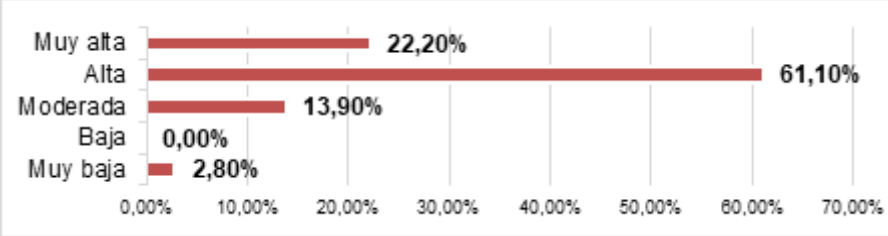
The most relevant data are presented below:

When asked about the level of understanding of concepts related to internal combustion engines after using AR, the majority of students have shown improvement, thanks to the use of AR, with a significant group reaching a high level (41.7%) of understanding. However, there is a smaller percentage (2.8%) that has not experienced significant progress in their knowledge of the subject. AR technology appears to be an effective tool for improving understanding of internal combustion engines for 36.1%, but may not be equally effective for all (19.4%). (See Graph 1).



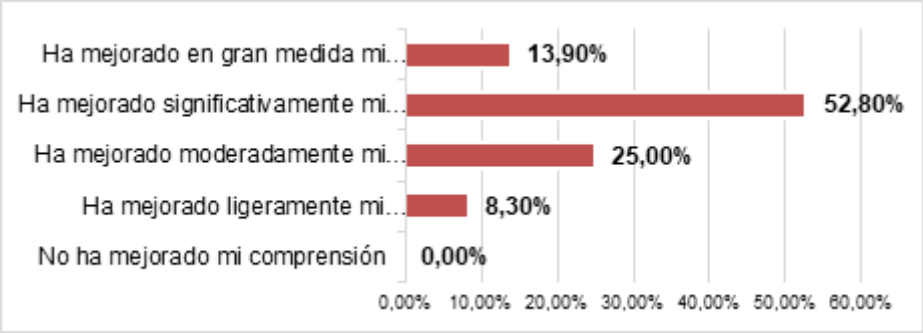
Graph 1: Level of understanding of concepts related to internal combustion engines after using AR.

The personal description on the level of motivation to learn about internal combustion engines using AR revealed that (61.10%) of the respondents have shown high (61.10%) and very high motivation (22.20%) to learn using AR. This points to the fact that this tool has been effective in stimulating interest and curiosity in the majority, leading to significant motivation to learn about the subject, although a small percentage shows moderate (13.9%) or very low (2.8%) levels of motivation (See Graph 2). (See Graph 2).



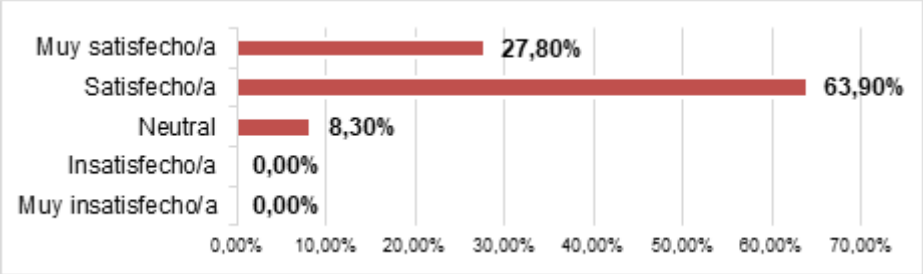
Graph 2: Personal description on the level of motivation to learn about internal combustion engines using AR.

When asked about the extent to which AR improved their understanding of the complex processes in internal combustion engines, 52.8% of the students reported having experienced a significant improvement, thanks to the use of AR, which implies that it has been effective in improving knowledge and understanding in the majority, although there is also a smaller group (8.3%) that has slightly experienced some level of understanding, indicating that, for certain students, AR has had an even more profound impact on their learning and understanding of the complex processes in question (See Graph 3). (See Graph 3).



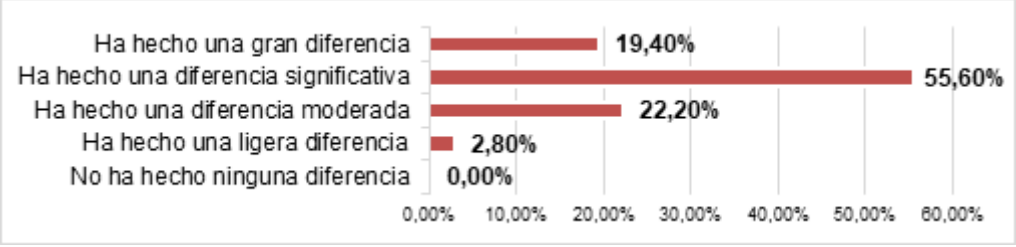
Graph 3: Extent to which AR had to improve their understanding of the complex processes in internal combustion engines.

In the level of overall satisfaction experienced with the use of AR as a teaching strategy to address internal combustion engines, 63.9% of the students reported feeling satisfied, which indicates that AR has been well received and positively valued. In addition, a significant percentage of them (27.8%), state that they feel very satisfied since AR has exceeded the expectations of some and has had a highly positive impact on their learning experience; a small percentage (8.3%), is neutral, which could indicate that, for some, AR may not have had a notable impact on their level of satisfaction (See Graph 4). (See Graph 4).



Graph 4: Level of overall satisfaction experienced with the use of AR as a didactic strategy to address internal combustion engines.

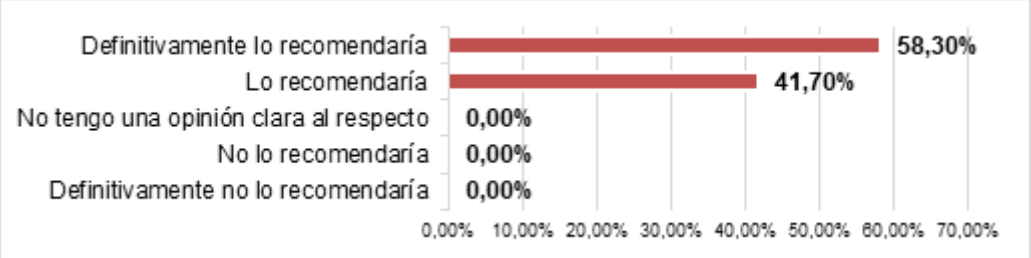
Particularly important was the finding that 55.60% of the students surveyed have experienced a significant difference in their level of interest, while 22.2% perceive that AR has made a moderate difference in the interest and attractiveness of learning about internal combustion engines; a smaller group feels that AR has made a big difference in their motivation and attractiveness to the subject studied (19.4%). The majority of the participants feel that AR has had a positive impact on making learning about internal combustion engines more interesting and engaging (See Graph 5).



Graph 5: Significant difference in the level of learners' interest with AR on the interest and attractiveness of learning about internal combustion engines.

As for the possibility of recommending AR as a teaching strategy to other students, 58.3%, a considerable number would even definitely recommend it, and 41.7% are

willing to recommend the use of AR. This data implies that AR technology has been well received and positively perceived as an effective way to improve teaching and learning. The high willingness to recommend AR reflects a generally positive perception of its usefulness and benefits for the study of internal combustion engines. (See Graph 6).



Graph 6: Willingness to recommend AR as a teaching strategy to other students.

Benefits of AR in the teaching of internal combustion engines.

The experience of using AR in the teaching-learning process of the diesel and gasoline engine maintenance and repair career outlined an attractive process and invaluable student motivation thanks to the innovative and interesting approach that managed to capture their attention. The integration of virtual elements into the real environment provided an immersive and exciting experience that stimulated curiosity and intrinsic motivation to explore and learn. This attractiveness promoted more engagement and participation in the learning process.

On the other hand, the hands-on interaction with virtual elements allowed students to interact directly with interactive 3D models of internal combustion engines, being able to explore and manipulate the virtual components in real time; this offered them a practical and tangible experience. This interaction facilitated the understanding of the concepts and processes related to engines, as students visualized and experienced in a more concrete way how engines work in the real world.

In the experience developed, the real-time visualization of the complex processes that occur within the internal combustion engines, made possible by AR, was a fact that enabled the observation and better understanding of the energy flows and expansion of gases, and other fundamental operations; students could see directly and concretely how the different components interact and how these complex processes are developed.

Proposal of a didactic strategy for the learning of internal combustion engines by students of the Higher University Institute Cotopaxi with AR

In the context of this experience and based on the results achieved, we propose that the design of an effective learning experience using AR involves several key aspects, which are articulated in a didactic strategy:

General Objective: To improve the understanding and learning of internal combustion engine concepts through the implementation of AR as an educational tool.

Specific Objectives:

- Introduce students to the theoretical fundamentals of internal combustion engines and their main components.
- Facilitate understanding of internal combustion engine processes and operating cycles through interaction with 3D AR models.
- Encourage the development of practical skills by allowing students to virtually manipulate the components and assemblies of an internal combustion engine.
- Motivate students' interest and active participation in the subject through immersive and engaging experiences.

✓ **Action 1.-Identification of key content and concepts to be taught:**

This action will help define what information and virtual elements to include in the AR experience. In the area of Diesel and Gasoline Engine Maintenance and Repair, a wide range of content and key concepts about the operation, diagnosis, maintenance and repair of these engines can be addressed. It is important to adapt this content to the specific objectives of the curriculum and the cognitive development level of the students, and the use of multimedia resources and practical demonstrations can also be incorporated.

✓ **Action 2.-Selection of the appropriate AR platform:**

This action involves choosing a suitable platform and the resources available and compatible with the technological devices used by students to provide the necessary functionalities and create an immersive and effective experience, in this sense the ZSpace platform is proposed, an AR and virtual reality (VR) platform of an educational nature that offers an immersive and three-dimensional learning experience, allowing interaction with virtual objects and scenarios using AR glasses and interactive pens.

✓ **Action 3.-Creation of interactive 3D models of internal combustion engines:**

The high quality virtual models suggested in this action should allow students to explore and manipulate the components in a practical way, disassemble them and manipulate

their parts virtually in AR, facilitating the understanding of the principles and processes involved.

- ✓ **Action 4.-Development of activities and practical exercises involving virtual manipulation of the motors:**

For the AR experience suggested in this action it is essential to design activities and exercises that involve virtual manipulation of internal combustion engines and allow the application of acquired knowledge, solve problems and experiment with configurations and scenarios, by: (a) access to technology that provides students with devices with AR applications or use AR equipment in the classroom; (b) simulation of processes using AR in the operating cycle of engines and visualize internal processes; (c) designing challenges to propose challenging, creative and problematizing practical activities where contradictions and problems related to the operation and maintenance of internal combustion engines using AR must be solved; (d) working in teams to foster collaboration in addressing the proposed challenges.

- ✓ **Action 5.-Evaluation of the learning experience:**

Conducting an evaluation of the learning experience using AR involves collecting data on learners' performance and understanding and obtaining feedback on their experience and perception. This evaluation will help identify areas for improvement and adjust the design and future implementation of the learning experience; it will be carried out by integrating formative assessment and personalized feedback in order to improve students' performance and understanding which will involve periodic follow-ups to assess progress in the use of AR and understanding of the concepts associated with the content.

- ✓ **Action 5.-Reflection and closure**

- Discussion and analysis: Conduct reflection sessions where students share their experiences and learning using AR.
- Synthesis and conclusion: Review the objectives achieved and highlight the usefulness and benefits of AR as a teaching tool.

Designing the AR learning experience requires careful planning and consideration of these aspects to ensure an effective and enriching experience.

Conclusions

The use of AR as a teaching strategy enhances the understanding of internal combustion engines. By providing an immersive, hands-on experience, AR makes it possible to visualize and manipulate the virtual components of the engines in real time. This facilitates a deep understanding of the principles and processes involved in the operation of these engines which is reflected in a significant improvement in the understanding of the subject.

The implementation of AR as a didactic strategy generates an increase in student interest and motivation creating an engaging and novel experience towards the subject matter. Hands-on interaction with virtual engines and the possibility to explore them in a visually enriched way fosters curiosity and enthusiasm, captures attention to the subject matter. AR offers students the opportunity to develop hands-on skills in the virtual manipulation of internal combustion engines. By interacting with the virtual components, they gain skills in exploring, identifying parts, assembling and understanding the different mechanisms and processes. These hands-on skills not only enhance their understanding of the subject, but also provide them with skills applicable in professional environments related to engineering, mechanics and technology.