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REVIEW

# Intelligent gesture interfaces in immersive education

## Interfaces gestuales inteligentes en la educación inmersiva

Susana Masapanta-Carrión[1], Javier Guaña-Moya[1], Yamileth Arteaga-Alcívar[2]

[1]Pontificia Universidad Católica del Ecuador, Facultad de Hábitat, Infraestructura y Creatividad. Quito, Ecuador.
[2]Instituto Superior Universitario Japón, Unidad de Investigación. Quito, Ecuador.

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**Corresponding Author:** Javier Guaña-Moya

## ABSTRACT

**Introduction:** intelligent gesture interfaces are transforming immersive education by enabling more intuitive and efficient interactions between students and digital content through bodily movements, especially facial and manual gestures. When integrated with technologies such as augmented reality and virtual reality, these interfaces enhance body perception, information retention, and the understanding of complex concepts, promoting a more active and personalized learning experience.
**Method:** this study employed a Systematic Literature Review (SLR) based on Kitchenham's methodology, structured in planning, execution, and presentation phases. Academic and empirical studies published since 2019 were selected, focusing on the integration of gesture interfaces with artificial intelligence in educational contexts and assessing their effectiveness, applicability, and associated challenges.
**Results:** the findings revealed that these interfaces support student engagement, adapt to individual needs, and strengthen multimodal learning. Technologies such as depth sensors, neural networks, and multimodal systems were identified as enabling more fluid and natural interaction. Despite their potential, technical challenges were noted, including gesture variability, real-time processing demands, and lack of standardization, as well as pedagogical barriers such as curricular integration and learning assessment.
**Conclusions:** it is concluded that intelligent gesture interfaces, when complemented by artificial intelligence, hold strong potential to enrich educational experiences, support personalized and student-centered learning environments, and align pedagogical practice with participatory and constructivist models of education.

**Keywords:** Gesture Interfaces; Immersive Education; Virtual Reality; Experiential Learning; Artificial Intelligence.

## RESUMEN

**Introducción:** las interfaces gestuales inteligentes están transformando la educación inmersiva al permitir interacciones más intuitivas y eficientes entre los estudiantes y el contenido digital mediante movimientos corporales, especialmente gestos faciales y manuales. Al integrarse con tecnologías como la realidad aumentada y la realidad virtual, estas interfaces mejoran la percepción corporal, la retención de información y la comprensión de conceptos complejos, promoviendo una experiencia de aprendizaje más activa y personalizada.
**Método:** este estudio empleó una Revisión Sistemática de la Literatura (RSL) basada en la metodología de Kitchenham, estructurada en fases de planificación, ejecución y presentación. Se seleccionaron estudios académicos y empíricos publicados desde 2019, centrados en la integración de interfaces gestuales con inteligencia artificial en contextos educativos y evaluando su eficacia, aplicabilidad y desafíos asociados.
**Resultados:** los hallazgos revelaron que estas interfaces fomentan la participación del alumnado, se adaptan

a las necesidades individuales y fortalecen el aprendizaje multimodal. Se identificaron tecnologías como sensores de profundidad, redes neuronales y sistemas multimodales que facilitan una interacción más fluida y natural. A pesar de su potencial, se observaron desafíos técnicos, como la variabilidad gestual, las exigencias de procesamiento en tiempo real y la falta de estandarización, así como barreras pedagógicas como la integración curricular y la evaluación del aprendizaje.
**Conclusiones:** se concluye que las interfaces gestuales inteligentes, al complementarse con inteligencia artificial, tienen un gran potencial para enriquecer las experiencias educativas, fomentar entornos de aprendizaje personalizados y centrados en el estudiante, y alinear la práctica pedagógica con modelos educativos participativos y constructivistas.

**Palabras clave:** Interfaces Gestuales; Educación Inmersiva; Realidad Virtual; Aprendizaje Experiencial; Inteligencia Artificial.

## INTRODUCTION

Among the most interesting tools for improving the educational experience in immersive virtual reality environments are intelligent gestural interfaces, which are characterized by taking advantage of the natural movements of the human body (especially the face) in order to facilitate interaction with digital educational content, allowing to improve the intuition and interest of students regarding the learning process.[1] The use of this technology in immersive virtual environments has the potential to transmute the same environments, leading students to interact differently with digital educational resources, recognizing the presence of a new type of learning, one that is more active and experiential.[2]

The integration of this type of gestural interfaces, or also called natural user interfaces, with augmented reality environments allows students to interact with virtual objects in a similar way as they would with real objects, which increases the feeling of presence and the feeling of body perception within the virtual environment, leading to improved information retention and understanding of complex concepts, giving a greater sense of control and empowerment over their own exploration; especially when the sensorimotor system is involved with meaningful gestures that are congruent with the content to be learned, thus activating more neural pathways, which can result in a stronger learning signal or a more lasting memory trace.[3,4]

In the last two decades, education has seen a notable change driven by technological advances and new forms of interaction; with the emergence of intelligent gestural interfaces and immersive virtual reality environments, new concepts and topics of relevance have been generated in the educational field. This field must have the responsibility of guiding this technological revolution, crossing fronts such as knowledge, people and digital tools.[5]

In relation to immersive education, which corresponds to this type of learning, where students have the feeling of being in the specific environment that is to be taught, the efficiencies of interfaces supported by intelligent gesture recognition systems allow: generating the feeling of being present in virtual environments, improving the retention of information and the understanding of complex concepts, adapting to the individual needs of each student, and providing them with personalized and self-directed learning.[6]

Regarding learning, the development of gestural applications presents challenges, both technical and pedagogical, since it is necessary that the design of these applications show the taking of gestures as a more natural, intuitive and friendly form of interaction when learning, but can also ensure the accuracy and reliability of the recognition of the taking of gestures. In this context, various studies reveal that some educational institutions still adhere to conventional teaching methods, where students maintain a passive role in the acquisition of knowledge; however, their results also indicate that they can become active agents of their own learning when they experience an increase in their interest and participation.[7]

Therefore, promoting the incorporation of these technological tools with the aim of stimulating student interest in academic content has great advantages due to the more practical and self- taught learning experiences that they can generate.

## METHOD

For the development of this phase, the RSL type of research was used, or Systematic Review of the Literature by its acronym, which is defined as a segmentation of phases within a study that serves to identify, evaluate and synthesize the analytical, descriptive or scientific evidence related to the main objective and problem of the study.[8]

With this type of study, we seek to provide a meticulous information framework, since it presents a solid structure divided into three parts: planning, execution and presentation. Structure validated by several experts in the field of education, and mainly, in the field of research and educational technology. Such authors as

Barbara Kitchenham, recognized for her contributions to the world of academic research.[9]

The author presents an interesting research methodology, which is used in this document, since it combines the basic foundations of RSL with her academic research knowledge, seeking to provide a credible and solid basis for the research. With contributions such as search criteria, key questions, description of the search process, and quality assessment, which are better defined in table 1.

**Table 1.** RSL based on Kitchenham's contributions

| Competency level | Percentage of teachers |
|---|---|
| Planning the RSL | Identify the need for the review<br>Specify the key research questions<br>Evaluate the review protocol |
| Executing the RSL | Select Primary Studies<br>Establish inclusion and exclusion criteria<br>Evaluate the quality of the studies<br>Extract and monitor data |
| Presenting the RSL | Synthesize data<br>Answer research questions<br>Evidence results |

## RESULTS

### Planning

*Identification of the need*

This article sought to determine the methods and techniques necessary for the integration of gestural interface technology in immersive education and, therefore, its objective is oriented to answer how these techniques can be applied to increase immersion within educational processes, making it possible for students of all kinds to access learning through this technology.

Having as target groups students who have some difficulty in carrying out activities in learning environments; certain difficulties that may be based mainly on disability or disorder.[10]

*Key questions*

The research questions, or main doubts, are very important for the development of this RSL, thanks to the fact that they provide a basis and start to generate the criteria and search for ideas that will have the following two phases of the study. These questions allow us to define the purpose, the guide and the data analysis to follow the review.[11]

These research questions or key questions are based on the themes raised in the introduction of this article, being essential for the construction of the main argument of the study. This can be best observed in table 2, which describes the central objectives of each question.

**Table 2.** Key research questions

| N° | Question | Objectives |
|---|---|---|
| 1 | How can gesture recognition technologies be adapted to tools such as AI to create more intuitive interfaces in immersive educational environments? | Investigate the possibility of using gesture recognition systems with artificial intelligence for an immersive learning experience.<br>Review the current capabilities of systems that can recognize gestures.<br>Investigate ways in which artificial intelligence can improve gesture recognition and examine possible uses in immersive educational environments. |
| 2 | What impact does the use of intelligent gestural interfaces have on information retention and understanding of complex concepts in immersive learning environments? | Evaluate the impact of artificial intelligence in the use of gestural interfaces on information retention and understanding of complex concepts.<br>Compare learning processes such as short- and long-term memory information retention and understanding of concepts in traditional learning methods and those involving the use of intelligent gestural interfaces.<br>Satisfy factors such as student engagement, interactivity, and personalized learning. |
| 3 | What are the main technical and pedagogical challenges in implementing intelligent gestural interfaces for immersive learning, and how can they be addressed to ensure their effectiveness? | Specify the main technical and pedagogical barriers that arise in creating these technologies for the immersive learning environment and suggest options for their solution.<br>Conduct a comprehensive literature review on the implementation of gesture-based interfaces in education while specifying the problems. |

*Evaluation of the RSL protocol*

Throughout this methodology, we sought to provide the review with a protocol that is adequate, in terms of having well-formulated questions and clear objectives, as well as having arguments for the answers, which use reliable and well-founded information.

The protocol was structured around the following segmentation: purpose of the review, main research questions, inclusion and exclusion criteria, document search strategies, databases, keywords, search string, data extraction, data synthesis and quality assessment. Considering the limitations present due to the study topic, these being the possible scarcity of empirical studies due to the novelty of the field, and the rapid technological evolution that may cause some findings to become outdated.

Likewise, the protocol presented certain strengths and vulnerabilities, part of which were influenced by the schematization provided by the RSL proposed by Kitchenham. First, its strengths were oriented towards clarity in the objectives and well-defined research questions, clearly established inclusion and exclusion criteria, a search strategy based on the systematic selection of studies, and on a solid data extraction and synthesis. On the other hand, its vulnerabilities were characterized by the temporal limitation of the information search to the last five years, which reduced the number of documents to be considered, as well as the data that could be found in previous research. Thus, they also included a certain risk of bias in the selection of studies and a certain lack of specificity in the evaluation of the quality of the studies.

**Execution**

*Selection of primary studies*

The primary studies in this study were based on the collection and analysis of data carried out directly from original sources, as well as considering research where surveys, interviews, observations, experiments or discussion groups were used that collected data relevant to their research questions or main problems raised.

Some of the primary studies on which this research focused are related to topics such as the exploration of techniques applied with educational theories to the design of immersive virtual reality, with the use of gestures and manual controls for embedded learning; another topic was the demonstration of gesture recognition systems for immersive mathematics education in children; the potential of mixed reality in improving the learning experience and academic performance of students was also taken into account; and finally, studies with the theme of AI analysis in enhancing the gestural interactions of students from some type of educational institution were used.

*Inclusion and exclusion criteria*

For the development of this phase, the search criteria allowed us to delimit the scope of the research and thus ensure that each selected study was relevant and of good quality. Using criteria that covered both technological and educational aspects, it was possible to include research that integrated gesture recognition technologies with AI in virtual, augmented or mixed reality contexts applied to education; as well as empirical studies, systematic reviews and meta-analyses that presented evaluations on the effectiveness of gestural interfaces in learning.

Likewise, thanks to the search criteria detailed in table 3, the most important studies that contributed to answering the research questions were identified (figure 1).

**Table 3.** RSL search criteria

| Type of criterion | Inclusion criteria | Exclusion criteria |
|---|---|---|
| Time interval | Documents published after 2019 | Published before 2019 |
| Integration of similar themes | Studies that addressed gestural interfaces in immersive educational environments | They did not address this main theme |
| Applications | Research integrating gesture recognition technologies with AI and assessing their effectiveness in learning interfaces | They did not integrate such applications into their research |
| Type of document | Systematic reviews, journal articles, scholarly research papers | Blogs, web pages, opinion pieces, conferences, research with sources |
| Language of publication | Studies in English or Spanish | With languages not mentioned |

As for the search strings used, with the exception of the bibliographic sources Google Scholar and Springer in which the English keywords of this research were used.

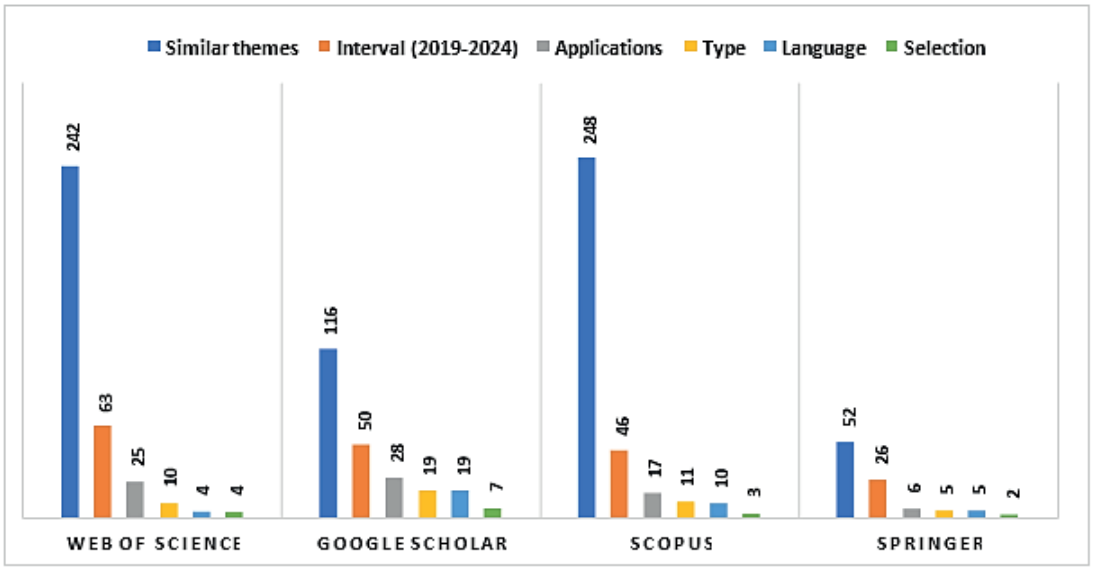


**Figure 1.** Number of documents selected according to search criteria

The following string was used in Scopus ((“gesture interface” OR “gesture-based interaction” OR “hand gesture”) AND (“immersive education” OR “immersive learning” OR “virtual reality” OR “augmented reality” OR “mixed reality”) AND (“intelligent” OR “Smart” OR “adaptive”)). In the case of Web of Science, a string with slight changes in its keywords was used, as can be seen ((gesture interface OR “gesture-based interaction”) AND (immersive (education OR learning OR teaching) OR “virtual reality” OR “augmented reality” OR “mixed reality”) AND (intelligent OR smart OR adaptive)).

Consequently, the exclusion criteria helped to filter out the number of studies less connected to the premise of this study, avoiding including studies that do not specifically focus on educational environments, or are not based on non-immersive gestural interface integration techniques, as well as those that do not incorporate AI elements in gestural recognition with a focus on “smart” interfaces

*Quality assessment*

In this phase, the evaluation of the research design, the size and representativeness of the sample, the data collection procedures and the analysis techniques implemented was carried out. In parallel, the internal and external validity of the research, the reliability of the instruments used, the effectiveness of gestural interfaces in immersive educational contexts (as well as in other binding areas) were also assessed.

The evaluation of the studies allowed us to identify their relevance and applicability in the context of immersive education, being chosen to answer the questions of the article and measured according to the degree to which their findings contributed to the understanding of the application of these technologies in pedagogy and learning. In the case of studies from sources such as Scopus and Web of Science, quality assessment by at least two independent evaluators was considered, with the aim of guaranteeing uniformity and objectivity in the evaluation process in these two sources characterized by their studies of excellence.[12]

*Extraction and monitoring*

The nature of this segment of the SLR is based on the systematic collection of relevant information from each study through a template with specific fields on the research topic, covering general information such as authors, the year of publication of the study and how the study was designed. Also, based on the search criteria previously outlined, this phase of the article could be streamlined. Rather, with the criteria well established, special focus was placed on areas such as the extraction of quantitative data such as gesture recognition rates, learning metrics and immersion levels, as well as qualitative data such as user experiences and implementation challenges.

For the analysis of data collected during the systematic review concerning intelligent gestural interfaces in the field of learning, the selected studies were analyzed comprehensively to identify the following aspects: types of gestural interfaces, implemented AI technologies, research methodologies and techniques, areas of study and academic disciplines addressed, impact on learning, and knowledge retention.

**Presentation**

*Data synthesis*

For the development of this SLR segment, the pre-selection of the studies that have been part of the analysis

was relevant. Likewise, this analysis provided an overview of the most important aspects that have been found in the literature related to intelligent gesture interfaces in the academic area by ordering them as follows.

*Technologies and methods*

- Gesture recognition using computer vision and sensors.
- Machine learning algorithms in convolutional neural networks.
- Integration of natural interfaces based on hand and body gestures.

*Applications in education*

- Improving student interaction and engagement.
- Early education under the development of communicative skills.
- Application in immersive learning environments and virtual/augmented reality.

*Influence in the field of learning*

- Improved information retention and understanding of complex concepts.
- Dissemination of communication and participation in the classroom.
- Better adapted learning styles and special needs.

*Considerations*

- Requirement for intuitive and natural gesture design for users.
- Relevance of accuracy and speed in gesture recognition.
- Importance of privacy and security when implementing vision systems.

**Answers to the questions**

*Question 1: how can gesture recognition technologies be adapted to tools such as AI to create more intuitive interfaces in immersive educational environments?*

Artificial intelligence tools are characterized by the free personalization of learning based on learners' gesture patterns, generating systems that can analyze learners' movements to adapt the interface and educational content according to individual patterns and needs, or groupable depending on the educational context applicable in the present environment.

To answer this question, several AI tools were identified that integrate very efficiently in the field of gesture recognition.

The first tool is the use of advanced sensors such as depth cameras, infrared cameras and LiDAR (an acronym that stands for light detection and ranging) which is a laser-based sensing technology to accurately capture motion in three-dimensional space, enabling more natural and fluid interaction in virtual educational environments. Consequently, the use of RGB-D cameras such as Microsoft Kinect or Intel RealSense was also identified, which helped improve the ability of gesture recognition systems to perceive three-dimensional motion interactions from gestures.[13]

Convolutional and recurrent neural networks, on the other hand, prove to be able to better integrate with dynamic gesture recognition and handwriting in the air. Since, machine learning algorithms and neural networks combine to be able to train and classify themselves in gesture recognition in real time, integrated systems can respond more quickly to students' actions in the academic setting.[14] Furthermore, by integrating deep learning algorithms into these neural networks, AI models can automatically learn complex gesture features from large datasets.

Thirdly, the combination of gesture recognition with other input modalities, such as voice recognition and eye tracking, creates robust multimodal interfaces such as the applied GestureTeach system, designed to interpret gestures as a natural form of interaction involved in enhancing teacher response or interaction, and thus student engagement in the online teaching-learning process through animations using handwritten sketches, thus improving the visual effects of interaction and understanding of knowledge.[15]

In another instance, with visual tools based on intelligent computers, gestural recognition can be improved, mainly with techniques such as the detection of key points of the hands and the processing of the gestural information provided by the same, whose operation can be observed in educational applications with fluid interaction, such as Kahoot, for example. Tools such as Kahoot allow multimodal interfaces to be generated by combining gesture recognition with different types of interaction, and through an immersive educational system students can use gestures in conjunction with voice commands to manipulate virtual objects or navigate their course content.

In the research by [16], a computer-aided learning system called StarC is proposed that incorporates gesture recognition technologies for the preparation of lessons, tests and teaching topics. Although the focus of the research is not to create an immersive environment within the educational environment, it portrays several

features and functionalities of artificial intelligence interface technology.[17]

Continuing with the interfaces that are part of the educational process, in relation to the learning-teaching process, algorithmic developments that incorporate artificial intelligence carefully consider each of the body movements and gestures that the person makes, in which the student interacts with the virtual object and at the same time solves complex mathematical problems. In other words, gesture recognition and other intelligent interfaces can develop more realistic educational environments by facilitating navigation in three dimensions of virtual spaces, such as 3D objects, as well as interacting intuitively with content without conventional input devices.[18]

*Question 2: what impact does the use of intelligent gestural interfaces have on the retention of information and understanding of complex concepts in immersive learning environments?*

To answer this question, the impact of intelligent interfaces must be intrinsically positive with respect to improvements in cognitive abilities due to two main factors: multimodal learning and reduction of cognitive load. On the one hand, the multimodal learning process refers to the combination of various types of information such as visual, auditory and kinesthetic, with the "learning while gesturing" dynamic at its core, which creates connections between logical concepts with concrete physical experiences.[19]

Studies such as the one conducted by [20], demonstrate the effectiveness and truthfulness in the practice of multimodal learning through gesturing, given the implementation of this factor in an educational learning environment in relation to the comprehension and understanding of basic biology topics; where students who did not use gesturing to represent this knowledge were slow to understand it fully while those who did so generated long-term comprehension and retention.

On the other hand, cognitive load reduction can be defined as the way in which the different body systems distribute energy between them to process information in a better way in order to create a deeper synthesis of information content. Gestures are the main tools in immersive VR environments, as they act as physical anchors for abstract concepts, facilitating their understanding and memorization.[21]

Table 4 below sets out different sources showing different and similar results that strengthen the research objectives and demonstrate the impact of interfaces in the field of immersive education.

**Table 4.** Research results on the impact of gestural interfaces in the educational environment

| Participants | Usability properties | Interface Preferences | Statistical analysis | Author(s) |
|---|---|---|---|---|
| 12 university students | Overall satisfaction<br>Accuracy<br>Comfort<br>Ease of use<br>Immersion<br>Fun and games<br>No fatigue | 58 % prefer to use them with both hands<br>67 % use instead of keyboard and mouse<br>92 % use HDM instead of a monitor | Use of ANOVA and Scheffé tests to verify results. | Lee et al.[4] |
| 38 students of the B1 cycle of the UCC Language Centre | Methodologies applied<br>Technological tools<br>VR in English classes | In terms of applied methodologies:<br>39 % neutral satisfaction<br>61 % highly satisfactory<br>In terms of the use of technological tools:<br>68,4 % highly satisfactory<br>23,7 % very satisfactory<br>In terms of VR in English classes:<br>60,5 % highly satisfactory<br>29 % very satisfactory. | Using Cronbach's alpha with a reliability of 0,93<br>Pearson's Chi- square analysis with a value of 0,006 | Agurto- Cabrera et al.[7] |
| 12 participants<br>Averaging 32 years of age | Ease of learning gesture-based interaction system<br>Effectiveness of syntax<br>Preference for location awareness functionality | 58 % find learning syntax easy<br>83 % appreciate the functionality of location awareness<br>42 % find it uncomfortable to gesticulate in the air. | Likert scale to assess acceptance and effectiveness of syntax<br>Calculation of agreement scores for proposed actions | Bernard et al.[22] |

With the consideration of these two essential factors, intelligent gestural interfaces can adapt to the learner and provide feedback effectively in immersive learning environments. Primarily, in areas that require a lot of comprehension and mental effort such as language learning, learners can use e-learning platforms with intelligent interfaces to better acquire and retain the vocabulary and language of the learned language.[23]

As learners' ability to interact with visual representations of complex concepts through gestural interfaces

is enhanced, their sense of engagement and motivation is also boosted. Learning models such as UAX (Affective User Experience) implement intelligent gestural interaction in classrooms or gamified learning environments, the combination of which influences the emotional state of learners.[24]

*Question 3: what are the main technical and pedagogical challenges in implementing intelligent gestural interfaces for immersive learning, and how can they be addressed to ensure their effectiveness?*

In this question, we take the problem posed as an object of analysis, in which we can observe how educational institutions and teachers seek to integrate intelligent gestural interfaces into learning environments considering a series of academic obstacles present in the integration. Among these academic challenges present, one can vary from the complexity of accurate gesture recognition to the adjustment of traditional approaches depending on their type, as can be seen in table 5.

**Table 5.** Technical and pedagogical challenges in the integration of intelligent gestural interfaces

| Type | Challenge | Description |
|---|---|---|
| Technicians | Variability of gesture patterns | There is a large gap between users in how they perform the same gesture, which makes it difficult for machine learning algorithms to generalize well across users This can result in poor classification or recognition accuracy in gesture systems.[25] |
| | Real-time processing | In the case of virtual reality type applications, where the use of gesture interpreters is required, the smoothness of the live experience is facilitated for the user, and therefore it remains a challenge to work at low latency and high accuracy, which is a significant cost when running on limited devices. |
| | Accuracy and reliability | It is also cautioned that not having the accuracy of responses generated by AI may undermine the quality of learning.[13] |
| | Lighting variations and complex backgrounds | Gestural approaches where vision is the primary mode of interaction are influenced by surrounding light and complex background conditions, and these have negative impacts on performance. |
| | Lack of standardization | The development of models that are able to generalize to such diverse standards and cover multiple applications is made difficult by the lack of standardization of gestures across applications and contexts |
| Pedagogical | Learning curve | Clearly, learners need time to understand gesture interfaces and how to use them in the educational foundation.[26] |
| | Curricular integration | Integrating gesture interfaces into existing curricula and aligning them with appropriate learning outcomes can be difficult for teachers. |
| | Learning assessment | The development of appropriate methods for assessing student learning and progress could be quite intricate. |

Consequently, to ensure the effectiveness of smart gesture interfaces in immersive learning, several strategies can be incorporated: in technical challenges, machine learning algorithms can be improved to develop more robust models that handle variability in gesture patterns and adapt to different individuals, as well as improving academic performance through advanced processing techniques by optimizing the resources of low-end devices. On the other hand, in pedagogical challenges, emphasis can be placed on standardization and training of learners, with the creation of general standards for gestures in gamification applications in education facilitating consistency and transfer of skills between different digital platforms.

## DISCUSSION

Progress in the field of education can be enhanced by the integration of contemporary technologies such as gesture recognition with AI tools, which can be used to create more intuitive interfaces in immersive educational environments, being an efficient combination in the provision of new possibilities to personalize learning and to improve the interaction between students and their learning process.

Around advances in hardware and advanced motion sensors (depth cameras, infrared and LiDAR systems), they manage to create a more accurate capture of gestures in three- dimensional spaces giving a more natural

and fluid interaction in virtual educational environments. Similarly, deep learning algorithms enable the recognition of dynamic gestures and handwriting in the air, the combination of machine learning algorithms and neural networks also enables real-time training and classification of gestures, which results in systems that are more responsive to student actions, and thus the integration of these deep learning algorithms enable AI models to automatically learn complex gesture characteristics from large data sets.

Following the idea, the interpretation of abstract or logical concepts through gestures presents an interesting challenge for AI algorithms and requires detailed interpretation of body movements and gestures to enable learners to interact with virtual objects and solve complex problems, where they can navigate digital scenarios and interact with content intuitively, without the need for traditional input devices.

On the other hand, multimodal interfaces that can combine voice recognition and eye-tracking provide robustness to these technological tools, such as the GestureTeach system, which handles gesture interpretation as a natural form of interaction in online learning, allowing students to use their gestures together through voice commands to manipulate virtual objects or navigate through academic content. Another relevant system mentioned here is StarC, which proves to be a useful application that does not focus on immersive environments but rather demonstrates how gesture recognition can be used in lesson preparation, assessment, and topics for the teaching and learning process.

The future implications for education lie in integrating gesture recognition technologies into AI systems to create interfaces that, when applied, could transform how new knowledge is taught and learned, with these technologies being a promising approach to fostering more personalized, interactive and engaging learning that is tailored to the individual needs of learners and potentially improves educational outcomes.[27]

## CONCLUSIONS

Together with advanced interface technologies, educational interactions in the virtual environment are revolutionized. In large part, this ease of interacting with content naturally leads to a high level of attention and interest from learners. Also, by generating the possibilities of moving three-dimensional objects as one does with real objects, people become much more engaged with the situation, which reinforces not only learning information, but also connecting at a deeper level with those abstract concepts surrounding the object of study.

With the help of these interfaces, immersive teaching is encouraged, allowing for greater interactivity and experience on the part of the learner, allowing it to be tailored to their educational needs and making the teaching and learning process unchallenging. This gives them, to a large extent, the freedom, at their own time and pace, to relate ideas and engage with the object of study using different movements to separate ideas. This, in most cases, not only makes it easier to understand the information, but also increases students' interest and involvement in their own educational process.

However, the creation of such interfaces is also fraught with challenges, including the need for a complex yet simple design that can be used by all learners regardless of their physical abilities or previous exposure to technology. Accurate recognition of hand movements and gestures would avoid frustrations and maintain the fluidity of the learning experience, and from a pedagogical aspect, mid-career teachers must be helped to learn how to incorporate such inventions into existing curricula, which in many cases would involve considerable backward- looking pedagogical revision.

Despite the fact that some educational institutions still cling to traditional teaching methods, which detract so much from students' ability to learn, students' gestural interfaces can awaken students' interest and with such a shift from being told many things to actively engaging with the material, students' attention is sustained from passive to active, which correlates with current educational conceptions that emphasize the need for active learning and knowledge construction on the part of the student.

In addition, technological issues noted include the need to deal in some way with variations in gesture patterns that may be employed by different people and the need for real- time processing to provide seamless interaction in the experience. And pedagogical challenges are such as how best to integrate these technologies into existing curricula and how to devise new forms of learning assessment that fit this interactive approach.

Finally, the combination of gesture recognition technologies and artificial intelligence tools has the potential to evolve education, offering the promise of more personalized, engaging and effective learning that can dynamically adapt to individual needs and learning styles.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## AUTHORSHIP CONTRIBUTION

*Conceptualization:* Javier Guaña-Moya, Susana Masapanta-Carrión, Yamileth Arteaga-Alcívar.
*Data curation:* Javier Guaña-Moya.
*Formal analysis:* Yamileth Arteaga-Alcívar, Susana Masapanta-Carrión, Javier Guaña-Moya.
*Research:* Javier Guaña-Moya, Yamileth Arteaga-Alcívar.
*Methodology:* Yamileth Arteaga-Alcívar, Javier Guaña-Moya.
*Writing - original draft:* Javier Guaña-Moya, Yamileth Arteaga-Alcívar, Susana Masapanta-Carrión.
*Writing - review and editing:* Javier Guaña-Moya.