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Integration of Virtual Reality and Conversational Agents in Physics Education: Competency Assessment in Engineering

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***Abstract*–This study examines an educational experience implemented in an introductory physics course for engineering students, focused on developing the competency to explain the functioning of engineering systems based on principles of natural sciences. The instructional design combined project-based learning with immersive technologies through the collaborative construction of an electric Go-Kart, complemented by the use of VirtualSpeech, an AI-supported virtual reality platform incorporating conversational agents and automated feedback to support technical communication. A descriptive–exploratory research design was adopted to characterize student engagement and competency-based performance within this authentic learning environment. Two complementary instruments were employed: the RCEE-A rubric to assess written technical argumentation and the UWES-9 scale, adapted to the educational context, to measure student engagement. The results indicate high levels of student engagement and generally strong performance in technical explanation and argumentation at the end of the project. Rather than establishing causal effects, the findings provide descriptive evidence of how the integration of project-based learning, immersive virtual environments, and AI-supported conversational interaction can support engagement and scientific reasoning in early-stage engineering education.**

***Keywords*--Educational Innovation, Higher Education, Active Learning, Virtual Reality, Competency Assessment.**

I. Introduction

The development of scientific and technological competencies in engineering education requires pedagogical approaches that meaningfully integrate theory, practice, and technology, particularly in early-stage courses where students are still constructing their disciplinary identity and modes of scientific reasoning. One of the key competencies is the ability to explain the functioning of engineering systems and devices based on principles of natural sciences. This competency requires not only conceptual knowledge but also the capacity to articulate coherent technical arguments, justify design decisions, and connect abstract principles with concrete engineering artifacts. However, in introductory physics courses, these competencies are often addressed in a fragmented manner, with limited connection between theoretical content and its application to real-world problems [1], [2]. As a result, students often demonstrate procedural knowledge without fully developing the explanatory and argumentative skills expected in professional engineering practice.

Active methodologies, such as project-based learning (PBL) and the use of immersive technologies, have proven effective in promoting meaningful learning and the development of complex competencies [3], [4]. Virtual reality (VR) and conversation-al agents offer new possibilities to enrich the learning experience by simulating authentic contexts and enabling interaction with digital environments that foster reflection, argumentation, and student engagement [5], [6]. These technologies have the potential to move beyond content visualization toward supporting higher-order cognitive and communicative processes when intentionally integrated into instructional design.

While prior studies have examined immersive technologies, student engagement, or project-based learning in isolation, fewer works have addressed their combined use as an intentionally integrated instructional framework for developing technical argumentation in early-stage engineering education. Existing research has tended to focus on learning outcomes, motivation, or technological affordances separately, rather than on how these elements support students' ability to explain and justify engineering systems using principles of natural sciences. This gap highlights the need for educational studies that examine how integrated active and immersive learning designs contribute to the development of explanatory and argumentative competencies in introductory engineering contexts.

This study describes an educational innovation introduced in an introductory physics course, where students engaged in building an electric Go-Kart as an integrative project. The initiative incorporated a conversational virtual agent within a virtual reality environment to enhance students' technical and scientific argumentation about the vehicle's operation. The conversational agent functioned as a simulated technical interlocutor, prompting students to explain, justify, and reflect on their design choices in a low-risk immersive setting. To characterize the outcomes of this educational experience, two complementary instruments were employed: the RCEE-A rubric, used to evaluate the quality of students' written technical argumentation, and the UWES-9 scale, adapted for educational contexts, to measure student engagement with the learning experience.

Within this context, the present work focuses on documenting and characterizing student engagement and competency-based performance within an authentic learning environment that integrates project-based learning, virtual reality, and conversational agents. Rather than aiming to establish causal relationships, the study adopts a descriptive perspective oriented toward reporting achieved outcomes associated with this instructional design, contributing empirical evidence to ongoing discussions on immersive and AI-supported learning in introductory engineering education.

A. Background and Literature Review

Active Learning and Competency-Based Assessment.

Several studies have shown that active learning significantly improves academic performance and the development of competencies in STEM education [7], [8]. Project-Based Learning (PBL) enables students to face real-world challenges, work collaboratively, and apply interdisciplinary knowledge, making it an ideal strategy for engineering education [9]. Competency-based assessment, in turn, requires tools that evaluate not only knowledge but also performance in authentic tasks [10]. This alignment between learning activities and assessment is essential for evaluating higher-order competencies such as technical argumentation.

Immersive Technologies and Virtual Agents.

The integration of technologies such as virtual reality and conversational agents in education has gained momentum in recent years. These tools allow for the simulation of complex scenarios, facilitate immediate feedback, and promote self-regulated learning [11], [12]. Virtual agents have shown the potential to enhance both oral and written argumentation by providing structured and personalized dialogue spaces [13]. When embedded within immersive environments, conversational agents may serve as mediators of reflection and articulation, supporting students in externalizing their reasoning processes.

Student Engagement and Meaningful Learning.

Engagement is a key factor in academic success. Instruments such as the UWES-9 allow for the measurement of this construction in educational contexts, assessing dimensions such as vigor, dedication, and absorption [14]. A high level of engagement is associated with greater persistence, satisfaction, and learning achievement [15]. In active and immersive learning environments, engagement not only reflects students' emotional involvement but also their willingness to invest cognitive effort in complex explanatory and argumentative tasks.

B. Educational Proposal

The educational intervention involved the use of the VirtualSpeech platform within a virtual reality setting to support students' scientific reasoning about the operation of an electric Go-Kart developed as part of a project-based physics course. Student performance was characterized by using two complementary instruments: the RCEE-A rubric, aimed at evaluating the quality of written technical argumentation, and the UWES-9 scale, used to assess student engagement in the learning experience. Consistent with the descriptive scope of the study, the research focuses on examining the relationship between the integrated instructional design and observed patterns of engagement and argumentative competence.

This study focuses on documenting the design and implementation of an integrated pedagogical architecture in which immersive environments, project-based learning, and competency-based assessment are intentionally aligned to support technical argumentation in early-stage engineering education, rather than evaluating virtual reality or conversational agents as isolated instructional tools.

The paper is structured as follows: Section II describes the methodology used to implement educational experience. Section III presents the results obtained. Section IV discusses the findings and their pedagogical implications. Finally, Section V offers conclusions and recommendations for future implementations.

II. Methodology

A. Design of the Educational Experience

The educational intervention involved a total of 51 second-semester engineering students from a private university in Mexico. Of these, 62.75% were male (n = 32) and 37.25% female (n = 19), with ages ranging from 18 to 20 years. Students were enrolled in various engineering programs and participated in the experience as part of their introductory physics course. The sample corresponds to a convenience cohort defined by course enrollment, which is typical in classroom-based educational innovation studies.

The study was intentionally designed as a descriptive–exploratory educational research. Rather than seeking to establish causal relationships between instructional components and learning outcomes, the methodological focus was placed on characterizing students' engagement levels and competency-based performance within an authentic instructional context. Accordingly, the study emphasizes outcome description and pattern identification rather than hypothesis testing or inferential comparison**.** This design choice is consistent with early-stage educational innovation studies, where the primary objective is to document achieved outcomes, identify performance patterns, and generate empirical evidence to inform future comparative or longitudinal research.

The innovation was implemented using a project-based learning (PBL) approach. The core of the course was the design and construction of an electric Go-Kart, a multidisciplinary project that enabled the integration of concepts related to electricity, mechanics, energy, and scientific argumentation. This experience was designed to foster the development of the competency: "Explains the functioning of engineering systems and devices based on principles of natural sciences." This competency was defined as the ability to articulate coherent explanations and justifications grounded in relevant physical principles, rather than solely demonstrating procedural or computational proficiency.

The project was carried out in collaborative teams, where students were required to design, assemble, and technically justify the operation of the vehicle. Throughout the process, they were encouraged to make evidence-based decisions, produce technical documentation, and reflect critically on the underlying physical principles. Team-based work was selected to mirror professional engineering practices and to promote peer discussion as a mechanism for refining technical explanations.

For the design and implementation of the intervention protocol, the teaching team received training from Novus, an initiative of the Institute for the Future of Education at Tecnológico de Monterrey. Novus promotes evidence-based educational innovation aimed at strengthening teaching culture and enhancing learning processes. More information about this initiative is available at: https://novus.tec.mx/es/experiencia-novus. This training ensured alignment between the instructional design, targeted competencies, and assessment strategies implemented during the course.

B. Integration of Virtual Reality and Conversational Agent

To strengthen students' technical argumentation skills, the VirtualSpeech platform was incorporated into the intervention. VirtualSpeech is an AI-supported virtual reality platform that enables the simulation of presentations and structured technical conversations with virtual avatars. The platform integrates automated feedback mechanisms—such as indicators related to speech structure, filler word usage, and non-verbal communication—positioning it as a conversational learning environment rather than a content-delivery tool. Within this study, VirtualSpeech was intentionally employed as a medium for eliciting students' technical explanations and justifications, rather than as a tool for introducing new disciplinary content. The platform was used by students to interact with a conversational agent embedded in the VirtualSpeech environment, which functioned as a simulated technical advisor or evaluator within an immersive and low-risk setting (see Fig. 1).

During these sessions, each student was required to explain the functioning of the electric Go-Kart, justify design decisions, and respond to technical questions. This dynamic promoted the practice of oral argumentation, evidence-based decision-making, and improvement in technical communication. The interaction format encouraged students to externalize their reasoning processes and to organize their explanations in a structured and coherent manner.

In addition to fostering fluency and clarity in oral expression, VirtualSpeech provided immediate feedback on key aspects such as body language, filler word usage, and speech structure. This feedback significantly contributed to the development of communication competencies in technical contexts. Students were allowed to iteratively adjust their explanations based on the automated feedback received, supporting reflective refinement of their technical discourse.

Fig. 1. Students use VirtualSpeech as a technical advisor and competency evaluator during the practical session.

C. Assessment of Learning and Student Engagement

To evaluate the impact of the educational experience, two complementary instruments were applied:

RCEE-A (Rubric for the Quality of Writing in Explanations and Argumentations): Adapted from the work of Figueroa et al. [16], this rubric was used to assess the quality of argumentative texts produced by students, considering dimensions such as clarity of position, the strength of arguments, the inclusion of counterarguments, and discourse organization.

UWES-9 (Utrecht Work Engagement Scale, educational version): This instrument, adapted to the context of the project, measured student engagement across three dimensions: vigor, dedication, and absorption [17]. The questions were contextualized to the virtual reality experience and the development of the Go-Kart project, allowing for the capture of participants' emotional and cognitive involvement.

Both instruments were administered at the end of the project, and the results were analyzed using both quantitative and qualitative approaches to identify patterns in academic performance and levels of engagement.

The study was conducted by a research protocol approved by Tecnológico de Monterrey. Informed consent was obtained from all participants, who were fully informed about the study's objectives, the voluntary nature of their participation, and the confidentiality of the data collected.

III. Results

A. Student Engagement with the Project (UWES-9)

To assess students' level of engagement with the learning experience, the UWES-9 questionnaire was administered at the end of the intervention and adapted to the virtual reality context of the project. The instrument evaluates engagement across three dimensions—vigor, dedication, and absorption—

using a Likert-type scale ranging from 0 (never) to 6 (always), where 6 represents the maximum possible value for each item. This allows for a quantitative description of students' emotional and cognitive involvement in the activity. The use of a post-intervention administration aligns with the study's descriptive purpose, focusing on students perceived engagement upon completion of the instructional experience.

In alignment with the descriptive–exploratory design of the study, the analysis of the UWES-9 data focused on reporting central tendencies and overall response patterns, without pursuing inferential statistical comparisons. Accordingly, results are interpreted as indicators of self-reported engagement levels rather than as evidence of statistically significant differences or causal effects.

The results show a consistently high level of engagement across all three evaluated dimensions. Items related to positive emotions and energy during the activity obtained the highest average scores. In particular, the statements "I felt enthusiastic about learning with virtual reality" and "I felt happy while using virtual reality to learn" both reached a mean score of 5.74, indicating a strong positive emotional response among participants. Similarly, the item "While using virtual reality, I felt full of energy" obtained a mean score of 5.71, reflecting high levels of vigor during the experience. These values suggest that the learning environment was perceived as emotionally stimulating and energizing by most participants.

Regarding the absorption dimension, the item "It was hard for me to disconnect from the virtual reality activity because I was very focused" reached a mean score of 5.02. While this value remains high, it is comparatively lower than those associated with enthusiasm and energy. This suggests that, although students reported sustained attention and focus during the activity, the degree of full immersion varied among participants. Such variability is consistent with prior findings in immersive learning environments, where individual differences in cognitive engagement and familiarity with technology may influence absorption levels.

Taken together, these results indicate that students generally perceived the learning experience as motivating, emotionally positive, and cognitively engaging. The UWES-9 data provide quantitative evidence of students' self-reported engagement with the project, highlighting particularly strong responses in the dimensions of vigor and dedication, and a slightly more heterogeneous response in absorption. These findings offer a descriptive overview of how students experienced the virtual reality–supported project in terms of engagement. Within the scope of this study, these results are interpreted as engagement profiles associated with the instructional design rather than as evaluative judgments of its effectiveness.

B. *Achievement Level of the Target Competency (RCEE-A)*

The achievement level of students' technical argumentation competency was evaluated using the RCEE-A rubric (Rubric for the Quality of Writing in Explanations and Argumentations). This instrument assesses both the explanatory and argumentative dimensions of written technical discourse through multiple criteria, including content accuracy, argumentative structure, coherence, and the use of evidence. Scores are reported on a four-level scale (1–4), where higher values indicate stronger performance in the corresponding dimension. The rubric was selected due to its alignment with the targeted competency and its prior validation in educational research contexts.

Consistent with the scope of the study, the results derived from the RCEE-A rubric are presented as descriptive indicators of achieved competency levels at the end of the educational experience. The analysis emphasizes observed performance distributions rather than comparisons across groups or time points.

Table I summarizes the descriptive statistics obtained from the application of the rubric. Overall, the results show mean scores close to or above 3.0 across most evaluated dimensions, indicating that students reached a generally high level of performance in the written explanation and justification of the electric Go-Kart's operation. This pattern suggests that, at the conclusion of the project, most students demonstrated competencies corresponding to the upper levels of the rubric scale.

TABLE I. EVALUATION OF STUDENTS' TECHNICAL ARGUMENTATION COMPETENCIES USING VIRTUALSPEECH.

Dimension	***Description***	**Mean**	**Std. Dev.**
CONF	Describes the Electric Go-Kart	3.06	0.24
ELI	Explains components	3.02	0.14
ORGE	Ideas flow logically	2.96	0.20
POS	Well-defined project positioning	3.04	0.20
IDEA	Technical arguments	3.02	0.14
CONT	Refutes with evidence	2.96	0.20
ORGA	Acceptably structured	2.84	0.37

Higher mean scores were observed in dimensions associated with conceptual clarity and explanation of system functionality. Specifically, the dimension CONF (description of the electric Go-Kart) obtained a mean score of 3.06 (SD = 0.24), while ELI (explanation of components and underlying principles) reached a mean score of 3.02 (SD = 0.14). These results suggest that most students were able to clearly describe the system and articulate the scientific principles involved in its operation. These dimensions reflect foundational explanatory competencies expected in introductory engineering contexts.

Similarly, the dimension POS, which evaluates the clarity of the student's technical positioning, achieved a mean score of 3.04 (SD = 0.20), and IDEA, related to the formulation of technical arguments, obtained a mean score of 3.02 (SD = 0.14). These values reflect a consistent level of performance in expressing and supporting a technical stance within the written discourse. This indicates that students were generally able to adopt and defend a coherent technical perspective.

Dimensions related to organization and argumentative complexity showed slightly lower mean values. The ORGE dimension (logical flow of ideas) and CONT (refutation using evidence) both reached a mean score of 2.96 (SD = 0.20), indicating that while students were generally able to structure their arguments coherently, the explicit use of counterarguments and evidence-based refutation was less consistently developed. The lowest mean score was observed in ORGA (overall text organization), with a value of 2.84 (SD = 0.37), suggesting greater variability among students in the global structuring of their written explanations. These dimensions typically require higher levels of disciplinary literacy and argumentative maturity, which are still developing in early-stage engineering students.

The RCEE-A results provide a detailed descriptive profile of students' written technical argumentation at the end of the project. The data indicates stronger performance in dimensions related to explanation and conceptual clarity, and comparatively lower—but still acceptable—performance in dimensions requiring higher levels of argumentative sophistication and structural organization. These findings offer a quantitative characterization of students' competency achievement as assessed through authentic written tasks. Within the descriptive scope of the study, these results are interpreted as indicators of achieved competency levels rather than benchmarks of mastery.

Taken together, the UWES-9 and RCEE-A results provide a descriptive overview of students' engagement levels and technical argumentation performance at the end of the educational experience. As anticipated by the methodological design, these results are interpreted as outcome characterizations rather than evidence of causal effects. While these findings characterize how students interacted with the project and articulated scientific explanations, they do not, by themselves, establish causal relationships between the instructional components and the observed outcomes. The following section discusses these results in relation to prior research and explores their pedagogical implications within the context of introductory engineering education. This transition emphasizes continuity between the empirical findings and their theoretical interpretation.

IV. Discussion

The results obtained from this educational innovation experience highlight the potential of integrating immersive technologies and active methodologies within introductory engineering education. This study explored an instructional approach that combined project-based learning (PBL), virtual reality, and competency-based assessment in an introductory physics course. The results presented in the previous section indicate high levels of student engagement and solid performance in technical argumentation at the conclusion of the project. In this section, these findings are discussed in relation to existing literature on active learning, immersive environments, and competency-based assessment, with particular attention to their scope, interpretation, and methodological limitations. The discussion is intentionally framed to contextualize the observed outcomes within contemporary engineering education research rather than to evaluate instructional effectiveness.

Consistent with the descriptive–exploratory design of the study, this discussion emphasizes the interpretation and scope of the observed outcomes rather than causal attribution, situating the findings within the context of prior research on immersive and competency-based learning approaches. This positioning seeks to ensure coherence between the methodological design and the level of claims advanced in the discussion.

A. *Engagement as a Driver of Learning*

The high average scores obtained through the adapted UWES-9 questionnaire indicate that students perceived the learning experience as emotionally positive, energizing, and cognitively engaging. Reported levels of vigor and dedication suggest that participants experienced sustained interest and motivation throughout the project, which is consistent with prior research highlighting engagement as a key factor in successful active learning environments within engineering education. From an interpretative standpoint, these findings reinforce the role of affective and motivational dimensions as enablers of active participation in complex learning tasks.

From a descriptive standpoint, these engagement results provide insight into how students experienced the integration of immersive technologies within a project-based framework. High engagement is particularly relevant in introductory engineering courses, where students often face conceptual difficulty and disengagement when theoretical content is presented in isolation. In this case, the combination of a tangible engineering challenge with an immersive virtual environment appears to have supported students' willingness to invest effort and attention in the learning process. This observation aligns with research emphasizing the importance of contextualized and authentic tasks in sustaining student engagement.

The slightly lower scores observed in the absorption dimension indicate some variability in the degree of deep immersion experienced by students. While most participants reported sustained focus during the activity, these results suggest that full cognitive absorption was not uniform across the cohort. This finding points to the potential need for additional scaffolding, clearer task structuring, or differentiated support to accommodate diverse learner profiles when implementing immersive technologies in early-stage engineering courses. Such variability is consistent with the heterogeneous nature of learners' prior experiences with immersive environments and self-regulation strategies.

Nevertheless, students' interaction with the conversational agent embedded in the VirtualSpeech platform was perceived positively, as it provided a structured, psychologically safe environment for practicing technical argumentation and receiving automated feedback. Such environments may be particularly valuable for reducing anxiety related to oral technical communication and for encouraging iterative practice in a low-risk setting. Within this context, the conversational agent can be interpreted as a facilitative element that supports practice and reflection rather than as a determinant of engagement outcomes.

Within the scope of this study, this interpretation is intended to characterize observed interaction patterns rather than to attribute causal effects to the use of conversational agents. This distinction is critical to avoid overinterpretation of descriptive engagement data.

B. Technical Argumentation and Competency-Based Performance

The results obtained from the RCEE-A rubric indicate that students reached performance levels ranging from "achieved" to "outstanding" across most evaluated dimensions of technical argumentation. Higher scores were consistently observed in dimensions related to conceptual clarity, system description, and explanation of scientific principles, suggesting that students were generally able to articulate how the electric Go-Kart functioned based on relevant physical concepts. These outcomes suggest successful alignment between the project tasks and the targeted explanatory components of the competency.

These findings are aligned with the objectives of competency-based engineering education, which emphasize not only conceptual understanding but also the ability to explain, justify, and communicate technical decisions. The observed performance patterns suggest that the project context provided students with an authentic framework for connecting theoretical physics content with a concrete engineering artifact. This authenticity appears to have supported students' capacity to translate abstract principles into structured technical explanations.

Dimensions associated with more advanced argumentative skills, such as counter-argumentation and global text organizations showed comparatively lower mean scores. This outcome is not unexpected in introductory courses, where students are still developing foundational disciplinary literacy and scientific writing skills. Argumentative sophistication, particularly the ability to anticipate and refute counterarguments using evidence, typically requires explicit instruction, modeling, and repeated practice over time. The observed pattern therefore reflects a developmental trajectory rather than a limitation of the instructional design.

Within the scope of this study, these patterns are interpreted as indicators of developmental progression in technical argumentation rather than as deficits in student performance. This interpretation is consistent with prior research on the gradual acquisition of scientific argumentation skills in early engineering education.

These results highlight the importance of integrating structured writing support into engineering projects, especially when technical argumentation is a targeted competency. The use of shared rubrics, annotated exemplars, and formative feedback cycles may help students progressively develop these higher-order communication skills in future implementations of the course. Such support may be particularly relevant for advancing students' abilities in evidence-based refutation and global discourse organization.

C. Pedagogical Implications

This experience underscores the pedagogical potential of designing authentic, multidisciplinary projects that integrate immersive technologies to support the development of technical argumentation and communication skills. By situating physics concepts within a meaningful engineering challenge, the project encouraged students to engage with scientific knowledge as a tool for explanation and justification rather than as isolated content. This approach aligns with contemporary views of engineering education that emphasize sense-making and reasoning over procedural task completion.

The integration of a conversational agent within a virtual reality environment represents a relevant contribution to current discussions on the role of emerging and AI-related technologies in engineering education. Rather than replacing instruction, the conversational agent functioned as a scaffold for reflection, practice, and feedback, supporting students' engagement with professional forms of technical discourse. This aligns with broader educational goals related to preparing future engineers to interact effectively with intelligent systems and digital tools. Importantly, the agent's role remained supportive and facilitative, preserving the central role of students' reasoning processes.

Additionally, the systematic use of validated assessment instruments allowed for a structured evaluation of both engagement and competency-based performance. This combination strengthens the educational design by aligning learning activities, assessment strategies, and targeted competencies a key principle in outcome-oriented engineering education. Such alignment enhances the interpretability and educational relevance of the reported results.

D. Limitations and Future Considerations

Despite the positive outcomes observed, several limitations must be acknowledged when interpreting the results of this study. First, the absence of a control or comparison group limits the ability to establish causal relationships between the use of immersive technologies and the observed levels of engagement or performance. Consequently, the findings should be interpreted as descriptive evidence of achieved outcomes within a specific instructional context. This limitation is inherent to the exploratory nature of study design.

Second, students' motivation and engagement may have been influenced by the novelty of the experience. The introduction of virtual reality, conversational agents, and a hands-on engineering project may have generated heightened enthusiasm that could diminish over time as such tools become more familiar. Future studies should therefore consider longitudinal designs to examine the sustainability of engagement and learning outcomes. Such designs would allow for the examination of persistence effects beyond initial exposure.

Another limitation relates to the role of the instructor as the primary facilitator of the experience. Variations in guidance, feedback, and interaction with student teams may have influenced the consistency of implementation. To enhance scalability and replicability, future iterations should include more detailed documentation of facilitation strategies and the development of standardized instructional protocols. This would support broader adoption across courses and institutional contexts.

Finally, while the project integrated concepts from physics, engineering design, and scientific communication, the degree of interdisciplinary cognitive integration was not directly measured. Future research could incorporate qualitative methods or specialized rubrics to examine how students transfer knowledge across domains, construct integrated explanations, and develop coherent interdisciplinary mental models. Such analyses would deepen understanding of learning processes beyond performance outcomes.

V. Conclusion

This study examined an educational experience implemented in an introductory physics course for engineering students, in which project-based learning (PBL) was combined with immersive technologies and competency-based assessment. Through the collaborative construction of an electric Go-Kart and the use of a conversational agent within a virtual reality environment, students were engaged in explaining and justifying the functioning of an engineering system based on principles of natural sciences. This instructional configuration positioned scientific explanation and argumentation as central learning outcomes rather than as ancillary skills.

The results presented in this work provide descriptive evidence of high levels of student engagement and solid performance in technical argumentation at the conclusion of the project. Data obtained from the adapted UWES-9 questionnaire indicate that students reported strong levels of vigor, dedication, and positive emotional involvement, while results from the RCEE-A rubric reflect generally high achievement across most dimensions of written technical explanation and argumentation. Together, these findings characterize how students experienced the learning environment and how they articulated scientific reasoning within an authentic engineering context. Importantly, these outcomes are interpreted as end-of-experience performance profiles consistent with the study's descriptive–exploratory design.

Rather than establishing causal claims, this study contributes to the understanding of how immersive technologies and active learning strategies can be coherently integrated within introductory engineering education. The combination of a tangible engineering challenge, immersive virtual environments, and structured opportunities for technical communication appears to offer a meaningful context in which students can practice explaining complex systems and engaging in evidence-based reasoning. This contribution lies primarily in documenting an integrated instructional approach and its associated learning outcomes.

From a broader perspective, this work contributes to ongoing discussions on the role of emerging and AI-related technologies in engineering education. The conversational agent integrated within the VirtualSpeech platform was not used as a content-delivery mechanism, but as an AI-supported scaffold to promote reflection, iterative practice, and feedback in professional engineering communication. This approach aligns with current educational priorities that emphasize preparing future engineers to interact effectively with intelligent systems while maintaining a strong grounding in disciplinary knowledge and reasoning. Within this framework, AI is positioned as support for human reasoning rather than as a substitute for instructional guidance.

Despite the promising outcomes observed, the findings must be interpreted in light of the study's limitations, including the absence of a control group, potential novelty effects, and variability in instructional facilitation. Therefore, while the proposed framework appears promising, its applicability to other institutional contexts, disciplines, or student populations requires further empirical exploration. These factors highlight the need for future research employing comparative, longitudinal, and mixed-methods designs to further examine the impact, sustainability, and transferability of the proposed instructional model. Such research would allow for stronger claims regarding effectiveness and generalizability.

In conclusion, this study presents a pedagogical framework that integrates project-based learning, immersive technologies, and competency-based assessment in a coherent manner within an introductory physics course. While further empirical validation is required, the experience demonstrates the potential of thoughtfully designed learning environments to support student engagement and the development of technical argumentation skills. As engineering education continues to evolve in response to technological advances, such approaches may play a valuable role in shaping learning experiences that are both academically rigorous and aligned with the demands of contemporary engineering practice. This work thus offers a foundation for future investigations seeking to bridge immersive technologies, competency development, and authentic engineering learning experiences.

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