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Research Article

Students' perceptions of the impact of interactive technology on engagement in STEM classes

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ABSTRACT

This study explores students' perceptions of their engagement with interactive technologies in STEM classes at an applied technology school in the United Arab Emirates (UAE). Specifically, the interactive technology (IT) involves artificial intelligence and virtual reality, along with collaborative digital platforms that incorporate AI elements such as Google Docs, Microsoft Teams, and Nearpod. The focus is on understanding how students perceive changes in cognitive, social, reflective, and goal-oriented engagement after using these technologies. Utilizing a mixed-methods approach, the study involved 126 male students from grades 9-12. The quantitative phase employed a pre-post survey with paired sample t-tests and repeated measures analysis of variance to assess changes in engagement. In contrast, the qualitative phase included focus group discussions to explore student perceptions. The results revealed that students perceived a significant improvement in various dimensions of engagement, including cognitive, social, reflective, and goal-oriented engagement, post-intervention following the use of IT. The findings suggest that interactive technologies can positively shape students' learning experiences, as these technologies cater to diverse student needs, improving academic outcomes and providing a more fulfilling educational experience. The results align with the UAE's educational goals of fostering a knowledge-based economy through innovative practices.

Keywords: interactive technology, student engagement, stem education, artificial intelligence, virtual reality

INTRODUCTION

The 21st century educational landscape is rapidly changing, driven by technological development that offers exceptional opportunities to reshape teaching and learning. Among these innovations, interactive technologies such as artificial intelligence (AI) and virtual reality (VR) hold great potential to enhance student engagement, a crucial factor in academic success. Interactive technology (IT) refers to digital tools and platforms that actively engage users in the learning process by enabling two-way communication, providing real-time feedback, and offering immersive experiences (Yang, 2021; Yang et al., 2023). This study presents a unique contribution of the United Arab Emirates (UAE) governmental schools. The applied technology schools in the UAE are gender-segregated, and this study focuses on a single-gender (male-only) group. This context remains underexplored in global research. The UAE's educational system is facing a rapid transformation in response to the national priorities. These priorities emphasize innovation, digital literacy, and alignment with the sustainable development goals (UAE National Committee, 2017). It is interesting to note that few empirical studies have explored how advanced technologies are perceived and experienced in actual classroom settings within the region (Jarrah et al., 2024; Khurma et al., 2023). Additionally, this study investigates the combined use of AI and VR in STEM education. These technologies have been studied in isolation (Chheang et al., 2024; Yang, 2021). However, there is a lack of research on the joint impact of these factors on student engagement, which is addressed in this study.

Student engagement refers to the degree to which students are invested in their learning and committed to their educational goals (Abbas et al., 2023; ElSayary, 2024a; Fulton et al., 2022). It includes various dimensions, such as cognitive, social, reflective, and goal-oriented engagement (Abbas et al., 2023; ElSayary, 2024a). *Cognitive engagement* refers to the mental effort that focuses students directly on understanding and mastering course content (Abbas et al., 2023). *Social engagement* involves the quality of interactions between students-students and students-instructors (ElSayary, 2024a). *Reflective engagement* refers to the extent to which students critically analyze their learning processes and make meaningful connections (Fulton et al., 2022). Finally, *goal-oriented engagement* concerns students' motivation, self-regulation, and persistence in pursuing their academic objectives (Fulton et al., 2022; Karimah & Hasegawa, 2022).

This study examines students' perceptions of how interactive technologies, specifically AI and VR, impact their engagement in STEM classes at applied technology schools in the UAE. Other AI-integrated collaborative applications, such as Google Docs, Microsoft Teams, and Nearpod, were included under the broader umbrella of IT (ElSayary et al., 2022). These tools were selected based on their capacity to support real-time feedback, immersive learning, and collaborative engagement, which are core elements of interactivity as defined in this study. This research aligns with the UAE's national agenda, which emphasizes the development of a knowledge-based economy and achieving the sustainable development goals, particularly SDG 4 (UAE National Committee, 2017). Applied technology schools in the UAE are uniquely positioned to utilize these technologies due to their focus on innovation and practical skills development. The principles of constructivism and experiential learning serve as the foundation of this study to understand how IT can create engaging learning environments that impact students' perceptions about their engagement, which leads them to actively construct knowledge, collaborate effectively, reflect on their learning, and pursue their academic goals with greater purpose. Recent studies have demonstrated the effectiveness of AI and VR in various educational settings. For example, a study by Brown et al. (2020) found that VR simulations in chemistry classes significantly improved students' understanding of molecular structures. Another study by Chheang et al. (2024) stated that generative AI-based virtual assistants enhanced students' learning in anatomy. Similarly, Yang et al. (2023) reported that AI-driven personalized learning platforms enhanced student performance in mathematics by providing tailored feedback and adaptive learning paths. Additionally, a study by Yang (2021) found that AI and VR enhanced students' engagement in learning, thereby transforming future education development. These findings highlight the potential of interactive technologies to cater to diverse learning needs and promote academic success. The rapid advancements in AI and VR offer a transformative potential to reshape the educational landscape. Educators' roles are important in designing learning experiences that foster student engagement, leading to improved academic outcomes, deeper understanding, and a more fulfilling educational journey (Bhat, 2023; Chengoden et al., 2023). As these technologies continue to develop, educational institutions need to integrate them to unlock the full potential of student engagement and learning (Bhat, 2023; Kearney & Maakrun, 2020). Accordingly, this study aims to investigate the impact of using interactive technologies on students' perceptions about their engagement in STEM classes in an applied technology school in the UAE. The following research question was developed to guide this study:

RQ1: How does the use of IT impact students' perceptions about their engagement in STEM classes?

RQ2: What are students' perceptions of using IT to enhance their engagement in STEM classes?

The following hypotheses were formulated:

H0: There is no significant difference in students' perceptions of their engagement before and after the use of IT.

H1: The use of IT positively enhances students' perceptions of their engagement.

FRAMEWORK OF THE STUDY

Constructivism and experiential learning provide a strong theoretical foundation for understanding how IT enhances student engagement (Bhat, 2023). Constructivism emphasizes the learner's active role in constructing knowledge through their experiences and interactions with the environment (Chan & Zhou, 2023). Similarly, experiential learning theory suggests that meaningful learning occurs when students engage in concrete experiences, reflect on those experiences, and then apply the acquired knowledge to new situations (Chan & Zhou, 2023; ElSayary et al., 2022). Integrating IT into education aligns well with these principles. It enables students to actively participate in their learning, manipulate virtual objects, explore simulated scenarios, and receive personalized feedback and guidance that shifts their perceptions toward increased engagement and motivation (Huang et al., 2010). Such interactive learning experiences can foster deeper cognitive engagement, encourage social collaboration, promote reflective thinking, and help students set and achieve their academic goals.

Moreover, the cognitive-affective-social-behavioral (CASB) model of student engagement posits that student engagement is a complex construct comprising four key dimensions: cognitive, affective, social, and behavioral engagement. This comprehensive framework provides a robust lens to examine the impact of interactive technologies on student engagement in STEM education (Henrie et al., 2015; Wang, 2019). The CASB model of student engagement provides another comprehensive theoretical framework for understanding the four types of engagement explored in this study. The cognitive dimension relates to the cognitive engagement discussed, including the mental effort, focus, and investment in learning tasks (Singh et al., 2022). The affective dimension aligns with the reflective engagement, involving students' emotional responses, attitudes, and metacognitive awareness (Burch et al., 2015; Muhammad et al., 2023). The social dimension is directly related to social engagement, highlighting the importance of interpersonal interactions and collaboration (Ben-Eliyahu et al., 2018; Veiga, 2016). Finally, the behavioral dimension connects to goal-oriented engagement, emphasizing observable actions, persistence, and pursuit of academic objectives (Ben-Eliyahu et al., 2018; Liang et al., 2023). By considering these well-established theories and engagement frameworks, the research can provide a robust, theoretically informed analysis of how integrating IT in STEM education can impact students' perceptions about their engagement across its multiple dimensions.

ENHANCING ENGAGEMENT THROUGH IT (AI AND VR)

Research has shown that integrating AI and VR technologies can positively impact student engagement across various dimensions.

Cognitive Engagement

Several studies have explored the potential of AI and VR to enhance students' cognitive engagement (Bhat, 2023). Intelligent tutoring systems powered by AI can provide adaptive, personalized content and feedback, enabling students to progress at their own pace and focus on areas that require reinforcement (Abbas et al., 2023). This adaptability helps maintain student interest and challenges them at appropriate levels, promoting a deeper understanding of course material. Furthermore, AI-driven automatic assessment tools can provide timely and detailed feedback, empowering students to reflect on their learning and make informed adjustments to improve performance (ElSayary, 2024a). VR environments can immerse students in interactive, experiential learning (Yang et al., 2023; Zhang et al., 2023). By simulating real-world scenarios or historical events, VR can help students visualize complex concepts, engage their senses, and make meaningful connections to the subject matter (ElSayary, 2024a; Salame & Makki, 2021). Cognitive engagement is further strengthened as students actively participate in these virtual environments, manipulating objects, testing hypotheses, and exploring solutions (Al-Gindy et al., 2020; Li et al., 2023). This leads to a shift in students' perceptions toward their learning and increases their motivation to actively engage in their lessons.

Social Engagement

Interactive technologies, such as VR, can foster social engagement by enabling students to collaborate, communicate, and explore course content (Kerimbayev et al., 2023). Virtual simulations and augmented reality applications can create shared, immersive learning experiences that promote student social interaction and teamwork (Al-Gindy et al., 2020; Kuhail et al., 2022). AI-powered group facilitation and virtual tutoring can support collaborative problem-solving, idea exchange, and the development of essential communication skills (Chengoden et al., 2023; Roschelle et al., 2020). AI agents can facilitate virtual group discussions, monitor participation, and provide real-time prompts to encourage equal contribution and productive dialogue (Dwivedi et al., 2023; Neji et al., 2023). Virtual tutoring powered by AI can also guide students through collaborative activities, offering suggestions, clarifying concepts, and providing feedback to enhance teamwork and communication skills (Li et al., 2023; Chiu et al., 2021). Students who utilize AI and engage in group-based learning are not only changing their perceptions about their engagement in learning but also developing critical 21st century skills necessary for success in their academic and professional pursuits (Kim et al., 2022), leading to high academic achievements (Falode et al., 2022).

Reflective Engagement

AI-driven learning analytics can also support reflective engagement by providing students with detailed insights into their own learning processes (Allagui, 2023; Chiu et al., 2021). Through data-driven feedback and personalized recommendations, students can be encouraged to think critically about their strengths, weaknesses, and areas for improvement (Ifenthaler & Yau, 2020). This promotes metacognitive awareness and fosters a growth mindset, empowering students to take ownership of their learning and make informed adjustments to their study strategies (Chen et al., 2020; Chowdhury, 2021). This plays a crucial role in shaping students' perception of being actively engaged in their learning. AI chatbots and virtual assistants can engage students in reflective dialogues, prompting them to explain their reasoning, articulate their thought processes, and consider alternative perspectives (Abdalla et al., 2025; Abrahams & Raimundo, 2025). These reflective engagements can impact students' perceptions about their learning and deepen their understanding, identify knowledge gaps, and develop critical thinking skills (Ginting & Linarsih, 2022; Toheri et al., 2020).

Goal-Oriented Engagement

Lastly, integrating AI and VR in education can enhance goal-oriented engagement by utilizing gamification features and personalized goal-setting (Alsubhi et al., 2021). Intelligent AI agents can provide real-time progress monitoring, motivation, and personalized goal-setting, helping students maintain focus, persistence, and a sense of agency in pursuing their academic objectives (Chengoden et al., 2023; ElSayary, 2024b; Neji et al., 2023). Virtual learning environments can also incorporate game-like elements, such as challenges, rewards, and leaderboards, to foster intrinsic motivation and a sense of accomplishment among students (Chiu et al., 2021; Lopez & Tadros, 2023). In examining the impact of technology on students' perceptions of their engagement, the literature highlights several drawbacks. Although technology enhances accessibility and provides innovative learning tools, its overuse can lead to a decline in critical thinking and interpersonal skills (Salas-Pilco et al., 2022), which can negatively impact students' perceptions and demotivate them in their learning. Research by Yousef et al. (2025) suggests that excessive screen time contributes to cognitive overload, reducing students' ability to retain and analyze information. Additionally, studies by Dontre (2020) argue that digital distractions, such as social media and gaming, undermine sustained focus and deep learning. In the UAE context, rapid technological adoption may raise gaps in engagement, with students potentially becoming passive recipients of content rather than active participants (Jarrah et al., 2024). Furthermore, the reliance on technology risks overshadowing traditional pedagogical methods that foster hands-on and collaborative problem-solving skills, which are vital in applied education settings (Khurma et al., 2023). This imbalance warrants a critical examination to optimize technology's role in enhancing, rather than hindering, student engagement.

METHODOLOGY

This research aimed to understand the effect of utilizing IT on influencing students' perceptions about their engagement in STEM education. An explanatory sequential mixed methods design was employed to comprehensively examine the research questions through both qualitative and quantitative approaches.

Table 1. The KMO values and Bartlett's test results

Engagement	KMO	Bartlett's test of sphericity		
		Approximate Chi-square	df	Significance
Cognitive engagement	.898	436.044	21	< .001
Social engagement	.838	375.835	15	< .001
Reflective engagement	.668	119.222	3	< .001
Goal clarity	.706	182.348	3	< .001

Participants

The study involved male students in grades 9-12 (n = 126) attending an applied technology school in the UAE that focuses on STEM education. The school offers specialized programs in areas like robotics, programming, and engineering, preparing students for technical careers or further studies, aligning with the UAE's vision for innovation and a knowledge-based economy. Initially, 136 students were purposefully selected from various school sections. Since the school does not have female students, only males were included. After applying inclusion and exclusion criteria, the final sample consisted of 126 students. The inclusion criteria were willingness to participate and the use of IT (AI and VR) in learning. The participants were distributed as follows: 21.43% (27 students) in grade 9, 30.95% (39 students) in grade 10, 22.22% (28 students) in grade 11, and 25.40% (32 students) in grade 12. Among them, 113 students (89.68%) reported having no disabilities, 6 students (4.76%) reported having disabilities, and 7 students (5.56%) preferred not to disclose their disability status. For the focus group discussion, 8 participants were purposefully selected: 3 from grade 9, 2 from grade 10, 1 from grade 11, and 2 from grade 12.

Instrumentation

Students' survey

The student survey was developed based on the study framework to gather data on the impact of IT on students' perceptions of their engagement. It consisted of two sections: demographic information (including grade level, disability status, and usage of IT) and students' engagement (see **Appendix A**). Adapted from Gebre et al. (2015), the survey included 19 items covering four types of engagements: cognitive engagement (7 items), social engagement (6 items), reflective engagement (3 items), and goal clarity (3 items). A five-point Likert scale was used, ranging from 1-strongly disagree to 5-strongly agree. Two educational experts reviewed the survey for content validity and provided feedback on its relevance, language accuracy, and length. Recommendations included rephrasing two items and translating the survey into the students' native language. Additionally, construct validity was assessed using exploratory factor analysis, as shown in **Table 1**. The KMO values and Bartlett's test results indicated a strong correlation pattern suitable for identifying distinct and reliable factors:

The survey's internal consistency, measured by Cronbach's alpha, was 0.985 overall, with the following values for each competency: cognitive engagement ($\alpha = 0.967$), social engagement ($\alpha = 0.959$), reflective engagement ($\alpha = 0.930$), and goal clarity ($\alpha = 0.934$). After confirming the survey's reliability, it was administered online to the students.

Focus group discussion

A focus group discussion involving a purposeful sample of eight selected participants (two in grade 12, one in grade 11, two in grade 10, and three in grade 9) was conducted to explore students' perceptions of how IT enhances their engagement. The sample was purposefully selected based on their high level of engagement with technology, as recommended by their teachers. This selection criterion ensured that the participants were familiar with and actively used interactive technologies, providing valuable insights for the study's focus on engagement. Adapted from Gebre et al. (2012, 2015), engagement themes included 16 open-ended reflective questions, with four reflective questions for each type of engagement. Conducted via Microsoft Teams, the session lasted 50 minutes. Two educational experts reviewed the questions to ensure face validity and clarity, leading to recommendations to reduce the number of repetitive questions. The questions were as follows:

Cognitive engagement:

1. Can you give examples of how you've used technology to understand concepts or compare ideas?
2. How do learning activities with technology help you solve problems or learn by doing?
3. Can you give an example of a creative solution or innovative idea you developed using IT in your coursework?
4. How has technology helped you think creatively or solve problems in new ways?

Social engagement:

5. How do you use technology to interact with your classmates?
6. Can you describe a situation where technology helped or made it harder to work with peers on an assignment?
7. How do you use different sources, including the internet, for your assignments?
8. What steps do you take to check if the information you find online is reliable?

Reflective engagement:

9. Can you share an example of how you express your ideas using IT in class?
10. How do you reflect on your learning experiences using technology?
11. How do you make sure you use technology ethically and responsibly?
12. What benefits and challenges do you find in using IT?

Goal clarity:

13. How do interactive technologies help you *understand* the learning goals for each session?
14. How does the use of technology in the classroom support your efforts to *achieve* the learning goals?
15. Can you explain how class materials presented through technology relate to what you need to learn?
16. How are you going to use IT in the future? What would you do differently?

Thematic analysis was employed to analyze the focus group data, systematically coding the transcripts to identify recurring themes and patterns. Two researchers independently coded the data to ensure reliability. Any discrepancies were resolved through discussion or consultation with a third researcher. This process ensured that the analysis was thorough and unbiased (Braun & Clarke, 2006). Additionally, we calculated inter-rater reliability using Cohen's (1960) kappa, which yielded a value of 0.85, indicating strong agreement between the coders.

Procedure

Before the study commenced, the research objectives and procedures were thoroughly explained to all participants. Students were informed that their participation was entirely voluntary and that they could withdraw from the study without any consequences. Ethical approval was obtained from the institution where the researcher worked, and parents were informed about the study through detailed information sheets. Written consent was obtained from both students and their parents, ensuring ethical compliance and respect for participants' autonomy. The study was conducted over two semesters, following a structured process designed to measure and analyze the impact of interactive technologies on students' perceptions of their engagement in STEM classes. At the beginning of the study, students completed a survey designed to measure their initial levels of cognitive, social, reflective, and goal-oriented engagement. This survey served as the pre-intervention data collection point. At the beginning of the year, teachers attended a three-week face-to-face training session on integrating IT into their lessons. The training covered a wide range of topics to prepare teachers for the effective integration of AI and VR tools in the classroom, as well as AI-integrated collaborative applications, such as Google Docs, Microsoft Teams, and Nearpod. In week 1, the training included practical sessions on the foundations and introduction of AI and VR in education. Specifically, it focused on understanding AI and exploring VR, integrating iPads into classrooms, conducting hands-on activities, and utilizing VR applications and experiences. In week 2, the focus was on integrating IT into lesson planning and teaching strategies. It also focused on differentiation strategies, inquiry-based learning, Apple applications that support VR and AI, VR simulations, Apple roadshow, best practices utilizing AI chatbots such as ChatGPT,

Table 2. Descriptive statistics of mean and standard deviation for the engagements

	Pre		Post	
	Mean	Standard deviation	Mean	Standard deviation
Cognitive engagement	3.65	1.06	4.00	.801
Social engagement	3.75	1.01	4.12	.705
Reflective engagement	3.55	1.08	3.93	.848
Goal clarity	3.64	1.08	3.97	.899
Overall engagement	3.66	.994	4.03	.724

Table 3. The paired sample t-test of the competencies

	Paired differences					t	df	Significance	
	Mean	SD	SE	95% CI of the difference				One-sided p	Two-sided p
				Lower	Upper				
PRE_CE/POST_CE	-0.351	1.379	0.123	-0.594	-0.107	-2.853	125	0.003	0.005
PRE_SE/POST_SE	-0.372	1.292	0.115	-0.600	-0.144	-3.233	125	< .001	0.002
PRE_RE/POST_RE	-0.376	1.410	0.126	-0.624	-0.127	-2.991	125	0.002	0.003
PRE_GC/POST_GC	-0.331	1.403	0.125	-0.578	-0.083	-2.647	125	0.005	0.009
PRE_Eng/POST_Eng	-0.369	1.271	0.113	-0.593	-0.145	-3.26	125	< .001	0.001

Notes. SD: Standard deviation; SE: Standard error; CI: confidence interval.

AI-integrated collaborative tools such as Google Docs, Microsoft Teams, and Nearpod, and elements of learning. In week 3, the training focused on advanced applications of AI and VR. The sessions this week focused on subject-specific contexts, in addition to addressing ethical considerations, classroom management strategies for using devices like iPads and VR headsets, and techniques for assessing student engagement using digital tools. This training equipped teachers with both technical skills and instructional strategies to implement the technologies over the two-semester intervention period. Over two semesters, interactive technologies, specifically AI and VR, were integrated into the students' STEM classes. After two semesters of using interactive technologies, the same survey was administered to the students again at the end of the study. This post-intervention survey aimed to capture any changes in engagement levels resulting from the use of interactive technologies.

The paired sample t-test was utilized to compare students' perceptions of their engagement levels before and after the intervention. This statistical test helps determine whether there is a statistically significant difference in the means of two related groups. For this study, the pre-and post-intervention engagement scores across cognitive, social, reflective, and goal-oriented dimensions were analyzed. A p-value of less than 0.05 indicated a statistically significant difference. To further evaluate the effect of time (pre- vs. post-test) on students' engagement scores and to determine if this effect varied by grade level, a repeated measures analysis of variance (ANOVA) was conducted. This analysis tests whether there are statistically significant differences in the means across multiple time points and whether these differences interact with other variables, such as grade level. Following the survey, focus group discussions were conducted to refine the lens and gain a deeper understanding of students' perceptions. Eight participants were purposefully selected for these discussions, which provided qualitative insights into how interactive technologies influenced their engagement. The discussions explored the students' experiences and perceptions, allowing for a more nuanced understanding of the quantitative results.

RESULTS

Paired Sample t-Test

The paired sample t-tests reveal statistically significant improvements across all dimensions of engagement, cognitive, social, reflective, goal clarity, and overall engagement, after the intervention. The observed p-values ($p < 0.05$) indicate that the differences in mean scores before and after the treatment are unlikely to have occurred by chance. Furthermore, the confidence intervals for all comparisons excluded zero, highlighting the reliability of the observed effects. The t-values further corroborate the significance of these findings, reflecting meaningful changes in engagement levels. The results, detailed in **Table 2** and **Table 3**, highlight meaningful increases in engagement scores post-treatment, confirming the intervention's positive

Table 4. Descriptive statistics of pre- and post-engagement scores by grade level

Grade level	N	Pre (mean ± standard deviation)	Post (mean ± standard deviation)
Grade 9	27	3.663 ± 1.015	3.758 ± 0.717
Grade 10	39	4.027 ± 0.711	4.270 ± 0.499
Grade 11	28	3.703 ± 0.865	3.853 ± 0.790
Grade 12	32	3.765 ± 1.089	4.074 ± 0.726
Total	126	3.660 ± 0.994	4.030 ± 0.724

Table 5. Multivariate tests for engagement scores

Effect	Value	F	Hypothesis df	Error df	Significance	Partial eta squared	Effect
Eng	.030	3.763	1.000	122.000	.055	.030	Eng
Eng * POST_Grade	.005	0.207	3.000	122.000	.892	.005	Eng * POST1_Grade

Table 6. Tests of within-subjects effects

Source	Type III sum of squares	df	Mean square	F	Significance	Partial eta squared
Eng	2.456	1	2.456	3.763	.055	.030
Eng * POST1_Grade	0.405	3	0.135	0.207	.892	.005
Error (Eng)	79.637	122	0.653			

impact. The overall engagement construct, though not explicitly included in the rubric, was calculated in SPSS as the average of all four engagement constructs. This was done to provide a comprehensive measure of engagement and validate the individual results.

ANOVA

An ANOVA was conducted to evaluate the effect of time (pre- vs. post-test) on students' perceptions of their engagement scores and to determine if this effect varied by grade level. **Table 4** presents the descriptive statistics for pre- and post-engagement scores across grade levels (9, 10, 11, and 12).

Several assumptions were tested to ensure the validity of the repeated measures ANOVA. First, Box's test of equality of covariance matrices is used to assess whether the covariance matrices of the dependent variables are equal across the groups being compared. In this analysis, Box's M = 18.791, $F(9, 128{,}700.456) = 2.024$, $p = .033$. The significant p-value indicates that the assumption of equality of covariance matrices was not met, suggesting some caution in interpreting the results.

Next, Mauchly's test of sphericity tests the assumption of sphericity, which is necessary for the validity of repeated measures ANOVA. For this analysis, Mauchly's W = 1.000, indicating that the sphericity assumption is perfectly met. With these assumptions satisfied, the multivariate tests were interpreted, as shown in **Table 5**. The main effect of time (Eng) was marginally significant, $F(1, 122) = 3.763$, $p = .055$, $\eta^2 = .030$. Although the p-value did not meet the conventional threshold ($p < .05$), the results indicate a trend toward an increase in engagement scores from pre- to post-test. This marginal result, alongside the moderate effect size ($\eta^2 = .030$), indicates potential practical significance, warranting further investigation with larger or more diverse samples. The interaction effect between time and grade level (Eng * POST_Grade) was not significant, $F(3, 122) = 0.207$, $p = .892$, $\eta^2 = .005$, suggesting that the change in engagement scores did not differ significantly across grade levels.

Table 6 presents the *tests of within-subjects effects*. The within-subjects effect of time on engagement scores approached significance, $F(1, 122) = 3.763$, $p = .055$, $\eta^2 = .030$. However, the interaction effect of time and grade level was not significant, $F(3, 122) = 0.207$, $p = .892$, $\eta^2 = .005$.

The repeated measures ANOVA results indicate a trend towards a significant increase in engagement scores from pre- to post-test, though the result reaches marginal levels of significance ($p = .055$). Additionally, there were significant differences in engagement scores across grade levels, with higher grade levels tending to have higher perceptions of engagement scores. However, the interaction between time and grade level was not significant, suggesting that the change in engagement scores was consistent across different grades. These findings highlight the importance of considering grade level in interventions aimed at enhancing students' perceptions of their engagement.

Focus Group Discussion

The focus group discussion with students from grade 9 to grade 12 highlighted the significant role of IT in enhancing cognitive, social, and reflective engagement, as well as goal clarity in their learning experiences. This section analyzes the insights gathered from the students' responses.

Cognitive Engagement

Q1. Can you give examples of how you've used technology to understand concepts or compare ideas?

Students highlighted how interactive technologies enabled them to process complex ideas at their own pace and enhance their understanding. A grade 10 student stated,

> "I used ChatGPT to compare active and passive cells in biology, which helped me understand the differences better."

Another student in grade 11 shared,

> "For end-of-term exams, I used ChatGPT to understand and simplify the key performance indicators in detail, something that was only briefly mentioned in our lessons."

However, one student mentioned a challenge in using these tools. A grade 9 student noted,

> "Sometimes the explanations on these tools are too advanced, and I need extra help from teachers to clarify."

Q2. How do learning activities with technology help you solve problems or learn by doing?

Interactive platforms like Nearpod were noted for fostering problem-solving and experiential learning. A grade 12 student remarked,

> "Nearpod quizzes and exercises helped me retain key biology concepts by testing me right after the lessons."

Students praised the immediate feedback in project design and computer science, which encouraged active learning. A grade 10 student appreciated this feature, saying,

> "The instant feedback helped me understand where I went wrong right away, so I could fix my mistakes before moving on."

However, limited classroom time to fully explore these technologies was a common concern, and they sometimes couldn't revisit the explanations in depth. A grade 11 student noted,

> "It would have been great if we had more time to go over the feedback and ask follow-up questions in class."

Q3. Can you give an example of a creative solution or innovative idea you developed using IT in your coursework?

Students used ChatGPT to brainstorm ideas, generating suggestions such as integrating solar panels on rooftops, implementing wind turbines in coastal areas, and using energy storage systems like advanced batteries.

One grade 10 student praised the tool, saying,

> "ChatGPT provided us with a range of creative ideas we hadn't thought of, like combining solar power with vertical gardening to maximize space in urban areas. It really sparked innovative discussions within our group."

The interactive tool helped students think outside the box and fostered collaboration as students built upon AI-generated ideas. One grade 12 student highlighted this, noting,

> "It was exciting to have a starting point that we could adapt and improve together as a group."

While ChatGPT provided creative suggestions, the group struggled to validate the technical feasibility of some ideas. For example, one suggestion involved installing wind turbines on skyscrapers, which sounded innovative but raised practical concerns. A grade 12 student noted,

> "We weren't sure if the AI's suggestions were realistic, so we had to spend extra time researching whether they could actually work."

Q4. How has technology helped you think creatively or solve problems in new ways?

The immersive nature of VR provided students with a hands-on, visual learning experience that made abstract concepts tangible, which helped them develop a deeper understanding. A grade 11 student shared,

> "Using VR simulations, I could visualize chemical reactions and see how molecules interact in 3D. For example, I finally understood how hydrogen bonds form in water molecules because I could manipulate the molecules and watch the process unfold. It was much easier to grasp than just looking at diagrams in the textbook."

A grade 10 student also commented,

> "It's like being inside the experiment instead of just reading about it."

Despite the benefits, not all students had equal access to VR equipment due to limited resources. A grade 9 student remarked,

> "The VR headset had to be shared among the whole class, so I only had a few minutes to try it out. I wish we had more time or more devices to use."

Social Engagement

Q1. How do you use technology to interact with your classmates?

Students highlighted using collaborative platforms like Microsoft Teams to connect and work together. A grade 12 student explained,

> "We use Teams to discuss assignments, share resources, and divide tasks, which makes group work much more efficient. For example, during a physics project, we created a shared workspace to upload our calculations and presentations, so everyone was always on the same page."

Seamless communication fostered teamwork, allowing students to collaborate in real-time, even outside school hours. A grade 10 student commented,

> "Having a central platform meant we could work on the project anytime without needing to meet in person, which saved a lot of time."

Q2. Can you describe a situation where technology helped or made it harder to work with peers on an assignment?

Collaborative tools streamlined group efforts by enabling real-time editing and organization. A grade 10 student remarked,

> "Using Google Docs, supported by AI feature, for a group report made editing super easy because we could all work on the document simultaneously. But there was one time when someone accidentally deleted a paragraph I wrote, and we couldn't remember what was there, which caused a bit of conflict."

A grade 11 student also noted,

> "With tools like Google Docs, we didn't have to worry about combining separate files, it saved so much time and reduced errors."

Miscommunication and accidental changes led to occasional frustrations. A grade 12 student reflected,

> "We had to establish rules for editing the shared document to avoid confusion, like discussing changes before making them."

Q3. How do you use different sources, including the internet, for your assignments?

Students discussed using AI-powered search tools and augmented reality (AR) applications to gather and validate information. A grade 9 student explained,

> "I used an AI search engine to find recent research papers on renewable energy and cross-checked the findings using AR apps that showed interactive 3D models of solar panels and wind turbines."

The combination of AI and AR provided deeper insights into complex topics. A grade 9 student shared,

> "The AR app helped me understand how wind turbines convert wind into electricity by showing me the internal mechanics in real-time."

Verifying the credibility of AI-suggested resources was a common concern. A grade 12 student remarked,

> "Some articles suggested by the AI seemed too good to be true, and it took a lot of effort to confirm their accuracy."

Q4. What steps do you take to check if the information you find online is reliable?

To ensure accuracy, students employed multiple strategies. For instance, a grade 12 student explained,

> "I use an AI fact-checking tool to validate the articles I find online. For instance, when researching renewable energy, the tool flagged an article as outdated, and it suggested more recent studies published in scientific journals."

A grade 10 student also shared,

> "I often run the same query across two or three AI platforms, like ChatGPT and another research-specific AI tool, to see if their suggestions align. If there are inconsistencies, I dig deeper to understand why."

A grade 12 student added,

> "If the AI output seems questionable, I double-check with my teacher or refer to trusted academic journals to verify the accuracy of the information."

These processes could be time-intensive, as a grade 11 student remarked,

> "Sometimes, validating the AI's outputs takes longer than finding the information, especially when I need to cross-reference multiple sources."

Reflective Engagement

Q1. Can you share an example of how you express your ideas using IT in class?

Students found interactive tools like Nearpod and AR applications helpful for expressing their ideas creatively. A grade 10 student shared,

> "For my computer science project, I used Nearpod to create an interactive presentation with live polls and quizzes for my classmates, which made it more engaging and helped me organize my ideas visually."

Interactive tools encouraged clarity and creativity in presenting ideas, making learning dynamic and engaging. A grade 9 student noted,

> "I used an AR app to build a 3D model for my project. It allowed me to showcase my understanding in a way that was easier to explain than a traditional chart."

Q2. How do you reflect on your learning experiences using technology?

Personalized feedback from AI and interactive tools fostered self-improvement by helping students identify weaknesses and refine their approach. A grade 11 student explained,

> "Nearpod quizzes with instant analytics showed me which topics I struggled with, like coding loops in computer science. Seeing those patterns helped me focus on improving specific areas."

Another grade 12 student added,

> "AI-powered learning platforms give me detailed feedback on my math assignments. For instance, it explained why my calculations were wrong and suggested alternative methods, which helped me learn better."

Q3. How do you make sure you use technology ethically and responsibly?

Students emphasized the importance of maintaining academic integrity while utilizing AI tools. A grade 12 student remarked,

> "I use ChatGPT to refine my assignments and improve my grammar, but I always rewrite the content in my own words to avoid plagiarism."

Another grade 11 student shared

> "When working on a research project, I make sure to cite AI-generated suggestions and cross-check their accuracy to ensure my work is honest and credible."

Some admitted struggling with time pressures. A grade 10 student confessed,

> "When I'm running out of time, it's tempting to copy AI-generated content, but I know it's not right."

Q4. What benefits and challenges do you find in using IT?

Interactive technologies made learning engaging and accessible, enhancing students' understanding of complex topics. A grade 10 student reflected,

> "The tools make learning fun and engaging, like using VR to explore concepts in a real-life models."

However, a grade 12 student highlighted connectivity issues, saying,

> "At home, the internet can be slow, which makes it hard to access these technologies when I need them most."

Goal Clarity

Q1. How do interactive technologies help you understand the learning goals for each session?

Interactive technologies simplify complex learning goals, promoting better focus and understanding. A grade 12 student shared,

> "When studying ecosystems, we first focused on energy transfer before moving to food webs, which made the topic easier to grasp."

Some students noted that not all teachers fully utilized these tools. A grade 11 student remarked,

> "When the technology isn't integrated properly, it feels like an extra step rather than a helpful tool."

Q2. How does the use of technology in the classroom support your efforts to achieve the learning goals?

Visual aids and simulations provided clarity and enhanced engagement, helping students focus on their objectives. A grade 9 student explained,

> "VR sessions in biology helped me visualize the human circulatory system, showing how blood flows through veins and arteries. This made the textbook diagrams much easier to understand."

However, access to equipment was sometimes limited. A grade 10 student noted,

> "We had to take turns using the VR headset, which meant not everyone had enough time to fully explore the session."

Q3. Can you explain how class materials presented through technology relate to what you need to learn?

Interactive tools helped students see the relevance of their studies to real-life scenarios, deepening their understanding. A grade 11 student stated,

> "Our teacher uses interactive slides with embedded videos and quizzes, which show real-world applications of the concepts we learn in physics, like using formulas to design bridges."

However, over-reliance on technology sometimes makes traditional methods seem less engaging. A grade 12 student commented,

> "When we switch back to textbooks, it feels harder to stay interested because they lack the interactivity we're used to."

Q4. How are you going to use IT in the future? What would you do differently?

Students recognized the long-term potential of AI and VR for continuous learning and professional development. A grade 10 student envisioned,

> "I see AI becoming my personal tutor, helping me review lessons and prepare for exams even after class. It's like having a teacher available 24/7."

Some are worried about over-dependence on technology. A grade 12 student added a note of caution,

> "While AI can be helpful, I think we need to use it as a tool rather than depend on it completely."

A grade 9 student noted,

> "If we rely too much on AI, we might forget how to solve problems on our own."

DISCUSSION

RQ1. How Does the Use of IT Enhance Students' Engagement in STEM Classes?

The results of this study generally support **H1**, indicating that the use of interactive technologies such as AI and VR may enhance students' perceptions of engagement. Although paired sample t-tests revealed statistically significant improvements across all dimensions, the repeated measures ANOVA showed a marginal effect when examining engagement over time across grade levels. This borderline result suggests a possible positive trend that may not have reached significance due to sample size limitations or variability between grades. On the other hand, the moderate effect size and consistent findings across multiple measures (both quantitative and qualitative) suggest practical significance, particularly in real-world classroom contexts where small gains in engagement can be meaningful.

Students' perceptions of *cognitive engagement* were most notably improved due to the personalized and immersive nature of AI and VR. AI tools, such as intelligent tutoring systems and adaptive feedback platforms, enable students to engage with content at a tailored pace and complexity. This differentiation helps students remain within their zone of proximal development, thereby maximizing learning potential (Abbas et al., 2023; Chengoden et al., 2023). At the same time, VR environments offer highly contextualized, experiential learning experiences. For instance, manipulating 3D models of molecules in chemistry allows students to move beyond abstract textbook diagrams to an interactive, hands-on understanding, which supports constructivist learning principles (ElSayary, 2024a; Yang, 2021). These technologies engage multiple sensory modalities, enhancing mental effort, deepening comprehension, and fostering memory retention.

The observed increase in students' perceptions of *social engagement* is best understood through the collaborative affordances of technology. Platforms like Microsoft Teams and Google Docs create asynchronous and synchronous opportunities for collaboration. VR and AI-supported environments provide shared virtual spaces where students interact not only with content but also with one another, promoting peer learning and dialogue (Dwivedi et al., 2023; Kuhail et al., 2022). The technology mediates participation by reducing barriers such as language proficiency, anxiety, or scheduling, thus encouraging equitable participation. This aligns with Vygotsky's sociocultural theory, which emphasizes the importance of social interaction in cognitive development. Moreover, the CASB model suggests that social dimensions of engagement are activated when students collaborate towards a common academic goal (Henrie et al., 2015). IT fosters these conditions by enabling persistent, structured, and engaging group interaction (Salame & Makki, 2021).

Students' perceptions of *reflective engagement* were also significantly enhanced through the use of IT, and this can be explained by the way AI-driven feedback mechanisms promote metacognitive thinking. Tools such as Nearpod and AI-powered analytics platforms provide students with immediate, personalized feedback on their performance, prompting them to reflect not only on what they got wrong but also why they made the mistake (Allagui, 2023; Chiu et al., 2021). This encourages students to take ownership of their learning and adjust their strategies based on performance insights, which is a key component of metacognition. Moreover, AI tools like chatbots enable reflective dialogue, asking students to explain their reasoning, which supports the development of higher-order thinking skills (Abdalla et al., 2025; Abrahams & Raimundo, 2025). These mechanisms reflect experiential learning theory, which emphasizes the cycle of experiencing, reflecting, thinking, and acting. Through structured AI feedback and immersive technology, students move beyond surface learning and become more aware of their cognitive processes.

The improvement in students' perceptions of *goal-oriented engagement* is primarily attributed to how AI and VR scaffold students' understanding of learning objectives and help them visualize progress toward those goals. AI platforms often incorporate gamification, such as progress bars, badges, and customized reminders, that sustain student motivation and reinforce self-regulation (Alsubhi et al., 2021; ElSayary, 2024b). Students reported that these features gave them a clearer sense of direction, enabling them to set, monitor, and adjust academic goals more effectively. VR tools also helped clarify instructional goals by visually connecting learning objectives with real-world scenarios, making goals not just understandable but meaningful. These findings align with motivational theory, particularly goal-setting theory, which holds that clear, specific, and challenging goals, when paired with feedback, lead to higher performance. By converting abstract objectives into concrete and personalized milestones, IT increases persistence and academic agency (Chiu et al., 2021).

The results of students' perceptions across all four dimensions of engagement confirm that interactive technologies do not merely supplement traditional instruction; they positively reshape the learning environment in ways that activate deeper learning and motivation among students. This transformation occurs because these technologies align strongly with established learning theories such as constructivism and experiential learning. For instance, by immersing students in meaningful tasks that allow them to manipulate content, receive feedback, collaborate, and reflect, AI and VR facilitate the active construction of knowledge, as described by Piaget and Kolb (Chan & Zhou, 2023). These results are further validated by the CASB model, which recognizes the cognitive, affective, social, and behavioral dimensions of engagement as interdependent, and all were positively impacted by the intervention (Henrie et al., 2015). Although the findings support the benefits of AI and VR in enhancing engagement, students also mentioned notable challenges that must be addressed for effective implementation. These included unequal access to VR equipment, insufficient classroom time to explore tools in depth, and technical issues such as slow connectivity at home (Jarrah et al., 2024; Khurma et al., 2023). Some students reported difficulty understanding overly advanced AI-generated explanations and challenges in validating AI-generated information, aligning with concerns raised by Yousef et al. (2025) and Dontre (2020) about cognitive overload and digital distractions. Others mentioned the risk of over-reliance on AI, which may discourage independent thinking and reduce engagement with non-digital content (Salas-Pilco et al., 2022). These concerns highlight the importance of teacher guidance, digital literacy development, and balanced instructional design that blends technology with critical thinking and reflection, as highlighted by ElSayary et al. (2022). To ensure that AI and VR support, rather than replace learning, educators must scaffold usage with clear goals, promote ethical application, and provide opportunities for student voice and validation.

The consistency between students' perceptions of self-reported engagement (via surveys) and their qualitative reflections (from focus groups) strengthens the credibility of the findings. For example, the significant quantitative increase in students' perceptions of cognitive engagement is reflected in their quotes, which describe how AI tools helped them explore ideas more deeply and VR simulations brought abstract concepts to life. Similarly, improvements in their perceptions of social and goal-oriented engagement were reinforced by their accounts of collaboration on shared platforms and the motivational pull of gamified learning features. This triangulation suggests that this mechanism is not only effective but also perceptible and meaningful to learners themselves.

RQ2. What are Students' Perceptions of Using IT to Enhance Their Engagement in STEM Classes?

The focus group discussions provided detailed insights into how students perceive enhancing their engagement through IT in STEM classes. These insights reinforce the quantitative findings and align with the existing body of literature, highlighting the multifaceted benefits of integrating AI and VR in educational settings.

Cognitive engagement

Students believed that their cognitive engagement was enhanced primarily because interactive technologies offered *agency*, *clarity*, and *depth*, three interrelated cognitive affordances that traditional methods often lack. AI tools such as ChatGPT gave students the autonomy to explore topics independently, allowing them to pace their learning and revisit content as needed. This self-regulation fostered deeper processing of material. For instance, a grade 11 student shared:

> "I used ChatGPT to simplify the key performance indicators for our business unit, something we barely covered in class. It helped me grasp what really mattered in the exam."

This process reflects *cognitive scaffolding*, where AI serves as an intelligent partner, enabling students to build upon what they know and identify conceptual gaps without waiting for teacher input. According to constructivist theory, such learner-driven exploration activates higher-order thinking and leads to more meaningful learning (Yang, 2021). Moreover, VR enhanced students' cognitive engagement by *making abstract concepts concrete*. Students described VR as a "shortcut to understanding," particularly in STEM subjects. A grade 11 student noted,

> "Using VR simulations, I could visualize chemical reactions and actually move the molecules. I finally understood hydrogen bonds in a way I never could from a diagram."

This aligns with experiential learning theory, where active manipulation and sensory engagement foster cognitive immersion and long-term retention (ElSayary, 2024a). In essence, cognitive engagement deepened because students were not merely consumers of information, they were problem solvers, analysts, and explorers within digital learning environments.

Social engagement

Social engagement, likewise, was enhanced, as per their beliefs, not just because technology enabled communication, but because it *restructured how collaboration happened,* making it more inclusive, efficient, and real-time. Technologies such as Microsoft Teams and Google Docs allowed students to break free from the constraints of time and space, supporting what can be termed *distributed collaboration*. For example, a grade 10 student shared:

> "We used a shared Google Doc with AI support to write our physics report. We could all edit at the same time, even from home, and it tracked who did what."

This transparency encouraged responsibility and reduced the interpersonal friction often seen in group work. Collaborative learning theory emphasizes that *structure and interdependence* are key to effective group work, features that were organically embedded in these platforms (Kerimbayev et al., 2023). Furthermore, students reported that AI agents and chatbots in group settings served as *mediators,* prompting quieter members to participate and offering real-time clarifications. A grade 12 student noted:

> "Our AI tutor helped balance group discussions by giving prompts when no one responded or someone dominated the conversation."

This reflects the social presence theory, where the perception of being seen and heard is crucial for engagement. The CASB model's social dimension is fulfilled here not just by interaction, but by *equitable, emotionally safe interaction* (Henrie et al., 2015).

Reflective engagement

Students also believed that reflective engagement was enhanced because interactive technologies functioned not only as content delivery tools but as *mirrors* that enabled students to monitor, question, and refine their learning processes. Students repeatedly mentioned how AI-based tools like ChatGPT and learning platforms with built-in analytics offered them the opportunity to pause, assess, and revise. A grade 11 student explained:

> "Nearpod quizzes with instant analytics showed me which topics I struggled with, like coding loops. Seeing that data helped me know exactly what to revise."

This supports the role of learning analytics in developing *metacognitive awareness*, which is critical for reflective engagement (Allagui, 2023). When students understand *how* they learn and what their weaknesses are, they become active agents in their academic improvement, rather than passive recipients of instruction. AI chatbots also facilitated reflection by encouraging students to verbalize and justify their reasoning. For example, a student in grade 12 said,

> "ChatGPT asked me why I chose a certain solution in math, and when I had to explain it, I realized I didn't fully understand it myself."

This process of articulating thought, what Dewey termed reflective thought, forces learners to move from intuition to analysis, deepening their conceptual understanding (Abdalla et al., 2025). These AI-facilitated dialogues support Kolb's experiential learning theory, which highlights the importance of reflection following experience as a critical step in learning.

Goal clarity

Interactive technologies also helped students believe that they achieve greater clarity in their learning goals. Visual Goal clarity, the final dimension, was reinforced through technology's ability to make learning objectives *explicit, personalized, and motivational*. Students repeatedly emphasized how AI platforms provided them with progress updates, suggested goals, and aligned learning activities with clear outcomes. A grade 12 student stated,

> "We always knew what the learning goals were because the platform showed us exactly what we needed to achieve and tracked how far along we were."

This transparency transformed vague academic expectations into manageable targets, enhancing *self-regulated learning*. Moreover, VR and simulation tools made abstract goals *visible* and *contextualized*. Instead of being told to "understand energy transfer," students were virtually guided through a food web simulation, where their goal was not only clear but also compelling. A grade 9 student described this by saying,

> "It wasn't just a lesson anymore–it felt like a mission I had to complete, and that made me want to finish it well."

These features support goal-setting theory, which asserts that learners are more engaged when they are given specific, achievable goals paired with feedback (Alsubhi et al., 2021; ElSayary, 2024b). The technology didn't just clarify the "what" of learning, it motivated the "why."

Overall, the focus group discussions highlighted a positive reception towards integrating IT in education. Students perceived these technologies as tools that aid cognitive and social engagement, support reflective practices, and clarify learning goals. These findings align with the broader literature, as seen in the review by Bhat (2023), which emphasizes the transformative potential of AI and VR in enhancing student engagement across multiple dimensions, which can have a positive impact on their perceptions of their engagement.

Implications

The study's results align with the UAE's educational goals, which emphasize the development of a knowledge-based economy through innovative educational practices. Educators can create more engaging and effective learning environments that cater to diverse students' needs by integrating interactive technologies. This approach enhances academic outcomes and prepares students for future challenges by equipping them with critical 21st century skills. Applied technology schools are ideal for this innovation, and this study demonstrates that even in a single-gender, resource-specific setting, significant gains in engagement can be achieved. However, it is essential to acknowledge that the study was conducted in a single-gender (male-only) applied technology school in the UAE, which may limit the broad applicability of the findings. Educational environments vary widely in terms of student demographics, resources, and institutional goals. For example, co-educational settings, private schools, or schools with less access to IT may experience different outcomes. Future research should examine how interactive technologies impact engagement in more diverse contexts, including schools serving female students, mixed-gender populations, or those in under-resourced areas. This would help determine whether the positive trends observed in this study are generalizable or context-dependent. Importantly, these results imply that when well-supported, interactive technologies can help close gaps in student motivation, participation, and performance, which are critical factors for preparing a future-ready workforce.

The quantitative findings revealed a significant increase in students' perceptions of their cognitive engagement, which was supported by students' reflections during the focus groups. They frequently mentioned how AI tools like ChatGPT and VR simulations helped them understand complex concepts better. This aligns with constructivist theory, which posits that learners construct knowledge more effectively through active engagement and interaction with their environment (Chan & Zhou, 2023; Falode et al., 2022). Similarly, the improvements in their perceptions of social engagement observed in the quantitative data were echoed in students' descriptions of enhanced collaboration through platforms like Microsoft Teams. This supports the CASB model's emphasis on the importance of social interaction in learning (Henrie et al., 2015). Reflective engagement demonstrated a significant shift in their perceptions, as enhanced by both quantitative data and students' reports of utilizing tools like Nearpod for immediate feedback and reflection. This is in line with Abdalla et al.'s (2025) findings on the role of AI in promoting metacognitive awareness and a growth mindset. Lastly, goal-oriented engagement improved, with students appreciating the clarity and direction provided by interactive technologies, supporting the findings of ElSayary (2024b) regarding AI's impact on motivation and persistence.

Recommendations

Based on the study's results, it is important to enhance student engagement in STEM education; integrating AI and VR technologies across the curriculum is essential. These tools create immersive, interactive experiences that facilitate a deeper understanding of complex concepts. Accordingly, teachers should receive adequate training to utilize these technologies effectively, enabling them to design lessons that captivate and engage students.

Collaboration through several communication platforms can enhance social engagement by encouraging teamwork and communication. Additionally, utilizing AI for personalized learning ensures that diverse student needs are met, tailoring instruction to individual learning styles and paces. AI-powered real-time feedback systems can also help students reflect on their learning and foster a growth mindset.

Lastly, ensuring equitable access to technology and robust infrastructure is imperative for maximizing the benefits of these tools. Continuous evaluation of the long-term impact of such technologies can provide valuable insights to refine and optimize their use in education. By adopting these strategies, educators can create engaging and effective learning environments that align with the evolving needs of students.

Limitations

While the study provides valuable insights into the impact of students' perceptions about their engagement after using interactive technologies on student engagement, several limitations must be acknowledged. Firstly, the study was conducted with a sample of 126 male students from a single applied technology school in the UAE. This limits the generalizability of the findings to other contexts, particularly co-educational settings or schools with different demographic profiles. Future research should include a more diverse sample to enhance the generalizability of the findings. Secondly, the study primarily measured the short-term impact post-intervention. The long-term impacts on students' perceptions of their engagement and academic performance were not assessed, which could provide a more comprehensive understanding of the benefits and challenges associated with using interactive technologies. Longitudinal studies are recommended to examine the sustained impact of these technologies on student engagement and learning outcomes. Thirdly, the study assumed that all students had equal access to the necessary technology and internet connectivity. In reality, disparities in access could affect the effectiveness of these interventions. Future studies should consider the impact of technology access on engagement and learning outcomes. Lastly, the data collected through focus group discussions and surveys are based on self-reported measures, which may be subject to bias or inaccuracies in student perceptions. Including more objective measures of engagement, such as observational data or academic performance metrics, could strengthen the study's findings.

CONCLUSION

This study highlights the transformative potential of interactive technologies, specifically AI and VR, in enhancing students' perceptions of their engagement in STEM classes. The research highlights how these technologies can create more engaging and effective learning environments by focusing on cognitive, social, reflective, and goal-oriented dimensions of engagement. The findings are significant in the context of the UAE's educational goals of fostering a knowledge-based economy through innovative educational practices. Interactive technologies not only cater to diverse students' needs but also enhance academic outcomes, providing a more fulfilling educational experience. Although interactive technologies showed promising potential to enhance student engagement, the study also revealed several practical challenges that educators must address. These include limited access to devices, students' over-reliance on AI-generated answers, and varying levels of teacher readiness to integrate these tools effectively. These challenges highlight the need for equitable access to technology, ongoing training for teachers, and balanced teaching strategies that encourage students to think independently and collaborate with others, both with and without digital tools. Tackling these issues will be critical to ensuring that technology integration supports, rather than hinders, meaningful learning. This study provides a strong foundation for future research and practice, emphasizing the need for continued integration and exploration of AI and VR in educational settings. The importance of this study lies in its comprehensive approach to understanding the multifaceted impact of interactive technologies on student engagement. By providing empirical evidence and detailed insights into student perceptions, the study offers valuable guidance for educators, policymakers, and researchers seeking to utilize technology to improve educational outcomes. The results suggest that strategic integration of AI and VR can significantly enhance student engagement, ultimately leading to improved academic performance and a more engaging and interactive learning experience for students.

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APPENDIX A: PRE- & POST STUDENTS' SURVEY

Purpose of the Survey

The purpose of this survey is to investigate the impact of interactive technology on both increasing student engagement and enhancing their STEM competencies.

How to Answer each Question

The survey will be divided into three sections: demographics, competency, and engagement. The demographic information section consists of four multiple-choice questions. The second section is measured using a five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree). The survey will take 15–30 minutes. The information collected from this survey will be kept confidential. Thank you for being part of this research. Your cooperation is highly appreciated. Please use the key below to indicate the extent of your agreement or disagreement with each statement.

Section 1. Demographics

1. What is your grade level?
   a. Grade 9
   b. Grade 10
   c. Grade 11
   d. Grade 12
2. What is your gender?
   a. Male
   b. Female
3. Would you consider yourself to have a disability?
   a. Yes
   b. No
   c. I prefer not to say
4. Did you use IT (e.g., Chatbots, ChatGPT, Apple application, Apple educational tools, etc.) before in learning?
   a. Yes
   b. No

Section 2. Student Engagement in Technology-Rich Classroom

Table A1. Student engagement in technology-rich classroom

Items	1	2	3	4	5
Cognitive engagement					
Classroom use of interactive technology supports my efforts to achieve the learning goals.					
I engage in representing my understanding of concepts using interactive technology					
I engage in analyzing information, comparing and contrasting ideas using interactive technology.					
Classroom activities involve individual problem-solving occasions using interactive technology.					
The learning activities have practical dimension (involve learning by doing)					
I can easily see the possible application of what I learned in this course to workplace settings					
Classroom activities and discussions in general are related to real world situations					
Social engagement					
I interact with other students in the course using emails and technology					
I engage in online, out of class discussion related to the course with my classmates					
I communicate with the teacher using emails and technology					
I cooperate with other students while working on assignments					
I use multiple sources of information (Internet, references, etc.)					
I engage in discussion with other students on the same table					
Reflective engagement					
The classroom allowed me to think loud (expression of ideas, procedures, algorithms, answers, etc. in the classroom)					
I engage in reflecting on my learning					
I engage in meaning making and constructing knowledge about the subject					

Table A1 (Continued).

Items	1	2	3	4	5
Goal clarity					
I am aware of the purpose(s) of each classroom session.					
The learning goal is clearly communicated in each session					
Class materials are related to learning goals					