Journal of Information Technology Education: Research

An Official Publication of the Informing Science Institute
InformingScience.org

JITEResearch.org

Volume 24, 2025

STUDENTS' PERCEPTIONS OF USING INTERACTIVE TECHNOLOGY IN DEVELOPING THEIR COMPETENCIES IN STEM CLASSES IN AN APPLIED TECHNOLOGY SCHOOL IN THE UAE

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ABSTRACT

Aim/Purpose	The primary objective of this study is to evaluate students' perceptions of the impact of interactive technology on developing their competencies in STEM classes at an applied technology school in the United Arab Emirates (UAE). Specifically, the study aims to (i) measure changes in students' perceptions about their competencies before and after the integration of interactive technology, and (ii) explore in-depth their perspectives of how these technologies influenced specific competencies.
Background	Over two semesters, interactive technologies, such as AI tools, virtual labs, simulations, gamified platforms, and collaborative software, were introduced into daily STEM lessons for the first time. Teachers received training to ensure these tools were used effectively to enhance student competencies through pedagogically grounded integration.
Methodology	Employing a mixed-methods approach with 126 male students in grades 9-12, the study utilized pre- and post-intervention surveys, as well as focus group discussions. The quantitative component consisted of pre-and post-intervention

Accepting Editor Stamatis Papadakis | Received: July 15, 2025 | Revised: September 18, September 24, 2025 | Accepted: September 25, 2025.
Cite as: Ragab, K., Martínez-Jiménez, E., & Fernandez-Ahumada, E. (2025). Students' perceptions of using interactive technology in developing their competencies in STEM classes in an applied technology school in the UAE. *Journal of Information Technology Education: Research, 24,* Article 37. https://doi.org/10.28945/5631

	surveys, while the qualitative component included focus group discussions. This design enabled the study to assess both measurable changes in perceptions and deeper insights into students' learning experiences.
Contribution	This study highlights the potential of interactive technology to prepare students for the demands of a technology-driven future, aligning with the UAE's strategic vision for educational innovation. It contributes actionable evidence on students perceived development in core competencies such as critical thinking, collaboration, and digital citizenship.
Findings	Results indicated significant improvements in students' perceptions about developing their competencies, such as digital citizenship, communication and collaboration, critical thinking, problem-solving, research and information literacy, creativity and innovation, and technology operations.
Recommendations for Practitioners	It is important for educators to integrate interactive technologies into STEM education to promote students' competencies and their perceptions in developing them. Also, professional development should emphasize equipping teachers with essential skills and strategies in using interactive technology effectively.
Recommendations for Researchers	Researchers should consider the long-term effect of interactive technology on developing students' competencies and beyond perceived changes. Accordingly, longitudinal studies should be considered as well as the role of gender differences.
Impact on Society	The findings suggest that continued investment in interactive technologies can significantly enhance student engagement and competency development, aligning with the UAE's vision for educational innovation.
Future Research	It is important to consider including diverse student populations from both genders and different educational level.
Keywords	interactive technology, students' competencies, STEM education

INTRODUCTION

In the 21st century, integrating interactive technology into educational practices has fundamentally transformed the learning landscape, especially in Science, Technology, Engineering, and Mathematics (STEM) education. The rapid advancement of digital tools and resources offers unprecedented opportunities to enhance student engagement, facilitate deeper understanding, and develop essential competencies. In the context of the United Arab Emirates (UAE), Applied Technology Schools are pioneering the adoption of these innovative approaches to education, aiming to prepare students for the challenges of a technology-driven future (Belpoliti et al., 2021; Owais et al., 2020). The UAE's 2021 Vision outlines a strategic plan to shift from traditional teaching methods, such as rote learning and teacher-centered approaches, toward more interactive and engaging educational practices (Dulaimi et al., 2022). Researchers have noted that Western frameworks for online learning may not effectively engage Arab learners, highlighting the need for context-specific investigations (Alma'aitah, 2023; Koran & Sarnou, 2022).

Interactive technology in education encompasses the use of digital tools and platforms that promote active learning, collaboration, and engagement (Alsswey et al., 2020; Kerimbayev et al., 2023; Pšenáková & Szabó, 2018). These technologies include simulations, virtual labs, educational games, and collaborative software, which can make abstract STEM concepts more tangible and accessible (Gao et al., 2020; Idrisova et al., 2020; Statti & Torres, 2020). By providing hands-on experiences and

immediate feedback, interactive technologies foster a learning environment where students can explore, experiment, and reflect on their learning processes (Duan et al., 2020; Herman et al., 2020; Kurniawan et al., 2025). Existing research has demonstrated the potential benefits of interactive technology in education, such as improved academic performance, enhanced problem-solving skills, and increased student motivation and satisfaction (Anwar et al., 2023; Dulaimi et al., 2022). However, many of these studies focus on Western or generalized educational contexts, with limited research conducted in Arab settings, particularly in Applied Technology Schools in the UAE.

Moreover, previous studies often emphasize learning outcomes without sufficiently exploring students' own perceptions of how technology supports their competency development. This represents a critical gap, as student perceptions can influence both engagement and sustained learning behaviors. The extent to which these technologies impact the development of specific competencies, particularly in the UAE's unique cultural and educational context, remains an area that warrants further investigation.

The UAE's commitment to educational innovation is evident in its substantial investment in technology-enhanced learning environments (AlShamsi et al., 2020; Jin & Peng, 2022). Applied Technology Schools in the UAE aim to utilize interactive technology to enhance students' competencies in STEM fields (Sandhu et al., 2021). Although national strategies promote technology integration, there remains a lack of empirical evidence on how students themselves experience and perceive this shift. This study seeks to evaluate the extent to which these technologies impact students' perceptions of their competencies, specifically focusing on digital citizenship, communication and collaboration, critical thinking, problem-solving and decision-making, research and information literacy, creativity and innovation, and technology operations and concepts. These competencies are conceptually anchored in internationally recognized educational frameworks such as the Partnership for 21st Century Skills (P21) and the ISTE Standards for Students, which advocate for equipping learners with critical 21st-century capabilities. These include digital citizenship, collaborative and communicative fluency, problem-solving, and digital literacy, core elements that have been contextualized and validated for educational settings in the UAE by ElSayary et al. (2022). Their framework serves as a foundational reference in this study to evaluate how interactive technologies influence the development of these vital student competencies (Bani-Amer, 2022; Padmo et al., 2022). Accordingly, this study was designed with two primary objectives: (i) to measure changes in students' perceptions of their competencies before and after the integration of interactive technology in STEM classes; and (ii) to explore how students describe the influence of these technologies on their learning, through qualitative insights.

The following research question was formulated to guide this study:

1. To what extent do the students' perceptions about their competencies in STEM classes change after integrating interactive technology for two semesters at an Applied Technology School in the UAE?
2. What are students' perceptions of developing their competencies through the use of interactive technology?

The following hypotheses were developed:

> H0: Interactive technology has no significant impact on students' perceptions of their competencies.
>
> H1: Interactive technology has a significant impact on students' perceptions of their competencies.

LITERATURE REVIEW

CONSTRUCTIVIST LEARNING THEORY

Constructivist Learning Theory posits that learners actively construct their own understanding and knowledge through experiences and reflection (Naureen, 2020). According to this theory, learning is a dynamic process where students build new knowledge upon their existing cognitive structures (Efgivia et al., 2021; Zhang et al., 2022). Key proponents such as Jean Piaget and Lev Vygotsky emphasize the importance of active engagement, social interaction, and meaningful contexts in the learning process (Efgivia et al., 2021). This theory provides a strong pedagogical foundation for integrating interactive technologies that offer immersive and experiential learning opportunities. For example, virtual labs and simulations enable students to manipulate variables, observe outcomes, and reflect on their experiences to construct new knowledge, thus facilitating inquiry-based learning and fostering deeper engagement (Chuaungo et al., 2022; Kerimbayev et al., 2023; Ndruru et al., 2025; Stoeckel, 2020). These features are especially relevant in STEM education, where abstract concepts often require visualization and experimentation.

TECHNOLOGY-ENHANCED LEARNING (TEL)

Technology-Enhanced Learning (TEL) is a pedagogical paradigm that emphasizes the integration of digital technologies to improve the quality and accessibility of education. This framework originates from educational technology and instructional design research, notably shaped by the work of scholars such as Conole and Oliver (2007) and elaborated in global policy frameworks by organizations like UNESCO and the OECD.

TEL focuses on the effective use of digital tools and strategies to enhance the teaching and learning process (Behnagh & Yasrebi, 2020; Chuaungo et al., 2022; Hoque et al., 2022). The core principles of TEL include personalization, interactivity, accessibility, and engagement (Hoque et al., 2022). In the context of this study, the integration of interactive technologies in Applied Technology Schools aligns with the TEL framework to support higher-order thinking, learner agency, and real-time feedback (Alfia et al., 2020; Iberahim et al., 2023). Specifically, TEL empowers students to tailor their learning pathways, interact dynamically with course content, and hone critical thinking, problem-solving, and creative abilities through the use of interactive technologies (Hoque et al., 2022). Recent TEL research in post-COVID education further highlights the importance of context-specific implementation, especially in underrepresented regions such as the Arab world (AlSheikh Theeb et al., 2022; Kerimbayev et al., 2023).

INTERACTIVE TECHNOLOGY AND STUDENT COMPETENCIES

Competence refers to an overall ability to perform tasks effectively, encompassing a broad range of skills and knowledge. In contrast, competency denotes specific, measurable behaviors or skills that contribute to effective performance in a particular context (Arifin, 2021). This distinction emphasizes why competency is useful for assessment and instructional design, as it captures observable and actionable student outcomes (ElSayary, 2023). The selection of specific competencies examined in this study is digital citizenship, communication and collaboration, critical thinking, problem-solving and decision-making, research and information literacy, creativity and innovation, and technology operations. These are grounded in the framework developed by ElSayary et al. (2022). This framework adapts global standards, notably the ISTE Standards and the Partnership for 21st Century Skills (P21), to the context of STEM education in the UAE. These competencies are critical for developing a workforce equipped to meet the demands of the digital economy, emphasizing ethical technology use, collaborative problem-solving, and adaptive learning strategies. Unlike the Critical Success Factors (CSF) framework presented by Aliazas et al. (2021), which focuses on organizational innovations in learning systems, ElSayary et al. (2022) provide a learner-centric, skills-based model that aligns more directly with student-level outcomes in competency development. This makes their model par-

ticularly relevant for evaluating the effectiveness of educational interventions in technology-rich environments, such as those in Applied Technology Schools. Recent studies (e.g., AlSheikh Theeb et al., 2022; Kerimbayev et al., 2023) also emphasize that, while interactive technologies can foster these competencies, most research has been conducted in higher education or Western contexts. Limited attention has been given to gendered experiences or the specific cultural dynamics of Arab secondary schools. This gap highlights the need for studies that capture students' own perspectives within localized contexts, especially in environments where technology adoption intersects with unique social and cultural expectations.

Digital citizenship

Interactive technologies play a crucial role in promoting digital citizenship among students (İmer & Kaya, 2020). Studies have shown that engaging with digital tools helps students understand the ethical and responsible use of technology (Milenkova & Lendzhova, 2021). For instance, educational platforms that incorporate lessons on internet safety, digital etiquette, and the implications of digital footprints help students develop a comprehensive understanding of digital citizenship and how to navigate the online world responsibly (Basilotta-Gómez-Pablos et al., 2022; Milenkova & Lendzhova, 2021). By providing interactive learning experiences focused on digital citizenship, these technologies empower students to become informed, ethical, and engaged digital citizens who can navigate the digital landscape effectively and contribute positively to online communities (Buchholz et al., 2020). Recent studies also highlight new challenges, such as the ethical use of generative AI tools like ChatGPT, highlighting the developing dimensions of digital citizenship education (Bhat, 2023).

Communication and collaboration

The use of interactive technology enhances students' communication and collaboration skills (Buchholz et al., 2020). Tools such as discussion forums, collaborative projects, and real-time communication platforms enable students to work together effectively, share ideas, and solve problems collaboratively (Govindarajoo et al., 2023; Hung, 2021; Rister & Bourdeau, 2021). Recent work emphasizes that although digital tools increase participation, teacher facilitation remains essential to ensure equitable contributions, particularly in diverse classrooms (Govindarajoo et al., 2023). Furthermore, the integration of videoconferencing, social media, and other interactive digital platforms allows students to engage in meaningful cross-cultural communication and collaboration, further developing their global awareness, intercultural competencies, and ability to navigate diverse cultural contexts (Haughton & Schödl, 2020; Yparrea & Montoya, 2021).

Critical thinking, problem-solving, and decision-making

Interactive technologies, particularly simulations and virtual labs, are instrumental in developing critical thinking and problem-solving skills (Geng, 2021; Li et al., 2020). These technologies provide students with complex, real-world problems that require critical analysis and innovative solutions (English, 2023). Studies suggest that engaging with these tools enhances students' ability to think critically and solve problems effectively (Inayah et al., 2023; Suryawan et al., 2023). Interactive technology promotes exploration of multiple perspectives, encouraging evidence-based decision-making. However, without instructional scaffolding, technology-rich environments may overwhelm students with too many tools or choices, which can limit the depth of reasoning (Naiditch & Santos, 2020). Rather than solely emphasizing the development of digital skills, interactive technologies in the context of Applied Technology Schools in the UAE can foster a more well-rounded set of competencies that prepare students for the demands of the future workforce (ElSayary et al., 2022).

Research and information literacy

Digital resources and online databases are essential for developing research and information literacy skills (ElSayary et al., 2022; Majid et al., 2020). Interactive technologies enable students to access, evaluate, and synthesize information from various sources (Castillo-Martínez & Ramírez-Montoya, 2021). Research shows that students who use digital tools for research purposes demonstrate a stronger ability to verify credibility, cross-check sources, and integrate diverse perspectives (Alfia et

al., 2020; Neuman, 2021). Accordingly, students become more self-directed and critical consumers of information. The post-pandemic surge in online learning and the fast development of AI in education have further reinforced the need for structural instruction in evaluating misinformation and developing critical digital literacy (Castillo-Martínez & Ramírez-Montoya, 2021; ElSayary, 2023).

Creativity and innovation

Interactive technologies provide platforms for creativity and innovation (Vilarinho-Pereira & Fleith, 2021). Tools such as coding platforms, design software, and multimedia projects allow students to express their creativity and develop innovative solutions (Selfa-Sastre et al., 2022; Sharmila, 2022). Evidence suggests that exposure to open-ended digital tasks nurtures imagination and fosters innovation-oriented mindsets critical to STEM education (Sharmila, 2022). Recent studies also stress that creativity outcomes vary by cultural context, as opportunities for expression and innovation are often mediated by curriculum standards and societal expectations (Vilarinho-Pereira & Fleith, 2021).

Technology operations and concepts

Interactive tutorials, coding exercises, and hands-on tech activities help students develop a strong understanding and application of technology operations and concepts (Dema-Pérez et al., 2021; Rufaidah et al., 2021; Selfa-Sastre et al., 2022). Research highlights that students who engage with these interactive learning experiences not only gain a deeper comprehension of how technology works but also acquire practical, tangible skills in various technology operations and applications (Bonthu & Dayal, 2022; Rufaidah et al., 2021). These technology-enhanced learning approaches empower students to become proficient in utilizing technological tools and resources, equipping them with the essential competencies required for success in the 21st-century digital landscape (Kerimbayev et al., 2023; Sari et al., 2021).

Although the existing literature provides insights into the potential benefits of interactive technologies in enhancing competencies across digital citizenship, collaboration, problem-solving, research, creativity, and operations, several methodological and contextual gaps remain. First, much of the research is concentrated in Western or higher education contexts, with limited empirical evidence from Arab secondary schools. Second, cultural adaptations of interactive learning frameworks are rarely discussed. Yet they are essential for ensuring effective technology integration in regions such as the UAE, where educational practices are shaped by unique socio-cultural dynamics (AlSheikh Theeb et al., 2022). Furthermore, the specific impact of these technologies on the development of students' competencies in the context of Applied Technology Schools in the UAE remains an area that requires further exploration (ElSayary et al., 2022). In addition, gender representation in the literature is uneven. Many studies do not specify gender or analyze gender differences. This study is limited to male students because Applied Technology Schools operate in gender-segregated settings. This cultural and institutional context should be recognized as a boundary of the study's scope, in order to highlight the need for future research to include female students to enhance generalizability. This study, therefore, addresses existing gaps by systematically evaluating male students' perceptions of interactive technologies in Applied Technology Schools in the UAE, offering context-specific insights while also identifying directions for future research on inclusivity and cultural adaptation in STEM education.

METHODOLOGY

This study sought to evaluate students' perceptions of the use of interactive technology in developing their competencies in STEM classes. The study employs an explanatory sequential mixed-methods design to extend the depth and breadth of the different inquiry methods. This design was selected because the quantitative method (survey) can identify measurable changes in students' perceptions, while the qualitative method (focus group) provides deeper explanations of how and why these changes occur, thus strengthening the validity of the findings.

PARTICIPANTS

The study participants were male students in grades 9-12 (n=126) enrolled in an applied technology school in the UAE. The initial sample was 136 students recruited through purposive sampling from different sections of the school to ensure inclusion of students actively enrolled in STEM classes integrating interactive technologies. After applying the inclusion and exclusion criteria, the final sample included n=126 students. The inclusion criteria required for participants in this study were to (1) guarantee their consent to volunteer in the study, and (2) ensure their enrollment in STEM classes that integrate technology (AI and VR) into learning. Students who did not provide consent or were not enrolled in STEM classes were excluded. It is important to note that this study was conducted in an all-male school, thus excluding female students. This limitation affects the generalizability of results across genders but ensures consistency in analyzing a single-gender cohort within the UAE's Applied Technology School system.

Over two academic terms, various interactive technologies, including AI and VR, were newly integrated into STEM classes for grades 9-12. Teachers were trained to apply these tools effectively, aligning their use with instructional goals to support student learning and skill development. Of the participants, 21.43% (27 students) were enrolled 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. Students who stated that they do not have any disability were 113 (89.68%), disability 6 (4.76%), and 7 (5.56%) stated that they prefer not to say. Participants (n=8) selected purposefully for the focus group discussion were distributed as follows: 3 in grade 9, 2 in grade 10, 1 in grade 11, and 3 in grade 12.

PROCEDURE

This study was conducted in accordance with the principles and guidelines established by the Education, Human Development, and Community Development Council within the Ministry of Education, United Arab Emirates. Ethical approval was also obtained from the researcher's institution, and authorization to conduct the study was granted by the school system's director on October 30, 2023. At the beginning of the study, all potential participants were provided with a detailed explanation of the study's purpose, procedures, and expectations. Participants signed a consent document stating their voluntary participation, understanding of confidentiality, and right to withdraw at any time. Additionally, parental consent was obtained in accordance with ethical research guidelines. No personally identifiable information was collected. Survey responses and focus group transcripts were anonymized by assigning random identifiers. All digital files were stored in encrypted systems accessible only to the research team. Confidentiality and anonymity were strictly maintained during data collection, storage, analysis, and reporting. They were assured of their right to withdraw from the study at any point without any negative consequences. Figure 1 shows the study structure and the study flow.

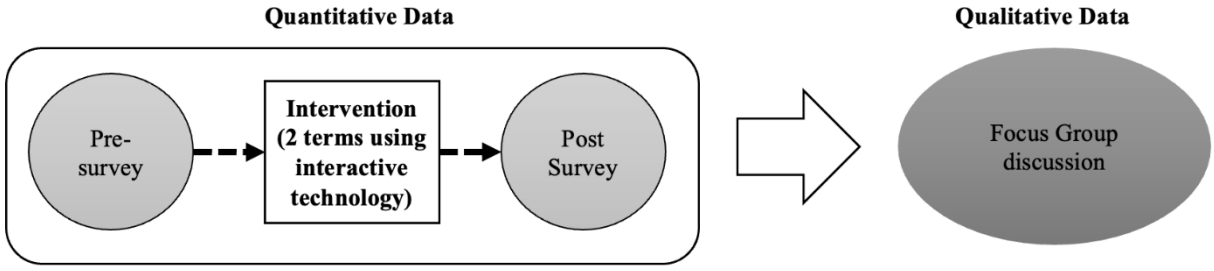

Figure 1. The flow of the study

The study began with the administration of a pre-survey to all participants at the start of the academic year, prior to any intervention with interactive technology. The pre-survey was distributed electronically via a secure web survey. The anonymity and confidentiality of the responses were guaranteed to encourage honest and accurate self-assessment.

The pre-survey data were analyzed using descriptive statistics to establish baseline competency levels. Means and standard deviations were calculated for each competency domain. Additionally, exploratory factor analysis (EFA) was conducted to confirm the validity and reliability of the survey constructs. Following the pre-survey, the intervention phase commenced. Over two academic semesters, interactive technologies, including artificial intelligence (AI) tools for real-time feedback, virtual labs for science experiments, educational simulations for conceptual visualization, gamified platforms for student engagement, and collaborative software such as Microsoft Teams and Google Workspace, were systematically integrated into daily STEM lessons. Interactive technology, including AI and VR, was introduced to these grade levels for the first time and integrated in STEM classes only. Teachers participated in targeted professional development sessions focused on pedagogy-driven technology integration, ensuring consistent and effective use of digital tools to support competency development. After the two semesters, a post-survey was administered to the same cohort of participants. The post-survey mirrored the pre-survey in structure and content, aimed at measuring any changes or improvements in the participants' competencies as a result of the interactive technology intervention. The post-survey was also conducted electronically, with procedures similar to those used in the pre-survey to maintain consistency. Participants were again assured of the confidentiality of their responses and reminded of their right to withdraw from the study at any point.

The post-survey data were analyzed using paired sample t-tests to compare pre-and post-intervention competency levels. Changes in means were assessed to determine significant improvements. Additionally, repeated measures ANOVA was conducted to evaluate the effect of time and interaction effects across different grade levels.

Following the post-survey completion, a focus group discussion was conducted to gain deeper qualitative insights into the participants' experiences and perceptions. Participants for the focus groups were selected purposefully to ensure a representative sample from each grade level. The focus group was conducted in a single session via the Microsoft Teams video conferencing platform, with the session lasting approximately 50 minutes. The discussion was recorded and transcribed for analysis, ensuring the qualitative data complemented the quantitative survey findings. The qualitative data from the focus group discussions were analyzed using thematic analysis. Transcriptions were coded to identify recurring themes and patterns related to the six competency domains.

INSTRUMENTATION

Students' survey

Based on the study framework, the students' survey collected data to address the main purpose of the study: to evaluate students' perceptions of using interactive technology in developing their competencies. The survey consisted of two main sections: demographic information that included questions to ask students about their grade level, if they have any disability, and the use of interactive technology. The survey was adapted from ElSayary et al. (2022). It included six competencies as follows: Digital Citizenship (4 items), Communication and Collaboration (4 items), Critical Thinking, Problem-Solving, and Decision-making (4 items), Research and Information Fluency (4 items), Creativity and Innovation (4 items), and Technology Operations and Concepts (4 items). The total number of items in this survey is 24 (See Appendix A).

The content validation of the survey started by sending it to two educational experts. These experts checked the survey items based on specific criteria: (1) the suitability of the items in meeting the study's purpose, (2) the alignment of the items with the targeted competency, (3) the accuracy of the language used for non-native students, and (4) the length of the survey. The professionals' feedback was positive; however, they suggested changing a few words in two items in the lesson planning.

They also suggested translating the survey into Arabic for the students (non-native speakers). The survey was culturally adapted to fit the UAE educational context. This adaptation involved translating the survey into Arabic and ensuring that the examples and terminology used were relevant to the local culture and educational practices.

In order to measure the construct validity, the Exploratory Factor Analysis was utilized to identify the relationship between the study's constructs, as presented in **Table 1**. For digital citizenship, the Kaiser–Meyer–Olkin (KMO) value is 0.776, and the Bartlett Chi-square approximation is 150.503 with $p < 0.001$; communication and collaboration (*KMO*=0.784, Chi-square approximation is 135.107 with $p < 0.001$); Critical Thinking, Problem-solving, and Decision-making (*KMO*=0.815, Chi-square approximation is 231.490 with $p < 0.001$); Research and Information Fluency (*KMO*=0.799, Chi-square approximation is 213.270 with $p < 0.001$); Creativity and Innovation (*KMO*=0.774, Chi-square approximation is 153.258 with $p < 0.001$); and Technology Operations and Concepts (*KMO*=0.744, Chi-square approximation is 184.279 with $p < 0.001$). The KMO value close to 1 indicated that the correlation pattern was compact enough to produce different and reliable factors.

Table 1. The KMO and Barlett's Test for the students' competencies.

KMO and Bartlett's Test				
Competencies	KMO	Bartlett's Test of Sphericity		
		Approx. Chi-Square	df	Sig.
Digital Citizenship	.776	150.503	6	<.001
Communication and Collaboration	.784	135.107	6	<.001
Critical Thinking, Problem-solving, and Decision-making	.815	231.490	6	<.001
Research and Information Fluency	.799	213.270	6	<.001
Creativity and Innovation	.774	153.258	6	<.001
Technology Operations and Concepts	.744	184.279	6	<.001

The internal consistency coefficient (Cronbach's Alpha) was used to measure the reliability for all survey constructs to form 0.979, with the following value for each competency: Digital Citizenship (α=0.817), Communication and Collaboration (α=0.938), Critical Thinking, Problem-solving, and Decision-making (α=0.958), Research and Information Fluency (α=0.906), Creativity and Innovation (α=0.887), and Technology Operations and Concepts (α=0.856). According to established thresholds, Cronbach's alpha values above 0.70 indicate acceptable reliability, values above 0.80 demonstrate good reliability, and values above 0.90 reflect excellent reliability (Nunnally & Bernstein, 1994; Tavakol & Dennick, 2011). Given these cut-off values, the results confirm that the constructs in this study exhibit strong internal consistency. Accordingly, the survey was sent to students through a web survey link.

Focus group discussion

The focus group discussion was conducted with selected participants (n=8) to determine the students' perceptions about developing their competencies through the use of interactive technology in learning. To ensure a representative range of perspectives while avoiding bias, participants were selected purposefully to reflect varying degrees of engagement with interactive technology rather than only high engagement. The focus group discussion was adapted from Gebre et al. (2014) to form twelve open-ended questions, with each competency including two reflective open-ended questions.

The questions addressed key areas such as students' ethical use of digital platforms (digital citizenship), collaborative experiences using digital tools (communication and collaboration), approaches to solving complex problems using simulations (critical thinking and problem-solving), strategies for finding and evaluating information online (research and information literacy), creative use of technology tools in projects (creativity and innovation), and understanding of digital tools and applications (technology operations and concepts). These subject areas directly align with the core competencies evaluated in the quantitative survey, providing complementary qualitative insights (See Appendix B).

The focus group was conducted online using the Microsoft Teams video conferencing platform and lasted for 50 minutes. Similar to the survey, the interview questions were also sent to two experts in educational technology. The main purpose is to confirm face validity and ensure clarity of the questions. The experts reviewed the survey in alignment with the purpose of the study. They recommended reducing the questions to avoid repetitions. Prior to participation, students signed a consent document affirming their voluntary involvement, confidentiality of responses, and right to withdraw at any time. For students under the legal age, parental consent was obtained as per ethical research guidelines. Thematic analysis was followed to provide rich, contextual insights that supplemented the quantitative survey data, offering a comprehensive understanding of how interactive technology influenced students' competency development.

RESULTS

PAIRED SAMPLE T-TEST

The paired sample t-tests for various competencies indicate significant improvements after the intervention, as shown in Tables 2 and 3. Below are the detailed interpretations:

Results of the *Digital Citizenship* show that mean weight differs before treatment (M=3.714, SD=1.14) and after taking the treatment (M=4.049, SD=0.723) at the 0.05 level of significance, $t(125)$=-2.77, p<0.05, 95% CI for mean difference: -0.574 to -0.101. The average weight was about -0.335 points greater than before the treatment.

For *Communication & Collaboration*, the mean weight differs before treatment (M=3.674, SD=1.14) and after taking the treatment (M=4.004, SD=0.736) at the 0.05 level of significance, $t(125)$=-2.85, p<0.05, 95% CI for mean difference: -0.557to -0.101. The average weight was about -.329 points greater than before the treatment.

For *Critical Thinking, Problem-solving, and Decision-making*, the mean weight differs before treatment (M=3.668, SD=1.14) and after taking the treatment (M=3.952, SD=0.777) at the 0.05 level of significance, $t(125)$=-2.25, p<0.05, 95% CI for mean difference: -.532 to -.034. The average weight was about -.283 points greater than before the treatment.

For *Research and Information Fluency*, the mean weight differs before treatment (M=3.611, SD=1.126) and after taking the treatment (M=3.966, SD=0.778) at the 0.05 level of significance, $t(125)$=-2.81, p<0.05, 95% CI for mean difference: -.604 to -.105. The average weight was about -.355 points greater than before the treatment.

For *Creativity and Innovation*, the mean weight differs before treatment (M=3.629, SD=1.108) and after taking the treatment (M=3.924, SD=0.739) at the 0.05 level of significance, $t(125)$=-2.53, p<0.05, 95% CI for mean difference: -.526 to .064. The average weight was about -.295 points greater than before the treatment.

For *Technology Operations and Concepts*, the mean weight differs before treatment (M=3.738, SD=1.098) and after taking the treatment (M=4.002, SD=0.761) at the 0.05 level of significance, $t(125)$=-2.23, p<0.05, 95% CI for mean difference: -.497 to -.029. The average weight was about -.263 points greater than before the treatment.

For *Overall competencies*, the mean weight differs before treatment (M=3.672, SD=1.076) and after taking the treatment (M=3.983, SD=0.673) at the 0.05 level of significance, $t(125)$=-2.74, p<0.05, 95% CI for mean difference: -.534 to -.086. The average weight was about -.310 points greater than before the treatment.

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

	Pre		Post	
	M	*SD*	*M*	*SD*
Digital Citizenship	3.714	1.142	4.049	.723
Communication & Collaboration	3.674	1.140	4.004	.736
Critical Thinking, Problem-solving, and Decision-making	3.668	1.145	3.952	.777
Research and Information Fluency	3.611	1.126	3.966	.778
Creativity and Innovation	3.629	1.108	3.924	.739
Technology Operations and Concepts	3.738	1.098	4.002	.761
Overall	3.672	1.076	3.983	.673

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

Paired Samples Test									
	Paired Differences					*t*	*df*	Significance	
	M	*SD*	*SE*	95% CI of the Difference				One-Sided p	Two-Sided p
				Lower	Upper				
PRE_DC POST_DC	-.335	1.354	.120	-.574	-.096	-2.77	125	.003	.006
PRE_CC POST_CC	-.329	1.294	.115	-.557	-.101	-2.85	125	.003	.005
PRE_CPD POST_CPD	-.283	1.413	.125	-.532	-.034	-2.25	125	.013	.026
PRE_RI POST_RI	-.355	1.415	.126	-.604	-.105	-2.81	125	.003	.006
PRE_ CI POST_ CI	-.295	1.308	.116	-.526	-.064	-2.53	125	.006	.012
PRE_ TO POST_ TO	-.263	1.327	.118	-.497	-.029	-2.23	125	.014	.027
PRE_Comp POST_Comp	-.310	1.268	.113	-.534	-.086	-2.74	125	.003	.007

Figure 2 shows the improvements in students' perceptions of the competencies development. Across all six competency domains, survey data revealed statistically significant improvements from pre- to post-intervention, which were further elaborated by focus group discussions.

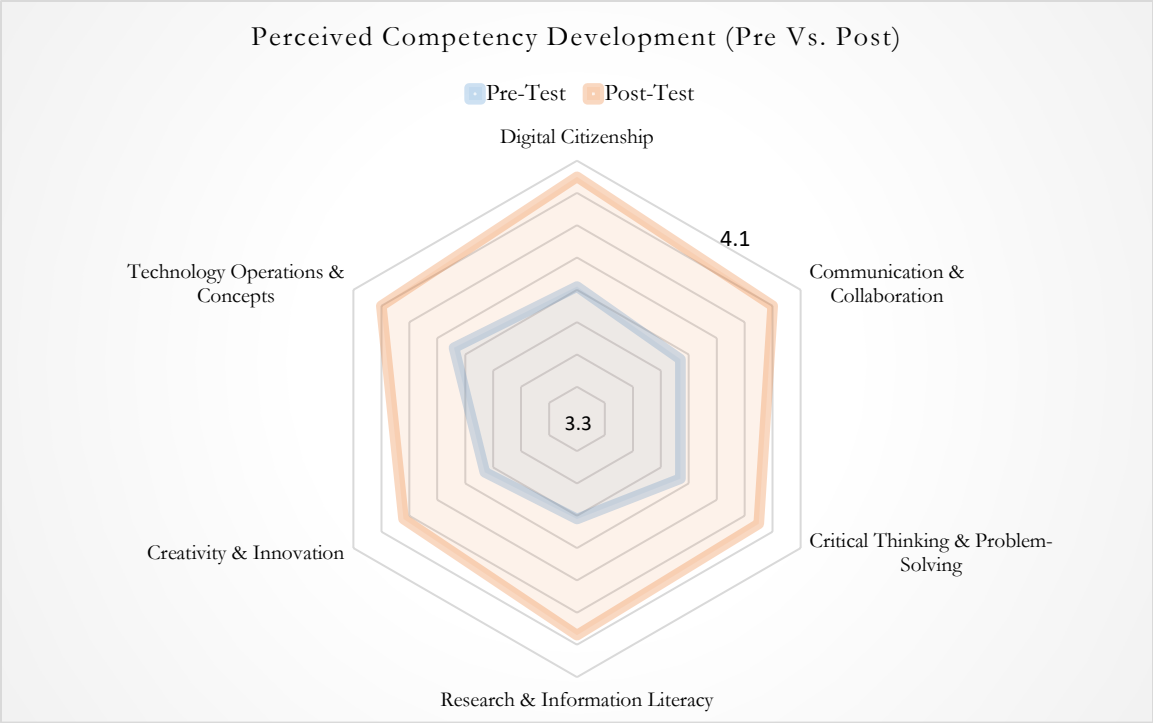

Figure 2. Perceived Competency Development

Repeated Measure ANOVA

Table 4 presents the descriptive statistics for pre-competency and post-competency scores across grade levels (9, 10, 11, 12). Overall, the mean competency scores increased from the pre-test (M = 3.67, SD = 1.08) to the post-test (M = 3.98, SD = 0.67) across all grades.

Table 4. Descriptive Statistics of Pre- and Post-survey by Grade Level

Grade Level	*N*	PRE (Mean ± *SD*)	POST (Mean ± *SD*)
Grade 9	27	3.44 ± 1.23	3.89 ± 0.65
Grade 10	39	3.94 ± 0.85	4.16 ± 0.59
Grade 11	28	3.70 ± 1.05	3.79 ± 0.69
Grade 12	32	3.52 ± 1.18	4.02 ± 0.75
Total	126	3.67 ± 1.08	3.98 ± 0.67

A repeated measures ANOVA was conducted to evaluate the effect of time (pre vs. post) on students' competency scores and to determine if this effect varied by grade level.

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 = 8.007, $F(9, 128700.456) = 0.863$, $p = .558$, indicating no significant differences in covariance matrices across groups.

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 assumption of sphericity is perfectly met.

With these assumptions satisfied, the multivariate tests were interpreted, as shown in Table 5. The main effect of time (competency) was significant, $F(1, 122) = 7.517$, $p = .007$, $\eta^2 = .058$, indicating a significant increase in competency scores from pre-test to post-test. The interaction effect between time and grade level (COMP * POST1_Grade) was not significant, $F(3, 122) = 0.671$, $p = .571$, $\eta^2 = .016$, suggesting that the change in competency scores did not differ significantly across grade levels.

Table 5. Multivariate Tests for Competency Scores

Effect	Value	*F*	Hypothesis *df*	Error *df*	Sig.	Partial Eta Squared	Observed Power
COMP	.058	7.517	1.000	122.000	.007	.058	.776
COMP * POST1_Grade	.016	0.671	3.000	122.000	.571	.016	.188

Table 6 presents the *Tests of Within-Subjects Effects*. The within-subjects effect of time on competency scores was significant, $F(1, 122) = 7.517$, $p = .007$, $\eta^2 = .058$. However, the interaction effect of time and grade level was not significant, $F(3, 122) = 0.671$, $p = .571$, $\eta^2 = .016$.

Table 6. Tests of Within-Subjects Effects

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	Partial Eta Squared
COMP	6.095	1	6.095	7.517	.007	.058
COMP * POST1_Grade	1.633	3	0.544	0.671	.571	.016
Error(COMP)	98.920	122	0.811			

The results indicate a significant improvement in students' competency scores from pre-test to post-test, demonstrating the effectiveness of the instructional intervention. However, the lack of a significant interaction effect suggests this improvement was consistent across different grade levels. The findings support the hypothesis that the instructional intervention of using interactive technology positively impacts student competencies, regardless of grade level.

Focus Group Discussion

The focus group discussion was designed to complement the survey findings by providing deeper qualitative insights into students' perceptions of competency development through interactive technology. Thematic analysis was conducted by following Braun and Clarke's (2006) systematic approach. However, in this study, the predefined framework of competencies, digital citizenship, communication and collaboration, critical thinking and problem-solving, research and information literacy, creativity and innovation, and technology operations, served as the guiding themes. This ensured that the analysis remained directly aligned with the study's conceptual model, while still allowing for sub-themes to emerge within each competency domain. In this way, the qualitative findings reinforced and expanded upon the survey results, offering a coherent and integrated understanding of how interactive technologies shaped students' perceived competency development.

Digital citizenship

Students demonstrated a strong understanding of ethical and responsible technology use. T2 (grade 12) emphasized the importance of originality in assignments, stating,

> *"We enhance our assignments to check the language, but we do not copy-paste the information. We do not use references as I am the one who wrote it."*

T5 (grade 10) added,

> *"In project design and computer science, we use various apps responsibly and make sure to cite sources properly."*

However, T3 (grade 11) noted,

> "Some students still rely heavily on AI tools like ChatGPT and sometimes just copy what it gives without really understanding the content. It can be tempting to take shortcuts."

Communication and collaboration

Technology facilitated effective communication and collaboration among students. T1 (grade 12) mentioned,

> *"We use Microsoft Teams to communicate with each other and other free forms."*

T8 (grade 9) shared,

> *"We used free forms in social studies and biology to collaborate on assignments."*

T3 (grade 11) highlighted the ease of uploading and sharing work through multiple platforms, saying,

> *"We use free form and multiple platforms to upload our work and send it back to the teacher."*

These tools enabled seamless collaboration, especially in project-based courses. T1 (grade 12) noted,

> *"Technology always helped to make it easier not harder, especially in the project design course; we communicate using different forms: emails, WhatsApp, video conferencing."*

Conversely, T5 (grade 10) commented,

> "Sometimes, when we're working in groups online, a few students don't participate and just let others do the work. It's harder to hold everyone accountable."

Critical thinking, problem-solving, and decision-making

Interactive technology supported students in understanding complex concepts and making informed decisions. T5 (grade 10) explained,

> *"I used ChatGPT to compare concepts. For example, in biology, we compared passive and active transport and used ChatGPT a lot in this."*

T3 (grade 11) described,

> *"For end-of-term exams, the school sends the KPI but not the details; I used it to go into the details and understand it better."*

T1 (grade 12) mentioned how interactive platforms helped retain information, stating,

> *"The use of interactive tech helped students to learn more and remember the concepts easily. For example, the biology teacher used Nearpod to assess our pre-information and refresher in the class to keep us informed and updated."*

Yet, T7 (grade 9) noted,

> *"With too many tools, it can sometimes get confusing. I wasn't always sure which platform to use or where to find the materials."*

Research and information fluency

Students utilized various online sources for research and validated information through multiple platforms. T5 (grade 10) stated,

> *"We searched for the answer on Google and other platforms and sometimes we check the outcomes with the teachers."*

T8 (grade 9) mentioned,

> *"It is faster than seeking teachers' information."*

T2 (grade 12) described a thorough approach to cross-referencing information to ensure reliability, saying,

> *"I check using different platforms and if I have different answers, I try with another prompt or get different answers."*

T5 (grade 10) also noted,

> *"Sometimes we ask the teacher to verify if the information we found online is reliable."*

In contrast, T3 (grade 11) remarked,

> *"There were times when I wasn't sure if the information I found online was correct, and I didn't always know how to check its accuracy."*

Creativity and innovation

Interactive technology encouraged creative thinking and innovation in coursework. T5 (grade 10) recounted,

> *"In the project, we had innovative solutions when we worked in groups; we shared ideas, and the teacher gave us high marks. On weekends, we collaborated and shared ideas. We also used ChatGPT to give us more information about it."*

T6 (grade 9) mentioned,

> *"By using different types of AI like image generator, music, or sound, it helps in getting references."*

T7 (grade 11) added,

> *"Using virtual labs in chemistry class has made it easier to understand complex reactions that are difficult to visualize in a traditional classroom."*

However, T2 (grade 12) added,

> *"Sometimes I feel overwhelmed by too many creative tools. I spend more time figuring out how to use them than actually completing the task."*

Technology operations and concepts

The use of technology in the classroom was pivotal in achieving learning goals. T1 (grade 12) appreciated the interactive presentation of materials, which enhanced understanding and engagement, stating,

> *"Yes, it does help to achieve our goals and improve our understanding. It can reach each level of us, and we are glad that the school is allowing us to use it."*

T2 (grade 12) provided an example,

> *"For instance, in grade 11, the physics teacher used Blocket to ask questions in the shape of games. It was a competition to check our understanding. It was really interesting to the extent that I couldn't forget it this year."*

T6 (grade 9) noted,

> *"In most science classes, we use VR to make learning more realistic and helped us to engage better in learning. For example, we learn the simulations better to understand the cause and effect."*

Still, T5 (grade 10) pointed out,

> *"Sometimes the technology doesn't work as expected, or the internet is too slow, which disrupts the class and makes it hard to stay focused."*

SUMMARY OF INTEGRATED FINDINGS

To better integrate the quantitative and qualitative findings, **Table 7** presents a consolidated overview of the results. The integration highlights how students' perceptions of growth aligned with specific experiences, such as improved collaboration through Microsoft Teams or enhanced critical thinking via simulations, while also drawing attention to challenges such as unequal group participation, tool fatigue, and infrastructure limitations. Importantly, these findings represent perceptions of competency development rather than direct assessments of actual competencies, highlighting the need for caution in interpreting perceived improvements as equivalent to measurable skill acquisition.

Table 7. Summary of Integrated Quantitative and Qualitative Findings on Perceived Competency Development

Competency	Quantitative Change (Pre → Post)	Qualitative Themes (Focus Group)	Interpretation
Digital Citizenship	+0.34, $p < .05$	Responsible use of AI tools; emphasis on originality and citation; concern over over-reliance on ChatGPT.	Students perceive stronger digital responsibility, though some practices indicate risks of superficial engagement.
Communication & Collaboration	+0.33, $p < .05$	Effective teamwork via MS Teams and collaborative platforms; unequal participation noted.	Perceptions of improved collaboration are evident, but equitable contribution remains a challenge.
Critical Thinking & Problem-Solving	+0.28, $p < .05$	Enhanced analysis using simulations and AI; occasional tool overload.	Students perceive growth in analytical skills, though using too many platforms can limit depth of engagement.
Research & Information Literacy	+0.36, $p < .05$	Cross-checking information across platforms; reliance on teachers for validation; uncertainty about credibility.	Perceptions suggest improved research skills, but difficulties remain in critically evaluating online sources.
Creativity & Innovation	+0.30, $p < .05$	Coding, VR, and design tools encouraged creative ideas; some overwhelmed by too many tools.	Students perceive enhanced creativity, but structured guidance is needed to maximize tool effectiveness.

Competency	Quantitative Change (Pre → Post)	Qualitative Themes (Focus Group)	Interpretation
Technology Operations & Concepts	+0.26, $p < .05$	Stronger fluency with VR, simulations, and coding; occasional technical barriers reported.	Perceptions indicate improved proficiency, though infrastructure issues sometimes constrained outcomes.

DISCUSSION

THE STUDENTS' PERCEPTIONS OF THEIR COMPETENCIES IN STEM CLASSES

The results of this study highlight the significant shift in students' perceptions of using interactive technology on the development of their competencies within the context of STEM education at an Applied Technology School in the UAE. The quantitative analysis, particularly the paired-sample t-tests, revealed meaningful improvements in various competencies after the implementation of interactive technology in the classroom. On the other side, the qualitative analysis provided in-depth information about students' experiences and perceptions on how they developed these competencies. This integration of the results allows for a deeper exploration into not just what changed, but also how and why these technologies influenced competency development.

Digital citizenship

The results demonstrate that interactive technologies significantly enhanced students' perceptions of digital citizenship, including ethical technology use, online responsibility, and awareness of digital footprints. Quantitative findings showed a positive shift in perceived competence, while focus group discussions provided depth by illustrating how students translated these perceptions into practice, such as emphasizing originality and appropriate citation of sources. These findings reinforce earlier studies that highlight the role of digital tools in promoting internet safety, etiquette, and responsible online behavior (Buchholz et al., 2020; İmer & Kaya, 2020; Milenkova & Lendzhova, 2021).

At the same time, the qualitative narratives revealed underlying challenges that contextualize the survey results. While students reported stronger awareness of digital ethics, they also acknowledged peer reliance on AI tools such as ChatGPT for completing assignments. This divergence suggests that perceived competence may not always reflect consistent behavior, as some learners combine tool usage with authentic digital literacy. Such findings confirm Falloon's (2020) argument that genuine digital competence extends beyond access to tools and requires critical digital literacy and ethical reasoning. The integration of quantitative and qualitative results suggests that while interactive technologies are effective in fostering students' perceived digital citizenship, these perceptions may hide superficial engagement or misuse of tools. This highlights the importance of embedding explicit instruction on critical digital literacy, ethical AI use, and responsible online practices to ensure that improvements in perception translate into sustainable competencies.

Communication and collaboration

The findings indicate that interactive technologies enhanced students' perceptions of their communication and collaboration skills, particularly through the use of platforms such as Microsoft Teams and other collaborative tools that enabled real-time interaction, resource sharing, and project-based teamwork. Survey results demonstrated significant growth in this domain, aligning with prior studies that emphasize the effectiveness of digital platforms in facilitating teamwork and communication (Hung, 2021; Rister & Bourdeau, 2021). Focus group narratives supported this improvement by providing concrete examples of how these tools allowed students to share ideas and coordinate tasks,

reinforcing their relevance for both academic and professional collaboration (Govindarajoo et al., 2023; Yparrea & Montoya, 2021).

However, the qualitative data also revealed important details. Several students reported unequal participation in group work, with some peers contributing less and relying on others to complete shared tasks. This difference reduces the positive survey results. It shows that although the tools help students communicate, they do not ensure fair collaboration without teachers' clear guidance and support. These findings are aligned with Yparrea and Montoya (2021) and Haughton and Schödl (2020), who argue that technology-supported collaboration requires explicit structures for participation. The quantitative and qualitative results integration highlights that technology alone cannot resolve the challenges of group dynamics; rather, its success depends on deliberate instructional strategies that foster inclusivity and accountability in collaborative learning.

Critical thinking and problem-solving

The results demonstrate that interactive technologies, particularly simulations and virtual labs, enhanced students' perceptions of their critical thinking and problem-solving abilities. Quantitative findings revealed significant improvements, while focus group results provided concrete examples of how students engaged with real-world problems, analyzed multiple perspectives, and generated creative solutions. These integrated results confirm previous research indicating that technology-rich environments support analytical reasoning and foster inquiry-based learning (English, 2023; Geng, 2021; Li et al., 2020).

At the same time, both strands of evidence highlighted an important limitation: the large number of platforms occasionally created confusion and hindered critical engagement. Some students expressed difficulty in navigating multiple tools, which aligns with Lin et al.'s (2023) caution that poorly scaffolded technological integration can lead to cognitive overload rather than deeper learning. This detail helps explain why perceived improvements in problem-solving may not always translate into consistent performance, while interactive technologies provide opportunities for higher-order thinking, their effectiveness depends on coherence, instructional alignment, and careful selection of tools.

Overall, the integration of quantitative and qualitative data suggests that interactive technologies are effective in enhancing students' perceived critical thinking and problem-solving skills, but this effect is mediated by how the tools are implemented. When supported by intentional instructional design, simulations and inquiry platforms can foster dynamic engagement and analytical reasoning; when overused, they risk overwhelming learners and weakening the intended benefits.

Research and information literacy

Both quantitative and qualitative findings indicate that interactive technologies strengthened students' perceptions of their ability to conduct research and engage with digital information. Survey results showed significant improvement in research and information literacy, and focus group discussions elaborated on these improvements by illustrating how students actively cross-checked sources, validated information with teachers, and used multiple platforms to synthesize knowledge. These findings align with prior studies that demonstrate the role of digital environments in improving learners' information fluency and capacity for critical engagement with diverse sources (Castillo-Martínez & Ramírez-Montoya, 2021; Majid et al., 2020).

At the same time, the qualitative data revealed persistent difficulties in evaluating the credibility of online content. Students described uncertainty about which information to trust, even when using multiple platforms. This contrasts with the quantitative results, as it indicates that although students perceive improvement in information literacy, the development of critical verification skills remains underdeveloped. These challenges confirm Neuman's (2021) assertion that digital literacy requires explicit instruction in evaluating credibility, not just exposure to information sources. The integrated results suggest that interactive technologies are effective in promoting students' perceptions of improved research skills, but they also highlight the importance of instructional scaffolding to address

gaps in source evaluation. Students' perceived progress may hide weaknesses in recognizing misinformation. This leads to preventing perceptions from developing into true competencies.

Creativity and innovation

The study revealed that interactive technologies positively influenced students' perceptions of their creativity and innovation. Quantitative results showed a significant change in this domain, while focus group narratives illustrated how students engaged with coding platforms, design software, and multimedia tools to generate novel ideas and solutions. These findings are consistent with previous studies demonstrating that technology-rich environments provide diverse opportunities for creative expression and problem-solving (Selfa-Sastre et al., 2022; Sharmila, 2022; Vilarinho-Pereira & Fleith, 2021). Interactive technologies fostered a sense of agency and encouraged students to pursue innovative approaches to STEM challenges.

At the same time, both survey and focus group results revealed that the variety of tools sometimes hindered productivity. Several students expressed feeling overwhelmed by platform complexity or unsure of how best to use certain applications. This detail contrasts with the overall positive perception, highlighting that while digital technologies expand opportunities for creativity, they also risk cognitive overload when integration lacks coherence (Zhang et al., 2022). These findings confirm Sharmila's (2022) caution that offering diverse digital tools without adequate scaffolding can weaken their impact. Accordingly, teachers' guidance and structured integration are crucial for maximizing creative outcomes. When the use of interactive technology is scaffolded effectively, it can foster innovative thinking. However, if it is left unstructured, it may overwhelm learners and limit creative productivity.

Technology operations and concepts

The results demonstrate that interactive technologies enhanced students' perceptions of their proficiency in technology operations and concepts, ranging from coding skills to the effective use of educational platforms. Quantitative results indicated significant improvement in this domain, while focus group discussions provided depth by showing how interactive tutorials and hands-on activities strengthened students' comprehension of technological processes. These findings are consistent with prior literature that highlights the effectiveness of experiential, technology-enhanced environments in promoting operational fluency and practical skills (Bonthu & Dayal, 2022; Zuniga-Velasquez et al., 2020).

However, both strands of evidence also highlighted important limitations. Several students reported encountering technical barriers, such as unreliable internet connectivity or system malfunctions, which at times disrupted the flow of learning. This aligns with Sari et al. (2021), who noted that infrastructure constraints often undermine the effectiveness of technology-enhanced instruction, regardless of the tools' pedagogical potential. Students think that they are progressing in using technology, but the difficulties they face show that their real skills and use of technology may be limited by other factors, such as the infrastructure and available resources. Ensuring consistent connectivity and providing sustained hands-on engagement are, therefore, critical to transforming positive perceptions into sustainable competencies that prepare students for future demands in a technology-driven world.

These findings contribute to the existing body of knowledge by providing empirical evidence on the effectiveness of interactive technologies in the UAE's unique educational context. This study confirms the benefits highlighted in global literature and demonstrates their applicability and impact within the UAE's educational framework. The cultural context of the UAE, which values technological advancement and innovation, plays a crucial role in the successful implementation of interactive technologies. The alignment with national educational strategies and cultural acceptance of technology-enhanced learning environments facilitates the integration and effectiveness of these tools.

IMPLICATIONS

The findings of this study have several important implications for educational policy and practice. The significant improvements across all measured competencies demonstrate that interactive technology has a positive impact on students' perceptions, which could lead to an enhancement in student learning in STEM education. This connection is theoretically grounded in the alignment between STEM pedagogy and 21st-century competencies, as highlighted in frameworks such as those by ElSayary et al. (2022) and the ISTE Standards. These competencies, including critical thinking, problem-solving, digital literacy, and collaboration, are essential in STEM contexts, where students must apply theoretical knowledge to real-world scenarios using digital tools. Interactive technologies support this by enabling inquiry-based, experiential learning consistent with constructivist principles, making abstract STEM concepts more tangible and engaging.

The findings support the hypothesis that interactive technology has a positive impact on student perceptions of their competency development, providing evidence for the effectiveness of these tools in the UAE's Applied Technology Schools. The demonstrated benefits of interactive technology suggest that schools should continue to invest in and integrate these tools into their curricula. Such investments align with the UAE's strategic vision for educational innovation and the shift towards more engaging and interactive teaching practices (Dulaimi et al., 2022).

Furthermore, the study highlights the need for ongoing professional development for educators. This finding echoes the work of Hoque et al. (2022) and Iberahim et al. (2023), who emphasize that technology's impact on student learning is significantly mediated by teacher readiness and pedagogical integration strategies. Effective use of digital tools requires not only technical proficiency but also the ability to align them with learning goals and student needs. To maximize the benefits of interactive technologies, teachers must be adequately trained in their use and integration into the curriculum. This ensures that educators are well-equipped to create dynamic and effective learning environments that utilize technology to its full potential. Additionally, fostering a culture of continuous improvement and innovation in teaching practices will better prepare students for the challenges of the 21st-century workforce. Overall, this study highlights the transformative potential of interactive technology in education and provides a compelling case for its broader adoption in schools to enhance student engagement and competency development.

LIMITATIONS

Several limitations must be considered when interpreting the findings of this study. First, the sample consisted solely of male students from a single Applied Technology School in the UAE, which limits the generalizability of the results. Future research should include a more diverse sample, including female students and students from different schools and regions, to enhance the generalizability of the findings. Additionally, the study's reliance on self-reported survey data may introduce response bias, as participants might overestimate their competencies or provide socially desirable answers. The study's duration, limited to two academic semesters, may not capture the long-term effects of interactive technology on competency development. This study focused on students' perceptions of the development of their competencies due to the integration of interactive technology applications, using a one-sample t-test, which cannot measure a real impact on their competencies. Accordingly, future studies should consider longitudinal designs to assess the sustained impact of technology integration over more extended periods.

RECOMMENDATIONS

The study's findings highlight several recommendations for educators and policymakers aiming to integrate interactive technologies into STEM classrooms. For educators, technology should be used as a tool to strengthen learning experiences and perceived competencies, consistent with research

showing that digital tools enhance student engagement and motivation when embedded in pedagogy (Anwar et al., 2023; Dulaimi et al., 2022). Explicit instruction in digital ethics and critical literacy is essential to reduce risks of superficial engagement and over-reliance on AI tools, reflecting Falloon's (2020) argument that genuine digital competence requires ethical reasoning beyond tool use, and recent calls to include AI ethics in digital citizenship education (Bhat, 2023; Buchholz et al., 2020). Teachers should also create accountability systems in group work to ensure fair participation, as collaboration through platforms such as Microsoft Teams has been shown to improve communication but does not guarantee equitable contributions without structured guidance (Govindarajoo et al., 2023; Yparrea & Montoya, 2021). Similarly, providing structured guidance when using multiple platforms can minimize tool fatigue and confusion, echoing findings that unscaffolded technology use may cause cognitive overload (Lin et al., 2023). In addition, teachers must support students in evaluating the credibility of digital sources so that positive perceptions of research ability become real competencies, a need widely noted in studies of information literacy (Castillo-Martínez & Ramírez-Montoya, 2021; Neuman, 2021). These practices can maximize the benefits of interactive technologies and ensure classroom activities lead to the intended learning outcomes with desired competency development.

In order to meet these goals, schools should adopt a structured tool map that sequences and limits platforms by grade and subject. This will help minimize tool overload and improve coherence of instruction, addressing concerns that exposure to too many tools may overwhelm learners (Sharmila, 2022). Additionally, teachers need to implement formative checks (e.g., short digital quizzes or exit tickets) that use platform analytics to adjust instruction in real time and establish transparent evaluation protocols that make learners' contributions visible in group work, aligning with evidence that continuous feedback enhances engagement (Hoque et al., 2022). Furthermore, weekly exercises in source verification, such as comparing AI outputs with scholarly databases or articulating credibility rationales, should be built into routines to strengthen critical information literacy (ElSayary et al., 2022; Majid et al., 2020). Another important recommendation is to introduce AI through stages (brainstorm → compare & analyze → create) to build maturity without fostering dependence, reflecting pedagogical frameworks for inquiry-based and constructivist learning (Li et al., 2020; Naureen, 2020).

For policymakers and school leaders, the study emphasizes the need for sustained systemic support to ensure the success of technology integration. This includes investment in reliable infrastructure to overcome barriers such as connectivity issues, consistent with findings that infrastructure constraints undermine learning outcomes (Sari et al., 2021). This should be paired with periodic infrastructure reliability audits and a simple reporting loop for teachers and students to flag disruptions and track remediation. Professional development should be beyond tool proficiency to focus on pedagogy-driven integration, echoing research that teacher readiness and instructional design are critical mediators of technology effectiveness (Hoque et al., 2022; Iberahim et al., 2023). It is important to mandate digital-pedagogy certification that combines technical skills with ethics, assessment, and classroom management, reflecting global frameworks on teacher digital competency (Falloon, 2020). Policies should also ensure inclusivity and generalizability of implementation. It is also recommended that leaders adopt an inclusion framework that pilots and evaluates initiatives in female and SEN contexts, addressing gaps in gender representation in current research (AlSheikh Theeb et al., 2022). Additionally, publishing clear system-level guidelines for ethical AI use (plagiarism standards, data privacy, and responsible prompting) will align classroom practice with national expectations (Buchholz et al., 2020; İmer & Kaya, 2020). Finally, competency tracking should be institutionalized via digital portfolios that document students' products and reflections across years, an approach supported by evidence of digital assessment as a driver of student growth (Voogt & Roblin, 2012).

Researchers should also consider expanding research and implementation efforts to include female students and diverse school contexts, thereby enhancing inclusivity and ensuring the generalizability of results. This is consistent with calls for culturally adapted frameworks in the Arab world (AlSheikh

Theeb et al., 2022; ElSayary et al., 2022). Longitudinal cohort studies are recommended to determine whether perceived improvements develop into sustained competencies, while multi-site comparisons can show how different contexts influence outcomes (Kerimbayev et al., 2023). Multi-site comparisons are important to show how different contexts influence outcomes. Paired teacher–student studies can also reveal where teaching goals match or differ from students' self-assessments. Finally, policies must remain closely aligned with national educational strategies and innovation agendas (Dulaimi et al., 2022; Mohamed et al., 2017), so that the integration of interactive technologies directly contributes to preparing students for the UAE's digital economy.

CONCLUSION

This study aimed to evaluate students' perceptions of using interactive technology to develop their competencies in STEM classes in an Applied Technology School in the UAE. The findings revealed significant perceived improvements across the six targeted competencies: digital citizenship, communication and collaboration, critical thinking and problem-solving, research and information literacy, creativity and innovation, and technology operations and concepts.

In relation to RQ1, the quantitative survey results demonstrated measurable improvements in students' self-perceptions across all domains after the integration of interactive technologies such as AI tools, virtual labs, and collaborative platforms. These improvements indicate that technology integration can enhance students' confidence in their skills, even though they reflect perceived rather than directly measured competencies. Regarding RQ2, the qualitative findings provided deeper insights into how students experienced these changes. Students described meaningful improvements in areas such as ethical technology use, collaboration, and creative problem-solving, but they also reported challenges, including unequal group participation, excessive reliance on AI, and difficulties in evaluating the credibility of online content. This distinction between perception and practice suggests that while interactive technologies can positively shape learners' self-assessments, actual competency development requires sustained guidance, structured learning opportunities, and reliable infrastructure.

The study highlights the transformative potential of interactive technologies in education, aligning with the UAE's strategic vision for educational innovation. To fully realize this potential, future research should focus on more diverse participant groups, include longitudinal studies, and incorporate teachers' perspectives to provide a holistic understanding of the impact of interactive technology on education. In conclusion, this study provides valuable insights into how interactive technology can enhance student competencies. It emphasizes the importance of continuous investment in educational technologies and professional development for educators. These efforts will better prepare students for the demands of a technology-driven future, ensuring they possess the essential competencies for success in the 21st century. However, for these perceptions to be translated into authentic competencies, both educators and policymakers must play an active role in providing scaffolding, professional development, and supportive digital infrastructure. By strengthening alignment between classroom practice and national educational strategies, interactive technologies can move beyond improving perceptions to achieving demonstrable competency improvements, thereby contributing to preparing students for success in the knowledge-driven economy.

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APPENDIX A – STUDENTS' PRE- AND POST-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 (competency) will be measured using 5-point scale items (1=*almost never*, 2=*a few times of semester*, 3=*1-3 times per month*, 4= *1-3 times per week*, and 5=*almost daily*).

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 Interactive Technology (e.g: Chatbots, ChatGPT, Apple application, Apple educational tools, etc.) before / in learning?
   a. Yes
   b. No

Section 2: Perceptions about Competencies

Digital Citizenship	**1**	**2**	**3**	**4**	**5**
1. Advocate and practice safe, legal, and responsible use of information and technology.					
2. Exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity.					
3. Demonstrate personal responsibility for lifelong learning.					
4. Exhibit leadership for digital citizenship.					
Communication and Collaboration	**1**	**2**	**3**	**4**	**5**
1. Interact, collaborate, and publish with peers, experts, or others employing a variety of digital environments and media.					
2. Communicate information and ideas effectively to multiple audiences using a variety of media and formats.					
3. Develop cultural understanding and global awareness by engaging with learners of other cultures.					
4. Contribute to project teams to produce original works or solve problems.					
Critical Thinking, Problem-Solving, and Decision-making	**1**	**2**	**3**	**4**	**5**
1. Identify and define authentic problems and significant questions for investigation.					
2. Plan and manage activities to develop a solution or com- plete a project.					
3. Collect and analyze data to identify solutions and/or make informed decisions.					
4. Use multiple processes and diverse perspectives to explore alternative solutions.					
Research Information Literacy	**1**	**2**	**3**	**4**	**5**
1. Plan strategies to guide inquiry.					
2. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.					
3. Evaluate and select information sources and digital tools based on the appropriateness to specific tasks.					
4. Analyze/process data and report results.					
Creativity and Innovation	**1**	**2**	**3**	**4**	**5**
1. Apply existing knowledge to generate new ideas, products, or processes.					
2. Create original works as a means of personal or group expression.					
3. Use models and simulations to explore complex systems and issues.					
4. Identify trends and forecast possibilities.					

Technology Operations and Concepts	1	2	3	4	5
1. Understand and use technology systems.					
2. Select and use applications effectively and productively.					
3. Troubleshoot systems and applications.					
4. Transfer current knowledge to learning new technologies.					

APPENDIX B – FOCUS GROUP PROTOCOL

Introduction

Good morning (or afternoon), and thank you for participating in this focus group discussion. The purpose of this session is to explore your experiences with interactive technology in the context of teaching and learning, particularly in relation to the development of STEM competencies. We are interested in understanding your perceptions of how interactive technologies influence your learning process, problem-solving abilities, creativity, and collaboration with peers.

This discussion will involve open-ended and reflective questions that encourage you to share your thoughts freely. There are no right or wrong answers; we are primarily interested in your honest opinions and personal experiences. Please feel comfortable expressing what you genuinely think and do, as your insights will help us identify best practices for improving learning activities and fostering student engagement.

Your contributions will be valuable in deepening our understanding of how interactive technologies can support effective learning, the development of competencies, and the promotion of responsible and ethical use of digital tools.

Digital Citizenship

1. How do you make sure you use technology ethically and responsibly?
2. What benefits and challenges do you find in using interactive technology?

Communication and Collaboration

3. Can you describe a situation where technology helped or made it harder to work with peers on an assignment?
4. Can you share an example of how you express your ideas using interactive technology in class?

Critical Thinking, Problem-solving, and Decision-making

5. Can you give examples of how you've used technology to understand concepts or compare ideas?
6. How do learning activities with technology help you solve problems or learn by doing?

Research and Information Literacy

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?

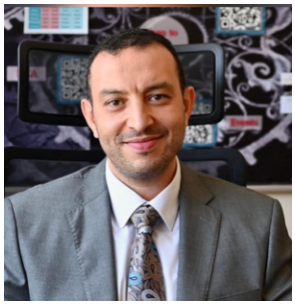
Creativity and Innovation

9. Can you give an example of a creative solution or innovative idea you developed using interactive technology in your coursework?
10. How do you reflect on your learning experiences with technology to develop new ideas or approach tasks in creative ways?

Technology Operations and Concepts

11. How do interactive technologies help you understand the learning goals for each session?
12. How are you going to use interactive technology in the future? What would you do differently?

AUTHORS



Karim Ragab is a UAE-based school leader and STEM educator with 22 years' experience spanning teaching, curriculum development, and K–12 leadership. He is Vice Principal at Ittihad Private School–Mamzar, where he has led literacy/numeracy initiatives, strengthened instructional quality, and driven measurable gains. Previously, Karim served as Principal for the Applied Technology High Schools (Dubai and Umm Al Quwain). An active IEEE member, he previously developed national Applied Technology curricula and mentored students for Emirates/WorldSkills competitions. He represented the UAE as the CNC turning expert in the WorldSkills competitions (Leipzig 2013 and São Paulo 2015). Karim holds an MSc in Mechanical Engineering (American University of Sharjah) and a BSc from Alexandria University, and he is completing a PhD in Educational Technology (Universidad de Córdoba, expected Mar 2026). His recent publications focus on interactive technology in STEM education and energy efficiency in schools.

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