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An AI-Powered STEM Learning Initiative in Space Education

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Abstract: This paper reports the an AI-enabled project in space education, which seeks to enhance k-12 school students' engagement in underexplored STEM domains through an intelligent AI-driven platform. By integrating Design Thinking and the Predict – Observe – Explain (POE) pedagogical framework, the project develops two core components: (a) a Subject-Specific Image Explanation Tool (SS-IET), fine-tuned on space education datasets using open-source large language models, and (b) a Subject-Specific Chatbot-based Learning Tool (SS-CLT) that scaffolds inquiry learning via adaptive question prompts. Preliminary results demonstrate that domain-specific fine-tuning improves explanatory accuracy, reduces hallucination, and aligns language style with the developmental needs of K – 12 learners. The paper discusses the project rationale, system design, interim findings, and outlines future research directions to strengthen the role of AI in advancing STEM education in space science.

Keywords: Space education, STEM education, LLM, fine-tuning, K-12

1. Introduction

STEM education plays an important role in preparing students for future careers in science, technology, and engineering (Yeung et al., 2024). However, conventional curricula often underrepresent fields such as aerospace, marine conservation, and biodiversity, despite their increasing importance in addressing global challenges such as climate change, sustainable development, and technological innovation (Meng et al., 2024; Fauville et al., 2024). These domains are characterized by abstract scientific concepts and complex technological systems, which are difficult to convey through traditional instructional methods.

Artificial intelligence (AI) offers new possibilities for addressing these challenges. Recent advances in large language models (LLMs) and multimodal AI systems provide opportunities to develop adaptive, interactive, and inquiry-based learning environments that can personalize support for diverse learners (Bewersdorff et al., 2025; Liu et al., 2025). Yet, while the potential of space education has been widely discussed, relatively few initiatives have focused on leveraging AI to support K – 12 learners in specialized space science domains (Bastos et al., 2025).

The project seeks to close this gap by designing an intelligent STEM (I-STEM) learning platform that integrates AI-powered tools with inquiry-based pedagogical frameworks. The project specifically targets K-12 learners, aiming to enhance conceptual understanding, stimulate interest in STEM careers, and promote critical thinking. In this paper, we report on the first phase of the project, focusing on space education as a pilot domain.

2. Theoretical and Pedagogical Framework

The design of the i-STEM platform is grounded in two complementary frameworks: Design Thinking and Predict-Observe-Explain (POE). Design Thinking emphasizes empathy, creativity, and iterative problem-solving, encouraging students to approach scientific inquiry as a process of identifying problems, generating solutions, and refining ideas (Wang, Sun, Yang, & Zheng., 2025). In the context of STEM education, Design Thinking allows learners to explore open-ended scientific problems in authentic contexts, promoting creativity and innovation (Dym et al., 2005).

The POE framework complements Design Thinking by structuring inquiry around three cognitive stages: prediction, observation, and explanation (White & Gunstone, 2014). By first predicting outcomes, students activate prior knowledge and make explicit their initial conceptions. Through observation of real-world or simulated phenomena, they confront discrepancies between their expectations and empirical evidence. Finally, the explanation phase enables them to reconstruct knowledge, refine reasoning, and strengthen conceptual understanding (Hume & Coll, 2008). Research in science education has demonstrated that POE promotes conceptual change, critical thinking, and long-term retention of knowledge (Özcan & Uyanık, 2022).

Integrating AI into these frameworks provides opportunities to scale personalized inquiry-based learning. AI-driven tools can scaffold prediction by prompting students with tailored questions, enrich observation through multimodal data representations, and support explanation by providing adaptive feedback (Mohammadi et al., 2025; Yannier et al., 2020). The i-STEM platform operationalizes this integration through two core components described below.

3. Methodology and System Design

3.1 i-STEM learning platform

The i-STEM system is a comprehensive STEM education platform designed for K – 12 students, aiming to advance scientific inquiry, engineering thinking, and innovation literacy through interdisciplinary content centered on aerospace and marine education (see Figure 1). Grounded in the design thinking framework, the platform structures the learning process into five progressive phases-Empathize, Define, Ideate, Prototype, and Test-each supported by a rich suite of integrated learning activities. These include instructional videos, interactive animations, formative assessment questions, and guided tasks that immerse students in authentic problem-solving contexts, enabling them to construct knowledge iteratively and develop competencies in addressing complex engineering challenges.

Figure 1. i-STEM System Home Page.

A key innovation of the i-STEM system is the integration of an AI Teacher that serves as an intelligent pedagogical agent throughout the learning journey. This AI Teacher is fine-tuned on domain-specific datasets in aerospace and marine education and further enhanced with educationally grounded prompt engineering based on constructivist and cognitive learning theories. At the beginning of each design thinking phase, the AI Teacher proactively engages students with targeted questions to stimulate inquiry and clarify learning objectives. When students encounter difficulties or pose questions during their exploration, the AI Teacher delivers structured, context-aware, and pedagogically sound responses within predefined educational boundaries. This ensures that feedback is not only accurate and discipline-specific but also developmentally appropriate, thereby scaffolding students' independent and deep learning. The AI-driven interaction enhances engagement, provides real-time support, and fosters a personalized learning experience.

Furthermore, the i-STEM system empowers educators to tailor learning pathways according to individual student needs. Teachers can activate specific course modules for different learners or groups, accommodating diverse learning styles, interests, and readiness levels.

3.2 AI tools in i-STEM

The AI tools in i-STEM platform comprises two central components: the Subject-Specific Image Explanation Tool (SS-IET) and the Subject-Specific Chatbot-based Learning Tool (SS-CLT). The SS-IET leverages the multimodal capabilities of large vision-language models. We fine-tuned the llava-hf/llava-1.5-7b-hf model (Liu et al., 2023) on a curated dataset of aerospace photographs and corresponding textual descriptions (Hu et al., 2021). The fine-tuning process employed LoRA (Low-Rank Adaptation) using the Llama-Factory tool (Zheng et al., 2024), enabling parameter-efficient adaptation of the base model for K–12 aerospace education. The primary purpose of the SS-IET is to generate grade-appropriate, scientifically accurate explanations of visual content, such as images of aircraft structures or satellite launches. By transforming abstract phenomena into accessible explanations, SS-IET reduces cognitive load and enhances students' ability to link visual stimuli with conceptual knowledge.

The SS-CLT is designed through subject-specific prompt engineering for aerospace education (Chen et al., 2024). The chatbot engages learners in inquiry by posing scaffolded questions aligned with their grade level and prior knowledge (Labadze et al., 2023; Looi & Jia, 2025). Unlike general-purpose chatbots, which often produce inconsistent or irrelevant answers, SS-CLT is constrained by domain-specific prompts and datasets, ensuring content accuracy and educational relevance. By dynamically adjusting question complexity, the SS-CLT promotes higher-order thinking and supports personalized learning trajectories.

4. Interim Results

The preliminary outcomes of model fine-tuning demonstrate significant improvements over baseline performance. Specifically, the fine-tuned SS-IET exhibited fewer hallucinations, produced explanations more suitable for K–12 learners, and achieved a converged training loss of approximately 0.2. These results suggest that domain-specific fine-tuning effectively aligns AI outputs with educational needs.

Prototype space learning activities have also been developed. These include: (1) an Aircraft Design Laboratory, in which students use SS-IET to analyze visual models of aircraft components; (2) a Simulated Rocket Launch Experiment, where SS-CLT guides students through predictions and observations of rocket dynamics; and (3) an Aircraft Running Orbit Exploration, which integrates interactive simulations with AI-driven questioning. Each activity demonstrates how AI tools can operationalize the POE framework, supporting prediction, observation, and explanation in authentic scientific contexts.

5. Discussion

The interim findings offer several insights into the integration of AI in STEM education. First, the results confirm the potential of domain-specific fine-tuning for aligning LLMs with age-appropriate learning needs (Kwak & Pardos, 2024; Rong et al., 2025). This addresses a critical limitation of general-purpose AI models, which often fail to adapt their language style or conceptual depth for school contexts (Xu et al., 2025). Second, the incorporation of AI into Design Thinking and POE frameworks enhances inquiry learning by providing timely scaffolding and multimodal representations (Saritepeci & Yildiz Durak, 2024). This demonstrates the value of combining technological innovation with evidence-based pedagogical design (Schell et al., 2025).

At the same time, the challenges encountered underscore important considerations for future research. The limited availability of suitable datasets highlights the need for collaborative efforts to build open-access, domain-specific corpora for educational fine-tuning (Bonthu et al., 2024). Ethical concerns, such as the transparency of AI-generated explanations and the avoidance of bias, must also be addressed to ensure equitable and trustworthy applications (Bellaby, 2024). Furthermore, the question of how AI tools interact with teacher roles in the classroom warrants further exploration, particularly regarding how teachers can mediate AI outputs to support deeper student engagement (Ding et al., 2025; Kim, 2024).

6. Conclusion and Future Work

This paper presented the first-phase outcomes of the project, which integrates AI-powered tools with inquiry-based pedagogical frameworks to advance STEM education in aerospace, marine, and biodiversity domains. The interim findings suggest that the SS-IET and SS-CLT have strong potential to enhance students' conceptual understanding, engagement, and inquiry skills in aerospace education.

Future research will focus on completing the development of SS-IET and SS-CLT, piloting the platform in K－12 classrooms, and expanding its coverage to marine conservation and biodiversity. A key objective will be to systematically evaluate the impact of Design Thinking and POE frameworks on student learning, motivation, and career aspirations (Das et al., 2024; Kuo et al., 2022). By connecting students with frontier scientific domains through AI-powered learning environments, this project aspires to broaden participation in STEM, bridge the gap between abstract concepts and concrete experiences (Lin et al., 2025), and prepare future generations for the challenges of a technologically advanced and environmentally fragile world (Gomez Gomez, 2024).

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References

Bastos, E., Clarke, G., Dodds, B., Higgs, S., Willcocks, K., & Bridge, N. (2025). Mapping ocean literacy educational journeys: a systematic scoping review. *Environmental Education Research,* 1–23. https://doi.org/10.1080/13504622.2025.2512088

Bellaby, R. (2024). The ethical problems of 'intelligence–AI.' *International Affairs (London), 100*(6), 2525–2542. https://doi.org/10.1093/ia/iiae227

Bewersdorff, A., Hartmann, C., Hornberger, M., Seßler, K., Bannert, M., Kasneci, E., Kasneci, G., Zhai, X., & Nerdel, C. (2025). Taking the next step with generative artificial intelligence: The transformative role of multimodal large language models in science education. *Learning and Individual Differences, 118,* Article 102601. https://doi.org/10.1016/j.lindif.2024.102601

Bonthu, S., Sree, S. R., & Krishna Prasad, M. H. M. (2024). Framework for automation of short answer grading based on domain-specific pre-training. *Engineering Applications of Artificial Intelligence, 137,* Article 109163. https://doi.org/10.1016/j.engappai.2024.109163

Chen, E., Wang, D., Xu, L., Cao, C., Fang, X., & Lin, J. (2024). *A Systematic Review on Prompt Engineering in Large Language Models for K-12 STEM Education* (No. arXiv:2410.11123). arXiv. https://doi.org/10.48550/arXiv.2410.11123

Das, P., Kar, B., & Misra, S. N. (2024). Career course, coach, and cohort framework: A design thinking approach to enhance career self-efficacy. *The International Journal of Management Education, 22*(1), Article 100898. https://doi.org/10.1016/j.ijme.2023.100898

Ding, L. J., Li, J. M., & Hui, B. H. (2025). Will Teacher-AI Collaboration Enhance Teaching Engagement? *Behavioral Sciences, 15*(7), Article 866. https://doi.org/10.3390/bs15070866

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education, 94*(1), 103–120. https://doi.org/10.1002/j.2168-9830.2005.tb00832.x

Fauville, G., Voşki, A., Mado, M., Bailenson, J. N., & Lantz-Andersson, A. (2024). Underwater virtual reality for marine education and ocean literacy: technological and psychological potentials. *Environmental Education Research,* 1–25. https://doi.org/10.1080/13504622.2024.2326446

Gomez Gomez, C. V. (2024). Teaching entrepreneurship in higher education: The application active based learning activities to environmental protection. *Thinking Skills and Creativity, 52,* Article 101502. https://doi.org/10.1016/j.tsc.2024.101502

Hu, E. J., Shen, Y., Wallis, P., Allen-Zhu, Z., Li, Y., Wang, S., Wang, L., & Chen, W. (2021). *LoRA: Low-Rank Adaptation of Large Language Models* (No. arXiv:2106.09685). arXiv. https://doi.org/10.48550/arXiv.2106.09685

Hume, A., & Coll, R. (2008). Student Experiences of Carrying out a Practical Science Investigation Under Direction. *International Journal of Science Education.* https://doi.org/10.1080/09500690701445052

Kim, J. (2024). Types of teacher-AI collaboration in K-12 classroom instruction: Chinese teachers' perspective. *Education and Information Technologies, 29*(13), 17433–17465. https://doi.org/10.1007/s10639-024-12523-3

Kuo, H.-C., Yang, Y.-T. C., Chen, J.-S., Hou, T.-W., & Ho, M.-T. (2022). The Impact of Design Thinking PBL Robot Course on College Students' Learning Motivation and Creative Thinking. *IEEE Transactions on Education, 65*(2), 124–131. https://doi.org/10.1109/TE.2021.3098295

Kwak, Y., & Pardos, Z. A. (2024). Bridging large language model disparities: Skill tagging of multilingual educational content. *British Journal of Educational Technology, 55*(5), 2039–2057. https://doi.org/10.1111/bjet.13465

Labadze, L., Grigolia, M., & Machaidze, L. (2023). Role of AI chatbots in education: Systematic literature review. *International Journal of Educational Technology in Higher Education, 20*(1), 56. https://doi.org/10.1186/s41239-023-00426-1

Lin, C.-J., Lee, H.-Y., Wang, W.-S., Huang, Y.-M., & Wu, T.-T. (2025). Enhancing reflective thinking in STEM education through experiential learning: The role of generative AI as a learning aid. *Education and Information Technologies, 30*(5), 6315–6337. https://doi.org/10.1007/s10639-024-13072-5

Liu, H., Li, C., Wu, Q., & Lee, Y. J. (2023). *Visual Instruction Tuning* (No. arXiv:2304.08485). arXiv. https://doi.org/10.48550/arXiv.2304.08485

Liu, J., Sun, D., Sun, J., Wang, J., & Yu, P. L. H. (2025). Designing a generative AI enabled learning environment for mathematics word problem solving in primary schools: Learning performance, attitudes and interaction. *Computers and Education. Artificial Intelligence, 9,* Article 100438. https://doi.org/10.1016/j.caeai.2025.100438

Looi, C.-K., & Jia, F. (2025). Personalization capabilities of current technology chatbots in a learning environment: An analysis of student-tutor bot interactions. *Education and Information Technologies, 30*(10), 14165–14195. https://doi.org/10.1007/s10639-025-13369-z

Meng, T., Mao, R., & Sun, S. (2024). Exploration and Reflections on Empowering Aerospace Control Education through Digitalization. *IFAC-PapersOnLine, 58*(16), 53–58. https://doi.org/10.1016/j.ifacol.2024.08.461

Mohammadi, M., Tajik, E., Martinez-Maldonado, R., Sadiq, S., Tomaszewski, W., & Khosravi, H. (2025). Artificial intelligence in multimodal learning analytics: A systematic literature review. *Computers and Education: Artificial Intelligence, 8,* 100426.

Özcan, G. E., & Uyanık, G. (2022). The effects of the “Predict-Observe-Explain (POE)” strategy on academic achievement, attitude and retention in science learning. *Journal of Pedagogical Research, 6*(3), 103–111. https://doi.org/10.33902/JPR.202215535

Rong, L., Zhang, Y., Tiwari, P., & Yu, M. (2025). BegoniaGPT: Cultivating the large language model to be an exceptional K-12 English teacher. *Neural Networks, 189,* Article 107488. https://doi.org/10.1016/j.neunet.2025.107488

Saritepeci, M., & Yildiz Durak, H. (2024). Effectiveness of artificial intelligence integration in design-based learning on design thinking mindset, creative and reflective thinking skills: An experimental study. *Education and Information Technologies, 29*(18), 25175–25209. https://doi.org/10.1007/s10639-024-12829-2

Schell, J., Ford, K., & Markman, A. B. (2025). Building responsible AI chatbot platforms in higher education: an evidence-based framework from design to implementation. *Frontiers in Education (Lausanne), 10.* https://doi.org/10.3389/feduc.2025.1604934

Wang, J., Sun, D., Yang, Y., & Zheng, Z. (2025). Exploring the developmental trajectory of students' creative thinking and intellectual interaction in a computer-supported collaborative learning environment. *Thinking Skills and Creativity*, 58, 101930.

White, R., & Gunstone, R. (2014). *Probing Understanding.* Routledge. https://doi.org/10.4324/9780203761342

Xu, Y., Hu, L., Zhao, J., Qiu, Z., Xu, K., Ye, Y., & Gu, H. (2025). A survey on multilingual large language models: corpora, alignment, and bias. Frontiers of Computer Science, 19(11), Article 1911362.

Yannier, N., Hudson, S. E., & Koedinger, K. R. (2020). Active Learning is About More Than Hands-On: A Mixed-Reality AI System to Support STEM Education. *International Journal of Artificial Intelligence in Education, 30*(1), 74–96. https://doi.org/10.1007/s40593-020-00194-3

Yeung, R. C. Y., Yeung, C. H., Sun, D., & Looi, C.-K. (2024). A systematic review of Drone integrated STEM education at secondary schools (2005–2023): Trends, pedagogies, and learning outcomes. Computers & Education, 212, 104999. https://doi.org/10.1016/j.compedu.2024.104999

Zheng, Y., Zhang, R., Zhang, J., Ye, Y., Luo, Z., Feng, Z., & Ma, Y. (2024). *LlamaFactory: Unified Efficient Fine-Tuning of 100+ Language Models* (No. arXiv:2403.13372). arXiv. https://doi.org/10.48550/arXiv.2403.13372