

Fostering Entrepreneurial Science Thinking through Technology-Integrated PBEST: An Innovative Model for Elementary Science Learning

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Abstract: Elementary science education needs learning approaches that move beyond conceptual understanding toward the development of useful and value-generating solutions. However, the integration of science learning, digital technology, and entrepreneurship remains limited in elementary education. This study aimed to examine the implementation of Technology-Integrated PBEST as an innovative model for fostering Entrepreneurial Science Thinking (EST) in elementary science learning. A quantitative descriptive approach was employed across six elementary schools. Data were collected using a four-point Likert-scale questionnaire assessing students' responses to the PBEST Model and the EduSciTech Market Simulator, comprising 25 indicators. The results showed very positive responses to both the PBEST Model (93.4%) and the EduSciTech Market Simulator (93.2%), with an overall response of 93.3%. Students particularly responded positively to project engagement, product development, and interactive transaction and product features. These findings provide initial empirical support for Technology-Integrated PBEST as a learning model that connects scientific inquiry, technology-supported learning, solution development, and value creation. The model offers a contextual learning environment with potential to support the development of EST in elementary science education, although further experimental research is needed to establish its effectiveness.

Keywords: Entrepreneurial Science Thinking; Technology-Integrated PBEST; Elementary Science Education

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A. INTRODUCTION

Science education at the elementary school level should extend beyond the acquisition of factual and conceptual knowledge to foster students' abilities to investigate phenomena, identify problems, use evidence, think creatively, and develop solutions to real-world challenges. Inquiry-based learning, STEM, and STEAM have strengthened the orientation of science education toward authentic problem solving and the application of interdisciplinary knowledge (Ferrero et al., 2021). However, a critical challenge remains in enabling students not only to understand scientific knowledge but also to apply it to develop solutions that are useful and value-generating.

Digital technologies provide opportunities to extend such learning experiences by creating environments that support exploration, inquiry, simulation, development, testing,

and evaluation of ideas (Kamarudin et al., 2024). Although technology has been widely used to facilitate observation, data collection, and conceptual understanding, its role as an environment for developing and testing solutions remains underexplored (Yun & Crippen, 2024). Meanwhile, entrepreneurship education provides an orientation toward identifying needs, developing ideas, fostering innovation, making decisions, and creating value. Integrating these perspectives offers an opportunity to connect scientific inquiry with solution development and value creation in elementary science education (Chen & Chen, 2025).

In this study, the integration of science learning and entrepreneurship is conceptualized as Entrepreneurial Science Thinking (EST), defined as students' ability to use scientific knowledge and processes to identify problems and needs, generate science-based ideas, develop and test solutions or products, and recognize the benefits and value generated by those solutions (Sitaridis & Kitsios, 2024; Ahmad & Siew, 2021). EST positions science as the foundation for understanding phenomena and solving problems, while entrepreneurship provides an orientation toward idea development, innovation, solution testing, and value creation. The EST process involves scientific exploration of phenomena, identification of problems or needs, development of ideas grounded in scientific knowledge, development and testing of solutions or products, and evaluation of their benefits and value (Ghafar, 2020).

Although research on technology-enhanced science learning, STEM/STEAM education, and entrepreneurship education continues to expand, these domains have largely been examined separately (Akrami, 2022; Branca et al., 2025; Atmojo et al., 2022). Limited research has investigated the integration of science learning, digital technology, and entrepreneurship within a single pedagogical model explicitly designed to foster Entrepreneurial Science Thinking among elementary school students. This gap highlights the need for a learning model that systematically connects scientific inquiry, technology use, solution development, and value creation within an integrated elementary science learning experience.

To address this gap, this study proposes Technology-Integrated PBEST as an innovative learning model that integrates science, technology, and entrepreneurship into elementary science education. The integration of the EduSciTech Market Simulator provides a simulation-based learning environment in which students can develop ideas, make decisions, test alternatives, and evaluate the benefits and feasibility of science-based solutions. Accordingly, this study aims to examine the implementation of Technology-Integrated PBEST as an innovative model for fostering Entrepreneurial Science Thinking in elementary science education. The model is expected to contribute conceptually by strengthening the framework of EST and pedagogically by integrating scientific inquiry, technology-supported learning, solution development, and value creation into elementary science education.

B. METHOD

This study employed a quantitative descriptive approach to examine students' responses to the implementation of Technology-Integrated PBEST in elementary science education (Thomas & Zubkov, 2023). The study was conducted in six elementary schools serving as model implementation sites. The learning activities integrated project-based learning with the EduSciTech Market Simulator, engaging students in scientific exploration, problem identification, science-based idea development, product creation, testing and refinement, and

evaluation of product benefits and value. In this process, the EduSciTech Market Simulator functioned as a digital simulation environment that supported product exploration, virtual transactions, and the provision of ratings and reviews as forms of feedback.

Data were collected upon completion of the learning activities using a four-point Likert-scale student response questionnaire, ranging from 1 (very poor), 2 (poor), 3 (good), to 4 (very good) (Yamashita, 2022). The questionnaire consisted of two sections designed to assess students' responses to the PBEST Model and the EduSciTech Market Simulator. The PBEST instrument covered five aspects: learning interest, ease of following the PBEST stages, engagement in project activities, opportunities to create and improve products, and the perceived contribution.

Table 1. Student Response Instrument for the PBEST Model

Aspect	Indicator Focus	Number of Items
Interest in learning	Students' interest and enthusiasm in participating in elementary science learning	3
Ease of following the PBEST stages	Students' perceived ease of understanding and following the PBEST stages	3
Engagement in project activities	Students' active participation and engagement in project activities	3
Product development and improvement	Opportunities to design, develop, test, and improve products	2
Benefits for understanding science	Students' understanding of science content and its relevance to real-life contexts	2
Total		13

The EduSciTech Market Simulator questionnaire covered five aspects: visual appeal, ease of navigation and use, clarity of instructions and information, interest in transaction and product features, and the usefulness of ratings and reviews. The instrument comprised 12 indicators.

Table 2. Student Response Instrument for the EduSciTech Market Simulator

Aspect	Indicator Focus	Number of Items
Visual appeal	Students' interest in the visual appearance and design of the simulator	2
Ease of navigation and use	Ease of accessing and using the simulator features	3
Clarity of instructions and information	Clarity of instructions and information provided in the simulator	2

Transaction and product features	Students' interest in transactions, products, and market simulation	3
Ratings and reviews	Usefulness of feedback for evaluating and improving products	2
Total		12

Data were analyzed descriptively by calculating the mean score and percentage for each aspect and categorizing the results according to the predetermined response criteria. The analysis was conducted separately for the PBEST Model and the EduSciTech Market Simulator and subsequently integrated to provide an overall representation of students' responses to Technology-Integrated PBEST. The findings were interpreted in relation to the concept of Entrepreneurial Science Thinking (EST), particularly students' experiences in exploring phenomena, identifying problems, developing science-based ideas, creating and improving products, testing solutions, and considering their benefits and value. As this study employed a student response questionnaire without a pretest-posttest design or control group, the findings were not interpreted as causal evidence of increased EST. Rather, they were considered empirical evidence of students' acceptance and learning experiences, indicating the potential of Technology-Integrated PBEST to support the development of EST.

C. RESULTS AND DISCUSSION

1. Students' Responses to the PBEST Model

Students' responses to the PBEST Model were assessed across five aspects comprising 13 indicators. All aspects were rated within the very positive category. Engagement in project activities received the highest mean score of 3.80 (95.0%), followed by interest in learning and the perceived benefits of the model for understanding science, each with a mean score of 3.76 (94.0%). Opportunities to create and improve products obtained a mean score of 3.72 (93.0%), while ease of following the PBEST stages recorded the lowest mean score of 3.64 (91.0%). The students' responses to the PBEST Model are presented in the following figure.

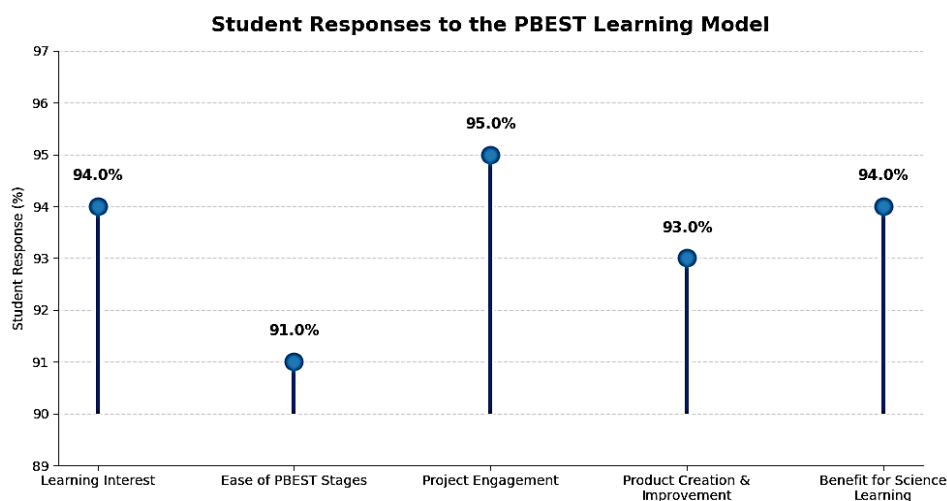


Figure 1. Students' Responses to the PBEST Model

2. Students' Responses to the EduSciTech Market Simulator

Students' responses to the EduSciTech Market Simulator were assessed across five aspects comprising 12 indicators. All aspects were rated within the very positive category. Interest in the transaction and product features received the highest mean score of 3.84 (96.0%). Visual appeal of the simulator and the usefulness of ratings and reviews each obtained a mean score of 3.76 (94.0%). Ease of navigation and use recorded a mean score of 3.68 (92.0%), while clarity of instructions and information received the lowest mean score of 3.60 (90.0%). These findings indicate that students responded particularly positively to the interactive and market-oriented features of the simulator. The students' responses to the EduSciTech Market Simulator are presented in the following figure.

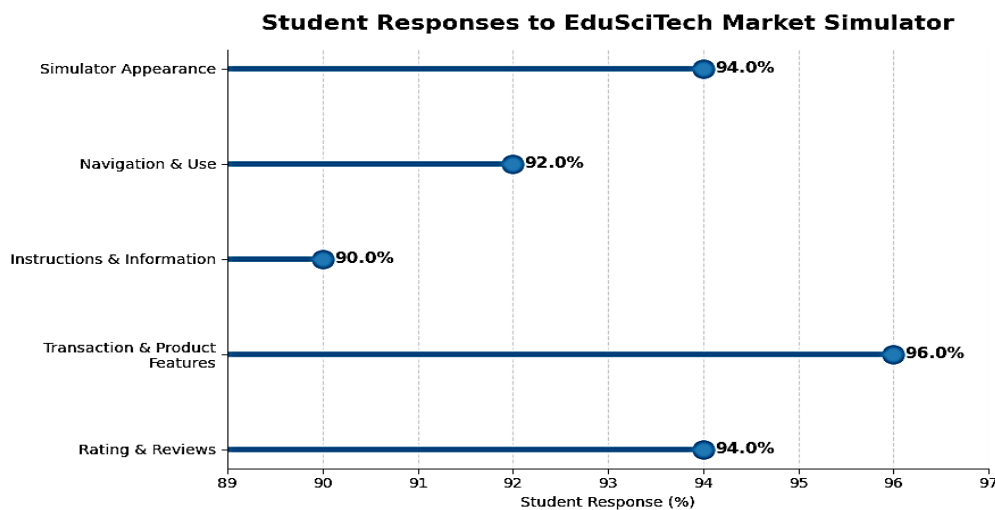


Figure 2. Students' Responses to the EduSciTech Market Simulator

The comparison of the two components shows that the PBEST Model received a slightly higher response than the EduSciTech Market Simulator (93.4% vs. 93.2%), with an overall response of 93.3%. Both components therefore contributed relatively equally to students' positive acceptance of Technology-Integrated PBEST. The PBEST Model achieved a mean score of 3.74 out of 4.00 (93.4%), while the EduSciTech Market Simulator obtained a mean score of 3.73 (93.2%). Overall, the mean score of 3.74 (93.3%) was classified as very positive.

Table 3. Students' Responses to Technology-Integrated PBEST

Component	Number of Indicators	Mean Score	Percentage	Category
PBEST Model	13	3.74	93.4%	Very Positive
EduSciTech Market Simulator	12	3.73	93.2%	Very Positive
Overall Mean	25	3.74	93.3%	Very Positive

The data in Table 3 indicate that students' responses to the two components were highly consistent, with only a 0.2 percentage-point difference between the PBEST Model and the

EduSciTech Market Simulator. For the PBEST Model, engagement in project activities received the highest response (95.0%), whereas ease of following the PBEST stages recorded the lowest (91.0%). For the EduSciTech Market Simulator, interest in transaction and product features received the highest response (96.0%), while clarity of instructions and information recorded the lowest (90.0%). Overall, the Technology-Integrated PBEST achieved a very positive response of 93.3%. These findings provide an empirical basis for further examining how the integration of PBEST and the EduSciTech Market Simulator can support elementary science learning by connecting project-based activities, product development, digital technology, and entrepreneurial experiences.

The findings indicate that Technology-Integrated PBEST received a very positive response from students, with an overall response of 93.3%. The relatively balanced responses to the PBEST Model and the EduSciTech Market Simulator suggest that students' acceptance was associated not only with project-based learning activities but also with the supporting digital learning environment (Anjum et al., 2020; Thanasi-Boçe, 2020). This finding reinforces previous research on technology-integrated inquiry in science education, which indicates that technology can support student engagement, conceptual understanding, thinking skills, motivation, and collaboration when embedded within an appropriate pedagogical design.

The strongest response to the PBEST Model was associated with student engagement in project activities. This finding suggests that active, contextual, and product-oriented learning experiences can provide meaningful opportunities for elementary science learning. Project activities enable students to apply scientific knowledge to understand problems, develop ideas, and formulate solutions. This characteristic is closely aligned with the concept of Entrepreneurial Science Thinking (EST), which positions scientific knowledge as the foundation for problem solving and entrepreneurship as an orientation toward innovation and value creation (Sitaridis & Kitsios, 2024). PBEST therefore provides a learning context in which scientific processes can extend beyond conceptual understanding toward solution development (Rahman et al., 2024). This interpretation is consistent with research on entrepreneurship education emphasizing active learning experiences to foster creativity, innovation, initiative, and entrepreneurial competencies (Rahman, Haifaturrahmah, et al., 2025).

The positive response to opportunities to create and improve products further strengthens the connection between PBEST and EST. Product development enables students to apply scientific knowledge through concrete solutions, while product refinement encourages them to consider outcomes, feedback, and user needs. From an EST perspective, this process represents an important pathway through which scientific knowledge can be transformed into useful and value-oriented solutions. Product development in PBEST thus provides a pedagogical space that connects scientific problem solving with an entrepreneurial orientation (Rahman, Wiranata, et al., 2025).

Within the EduSciTech Market Simulator, students showed the strongest response to the transaction and product features. This finding suggests that the simulation provides an additional context for students to recognize that developed products or solutions involve not only scientific considerations but also their usefulness and acceptance. The rating and review

features further extend this experience by providing feedback on student-generated products. From the EST perspective, such experiences introduce the dimension of value creation by encouraging students to consider the benefits of solutions in relation to user needs and responses (Ahmad & Siew, 2021; Siew & Ahmad, 2023). The EduSciTech Market Simulator therefore functions as a learning environment that extends science learning from exploration and solution development toward the evaluation of solution benefits and value.

The relatively lower responses to the ease of following the PBEST stages and the clarity of instructions in the simulator, although still within the very positive category, highlight the importance of clear instructional guidance. Students require not only engaging technology but also well-structured activities, clear instructions, and adequate support to understand the relationships among different stages of learning. This finding is consistent with research on simulation-based inquiry learning showing that learning effectiveness is influenced by the quality of guidance and the alignment between technological design and pedagogical strategies. Similarly, research on technology-enhanced collaborative inquiry emphasizes that the benefits of technology depend substantially on how it is integrated with learning activities and instructional objectives.

Overall, the findings suggest that Technology-Integrated PBEST provides a learning experience that connects elementary science education, digital technology, and entrepreneurship. Project engagement, product development, market simulation, and the use of ratings and reviews create a learning trajectory in which scientific knowledge is applied to develop and evaluate solutions. This pattern provides initial empirical support for EST as an integrative perspective linking science learning with entrepreneurial orientation. It also extends the role of technology in elementary science education from supporting inquiry activities toward providing an environment in which students can develop, test, and consider the value of solutions.

Importantly, the 93.3% overall response should be interpreted as evidence of students' positive acceptance and learning experiences rather than direct evidence of improved EST. Since the study relied on a student response questionnaire, future research could employ validated EST measures and pretest-posttest, experimental, or mixed-methods designs to examine more directly how Technology-Integrated PBEST contributes to students' ability to integrate scientific knowledge with problem identification, solution development, and value creation.

D. CONCLUSIONS AND SUGGESTIONS

Technology-Integrated PBEST received a very positive response from students, with an overall score of 93.3%. The model integrates project-based science learning with the EduSciTech Market Simulator to provide students with opportunities to explore problems, develop and refine products, and evaluate the benefits and value of proposed solutions. These findings provide initial empirical support for the concept of Entrepreneurial Science Thinking (EST) as an integrated approach that connects science learning with innovation and value creation. The implementation of Technology-Integrated PBEST can be further enhanced by strengthening instructional guidance and enriching the features of the EduSciTech Market Simulator to provide more interactive and contextual science learning experiences. Future

development may also extend the implementation of the model across diverse science topics and elementary school contexts to generate broader and more varied implementation experiences.

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