

Research Article

Development and Preliminary Evaluation of an Outdoor STEM-Based Extracurricular Activity Toolkit for Supporting Grade 6 Students' Entrepreneurial Skills in Problem-Solving, Creative Thinking, and Collaboration

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<https://doi.org/10.69523/sej.2026.42.17377>

Received: 5 May 2026

Revised: 18 August 2026

Accepted: 31 August 2026

ABSTRACT

This study used a convergent mixed-methods design to develop an outdoor STEM-based extracurricular activities toolkit that integrates agricultural enterprise activities with STEM learning and to investigate its preliminary effectiveness in enhancing Grade 6 students' problem-solving, creative thinking, and collaboration skills, components of entrepreneurial skills, over a 5-week period. The participants were 33 Grade 6 students from a public school, enrolled in Semester 1 of the 2025 academic year, selected through cluster sampling. The research tools included expert-validated pre- and post-entrepreneurial skill assessment forms (IOC = 0.80–1.00, Cronbach's α = .85), weekly reflective learning journals, and a student satisfaction questionnaire (IOC = 0.80–1.00, Cronbach's α = .88). Quantitative data were analyzed using descriptive statistics and a dependent t-test, while qualitative data were analyzed using thematic analysis. The developed toolkit consisted of five structured modules (Salad Shop Member, Seedling Grower, Soil Chef, Packaging Designer, and Salad Vendor) and was rated Excellent ($M = 4.83$, $SD = 0.28$) by experts. The findings revealed statistically significant improvements in students' problem-solving ($t = 8.94$, $p = .001$, $d = 1.56$), creative thinking ($t = 9.49$, $p = .001$, $d = 1.65$), and collaboration skills ($t = 6.15$, $p = .001$, $d = 1.07$) after participation. Students also reported very high satisfaction with the activity toolkit ($M = 4.94$, $SD = 0.24$). Preliminary findings suggest that implementing an outdoor STEM-based extracurricular activities toolkit that integrates interdisciplinary knowledge with real-world practice could support primary school students' entrepreneurial skills.

Keywords: Outdoor STEM education, Entrepreneurial skills, STEM activity package, Extracurricular activities

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Introduction

In the 21st century, rapid global changes in economics, technology, and society have necessitated a shift in educational approaches to prepare human resources with the quality and skills required for the modern era [1]. Essential skills include problem-solving, creative thinking, collaboration, and responsible entrepreneurship, which align with Thailand's 20-Year National Strategy (2018–2037) and the National Education Plan (2017–2036) [1]. STEM education—integrating science, technology, engineering, and mathematics—is a widely accepted approach to promoting these essential skills by enabling students to apply what they learn to solve real-life problems [2].

To cultivate these competencies effectively, this study draws on design-based STEM learning and entrepreneurial learning. STEM education provides a strong foundation for entrepreneurial success and prepares students for modern economies. The earlier we integrate entrepreneurial thinking into children's education, the more prepared they will be to start their own ventures in the future [3, 4]. These two fields are interconnected by interdisciplinary relationships that promote creativity and problem-solving skills [4, 5]. Furthermore, STEM is a powerful tool for developing entrepreneurial skills through hands-on learning, enabling students to apply STEM disciplines to create innovations they can use in future careers [6]. Entrepreneurial STEM education involves steps such as setting clear goals, building a strong foundation, taking calculated risks, and persisting through failures [7]. However, classroom-based STEM learning often limits students to curriculum-bound content, overemphasizes theory, and restricts their ability to explore personal interests or apply knowledge in practical environments [8, 9].

To address these limitations, this study utilizes the framework of outdoor education as a valuable alternative. Outdoor STEM education presents a valuable alternative. Outdoor learning offers opportunities to engage with complex problems, using the environment as a learning resource to support contextualized STEM pedagogies [10, 11]. Key aspects of outdoor STEM activities include hands-on challenges that require students to identify authentic problems, design solutions using natural materials, and iterate based on results [12, 13]. Implementing STEM activities in outdoor environments fosters connections to nature, whole-body exploration, and authentic community cooperation [10, 14]. Engaging youth in outdoor STEM subjects through extracurricular activities, summer camps, and clubs has been shown to boost interest, STEM literacy, creativity, and career aspirations [8, 15-19].

To integrate these concepts effectively, primary education must explicitly define 21st-century entrepreneurial skills. While most entrepreneurship research has traditionally focused on higher education, current scholarship indicates that cultivating these competencies should begin at the primary school level (ages 7-12). This period is recognized as a foundational stage for developing essential cognitive and non-cognitive skills, particularly problem-solving, creativity, and collaboration [20, 21]. These three dimensions were selected because they represent the essential developmental building blocks for youth entrepreneurship and can be effectively cultivated through experiential learning

Rooted in experiential learning theory, this approach ensures students actively construct knowledge through direct engagement and reflection. Problem-solving empowers students to evaluate suitable alternatives and address real-world constraints using structured approaches like the Engineering Design Process (EDP) [22-25]. Creative thinking fosters the cognitive flexibility needed to design beneficial innovations and add value to natural resources [22-25]. Finally, collaboration is vital, as successful entrepreneurs must work effectively with diverse teams and share responsibilities [22-25]. Providing a learning environment in which students engage with live

projects is highly beneficial for cultivating these foundational traits [26]. Extracurricular activities serve as a vital form of experiential learning that supplements formal university curricula by immersing students in business environments, raising awareness, and fostering entrepreneurial intentions [27-30]. Diverse extracurricular formats, such as business plan competitions, new product development, and clubs, encourage learning by doing [30, 31].

Building on these theoretical foundations, this study's conceptual framework posits that outdoor STEM learning environments serve as a practical catalyst for entrepreneurial skill development through the systematic application of the EDP and design thinking. By engaging in outdoor agricultural enterprises—such as cultivating seedlings, formulating soil, and designing eco-friendly packaging—students are immersed in authentic, real-world constraints. Within this context, the EDP provides a structured pedagogical pathway: phases such as Problem Identification and Solution Design directly stimulate problem-solving by requiring students to analyze environmental variables and evaluate suitable alternatives. At the same time, the need to add value to natural resources fosters creative thinking and cognitive flexibility. Furthermore, the hands-on, project-based nature of these outdoor challenges inherently necessitates collaboration, as students must share responsibilities, communicate effectively, and work as a cohesive unit to bring a tangible product to market. Consequently, a purposefully designed outdoor STEM toolkit systematically bridges the gap between scientific inquiry and practical business competencies.

While the literature highlights the use of general STEM-based activity packages to support students' career-related skills [32], a significant research gap remains regarding how to operationalize these concepts for younger learners in specific contexts. Previous studies tend to focus on entrepreneurship as a peripheral activity rather than embedding it deeply within a structured, outdoor STEM learning process [28, 30]. Specifically, comprehensive, toolkit-based interventions for primary education are lacking. Furthermore, agricultural enterprise activities are poorly integrated with STEM learning, missing an opportunity to use frameworks such as the EDP and design thinking to connect hands-on agricultural tasks with foundational business competencies.

To address gaps in previous studies, this research bridges agricultural practice and entrepreneurial STEM education. Therefore, this study aims to develop an outdoor, STEM-based extracurricular activities toolkit—centered on agricultural enterprise—to enhance the 21st-century entrepreneurial skills of grade 6 students and to investigate its effectiveness and student satisfaction.

Methodology

This research utilized a Research and Development (R&D) framework based on the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) instructional design model, incorporating a Convergent Mixed-Methods design during the implementation phase. This mixed-methods design was selected to collect quantitative data (skill assessments and satisfaction scores) and qualitative data (reflective journals) simultaneously, integrating both strands in the analysis to provide a comprehensive, cross-validated understanding of the toolkit's effectiveness. The study was divided into two distinct phases: 1) the development phase, focusing on designing, validating, and refining an outdoor STEM-based extracurricular activities toolkit; and 2) the study phase, which examined the toolkit's effectiveness in enhancing students' entrepreneurial skills and their overall satisfaction.

To ensure methodological transparency, Table 1 systematically details the stages, participants, procedures, decision criteria, and concrete revisions made during the development phase.

Table 1 Development phase of the outdoor STEM-based extracurricular activity toolkit.

Stage	Participants	Procedures	Evidence Collected	Criteria Decision	Revisions Made (Concrete Evidence)
1. Design & Drafting	Researcher	Designed the initial 5 activity modules based on the Engineering Design Process (EDP) and primary STEM curricula.	Alignment mapping with Grade 6 entrepreneurial skill indicators.	Content must integrate agricultural enterprise with STEM problem-solving.	N/A (Initial prototype generated).
2. Expert Validation	5 experts (science education, primary curriculum, educational innovation)	Experts assessed the content's accuracy, age-appropriateness, instructional design, and safety protocols using a 5-point Likert scale.	Quantitative ratings (<i>M</i> , <i>SD</i>) and qualitative written feedback.	Mean score ≥ 3.50 and IOC ≥ 0.50 for all criteria.	The toolkit was revised based on expert feedback. For example, the teacher manual explicitly added safety protocols for handling agricultural tools, and the grading rubric was clarified.
3. Pilot Testing	33 comparable Grade 6 students	Conducted a trial run of the revised toolkit prior to formal implementation.	Observational data on time allocation, student engagement, and task comprehension	Activities must be completed safely within the allocated time (1 to 4 hours per module).	Adjusted the appropriateness of the language, content, and time allocation. Specifically, the vocabulary in the student workbook was simplified to a grade 6 reading level, and an additional 30 minutes was allocated to the "Soil Chef" module.

Participants

In the development phase, the participant group included a validation panel consisting of five experts. Their expertise encompassed science education, primary curriculum and instruction, and educational innovation. The researchers purposively selected these experts based on strict criteria: advanced academic qualifications in their respective fields and at least 5 years of direct professional experience in STEM curriculum development, experiential learning, or pedagogical evaluation. Their primary role in validating the toolkit was to rigorously assess the content's accuracy, age-appropriateness, instructional design, and safety protocols for the "Growing Salad Seedlings" activities.

In the study phase, participants were selected systematically at the school and classroom levels. First, a public primary school under the Office of the Basic Education Commission (OBEC) in Nonthaburi Province was purposively selected because it actively supports extracurricular enterprise projects, specifically the "Goodness Creation Company" [33].

Second, the sampling frame for classroom selection consisted of all Grade 6 students enrolled in the selected school during semester 1 of the 2025 academic year. Out of 3 available Grade 6 classes, one intact classroom was selected through cluster sampling. Inclusion criteria required students to be willing and able to participate throughout the full 5-week activity period, be active members of the school's enterprise activity, and have obtained formal written parental consent.

The selected classroom yielded an initial sample of 33 Grade 6 students (19 males, 14 females; average age = 12.76 years). Throughout the 5-week intervention period, there was no participant attrition (0% dropout rate); therefore, the final analytical sample remained at 33 students. To ensure data validity and prevent testing effects, a separate group of 33 comparable Grade 6 students from a different classroom was used exclusively to pilot-test the toolkit before formal implementation with the target group.

The study followed strict ethical procedures throughout. The Ethics Committee of the University of Nonthaburi, Thailand, reviewed and approved the research protocol and data collection procedures (Approval number: PIM-REC 063/2567). All participants and their parents were fully informed about the study's objectives, data confidentiality, and their right to withdraw at any time without penalty.

Research Instruments and Data Collection Procedure

Developing the outdoor STEM-based extracurricular activity toolkit to enhance 21st-century entrepreneurial skills involved deploying specific research instruments systematically across the two phases of the study.

Initially, in the development phase, the researcher designed the Outdoor STEM-Based Extracurricular Activity Toolkit titled "*Growing Salad Seedlings*". This core instrument included a student workbook (with instructions, knowledge sheets, and worksheets) and a comprehensive teacher manual (detailing lesson plans and procedures) covering five themed activities: Salad Shop Member, Seedling Grower, Soil Chef, Packaging Designer, and Salad Vendor. To collect validation data, experts utilized the Activity Toolkit Appropriateness Evaluation Form, a 5-point Likert scale designed to assess the suitability of both the student and teacher components. Based on the experts' quantitative ratings and qualitative feedback, the researcher revised the toolkit accordingly. The researcher then piloted the revised activities with a separate group ($n = 33$) to assess

the appropriateness of the language, content, and time allocation before implementing them with the target group.

During the formal implementation of the learning activities with the target group, the researcher collected data using three specific assessment instruments at different stages of the learning process to ensure the integration of quantitative and qualitative strands:

1. **Entrepreneurial Skills Assessment Form:** Data on students' baseline and developed competencies were collected by administering this instrument across two scoring occasions: immediately before the intervention (pre-test) and upon completion of the 5-week activities (post-test). It consisted of 15 items targeting three core dimensions (5 items per category): problem-solving (e.g., "*Identifies alternative materials to solve structural issues*"), creative thinking (e.g., "*Designs unique eco-friendly packaging*"), and collaboration skills (e.g., "*Actively listens to group members and shares responsibilities*"). The expert panel established content validity, yielding an Item-Objective Congruence (IOC) index ranging from 0.80 to 1.00. In addition, to measure the extent to which the two independent human raters assigned the same scores to the same student performances, we calculated an Intraclass Correlation Coefficient (ICC). The ICC was .89, indicating excellent inter-rater reliability and confirming that evaluators applied the scoring architecture consistently.

2. **Weekly Reflective Learning Journal:** To capture continuous qualitative data throughout the implementation, individual students completed this open-ended form after each week's activity. This allowed the researcher to track students' reflections on what they learned, the obstacles they encountered, how they solved them, and their ongoing suggestions. The qualitative data were analyzed using Thematic Analysis. The coding procedure systematically progressed through three stages: open coding to identify initial recurring concepts in the students' writings, axial coding to group these concepts into related categories (e.g., design iteration, teamwork challenges), and selective coding to synthesize the categories into overarching core themes. To ensure qualitative credibility, the analysis employed data triangulation and member checking.

3. **Student Satisfaction Questionnaire:** Upon completing the full implementation of the toolkit, data regarding the learners' overall experience were collected using this instrument. The questionnaire comprised 15 closed-ended items on a 5-point Likert scale, evaluating key areas such as satisfaction with the content, enjoyment, perceived real-life application, time allocation, and the inspiration gained from the toolkit. The expert panel verified the instrument's content validity (IOC = 0.80-1.00), and reliability was confirmed with a Cronbach's alpha of .88.

The study protocol and all data collection procedures were reviewed and approved by the Ethics Committee of the university in Nonthaburi, Thailand (Approval number: PIM-REC 063/2567).

Intervention Procedure

The formal intervention took place over a 5-week period, structured through a strict week-by-week implementation schedule: Week 1 introduced youth entrepreneurship via the "*Salad Shop Member*" module; Week 2 focused on agricultural basics in "*Seedling Grower*"; Week 3 engaged students in environmental problem-solving as the "*Soil Chef*"; Week 4 required design thinking for the "*Packaging Designer*" module; and Week 5 culminated in real-world sales during the "*Salad Vendor*" module.

Students were organized into heterogeneous groups of 4 to 5 members to foster peer collaboration and distribute project responsibilities evenly. The teacher's role shifted from a traditional instructor to a facilitator, guiding students through the EDP rather than providing direct answers. The primary outdoor learning setting was the school's designated agricultural plot. Consequently, the team enforced strict safety procedures, including weekly briefings on proper handling of agricultural tools, weather precautions, and post-activity hygiene protocols. In addition, the team actively maintained fidelity monitoring throughout the 5-week period using a buddy teacher system; peer educators observed the outdoor sessions using a standardized checklist and participated in weekly Professional Learning Community (PLC) reflection meetings to ensure the intervention strictly adhered to the designed lesson plans. An overall intervention fidelity score of 94% confirmed that the sessions were implemented highly consistently with the designed instructional protocols and time allocations.

Data Analysis

In the development phase, expert evaluation scores were analyzed using descriptive statistics, specifically mean (*M*) and standard deviation (*SD*), and compared against predefined criteria to determine the toolkit's appropriateness. The mean scores were interpreted using a five-level scale: 4.21–5.00 = Excellent; 3.41–4.20 = Very good; 2.61–3.40 = Good; 1.81–2.60 = Fair; and 1.00–1.80 = Needs improvement.

For the study phase, the integration of both research strands occurred during the analysis and interpretation stages. The assessment consisted of 15 items targeting three core dimensions of entrepreneurial skills (5 items per category). Each item was scored using a 4-point performance evaluation rubric, resulting in a maximum possible score of 20 points per dimension. The scoring criteria explicitly specified that a dimension score in the 14–17 range indicated a "Good" level of competency for the STEM project outcomes. Representative rubric descriptors for the highest performance level (4 points) across the three dimensions included: Problem-solving: Systematically identifies and evaluates alternative natural materials to resolve structural and agricultural issues under authentic resource constraints. Creative thinking: Designs highly unique, eco-friendly packaging that demonstrates cognitive flexibility and significantly adds market value to the raw agricultural product. Collaboration skills: Actively listens to group members, equitably shares responsibilities, and successfully coordinates as a cohesive unit to bring a tangible product to market. To minimize subjective bias, two independent evaluators with advanced degrees and extensive experience in STEM education conducted the performance assessments. Before formal evaluation, these raters underwent rigorous training, including calibration sessions using pilot study data. Raters independently scored pilot performances and discussed discrepancies until they reached a consensus of over 90% agreement. During the formal study phase, strict blinding procedures were enforced; evaluators received anonymized performance data and were completely blind to the scoring occasion (i.e., they were unaware whether they were evaluating pre-test or post-test results). Before conducting inferential statistics, the researchers tested assumptions on the difference scores (post-test minus pre-test). The Shapiro-Wilk test confirmed the normality of the difference-score distributions for problem-solving ($W = 0.95$, $p = .124$), creative thinking ($W = 0.97$, $p = .285$), and collaboration skills ($W = 0.96$, $p = .182$). We analyzed students' quantitative entrepreneurial skill scores using means and standard deviations, and used a paired-samples t-test to determine the statistical significance of differences between pre- and post-

activity scores at the .05 level. To determine the practical significance and magnitude of the intervention's impact, effect sizes were calculated using Cohen's *d*.

Satisfaction questionnaire data were similarly analyzed using means and standard deviations to interpret the overall level of student satisfaction. To ensure rigorous precision when capturing negative feedback in the specific table contexts, the interpretation criteria strictly defined "Dissatisfaction" as falling within the ranges 0.00–0.80 or 1.00–1.50, depending on the table's formatting.

To triangulate the quantitative findings, the researchers analyzed qualitative data from the reflective journals using thematic analysis. To ensure credibility, two researchers independently coded the raw data and held peer-debriefing sessions to resolve discrepancies and reach a consensus. The findings were further validated through data triangulation—by cross-verifying reflections with quantitative scores—and member checking with students. The analysis progressed through three stages: open coding to identify initial concepts line by line, axial coding to group these codes into related categories, and selective coding to synthesize them into overarching core themes. For instance, a raw excerpt stating, "Designing packaging using banana leaves... after reinforcing it with bamboo strips, it became sturdier," was assigned an open code for "material reinforcement." This was grouped into an axial category of "design iteration and product improvement," ultimately forming the core theme of "creative problem-solving and design thinking." Finally, these qualitative themes were integrated with the quantitative results to provide deeper context for the statistical outcomes.

Results

Toolkit Development and Validation

The developed toolkit consisted of five thematic modules focusing on hands-on agricultural and entrepreneurial experiences (Table 2). The modules followed a six-step outdoor STEM process: Problem Identification, Related Information Search, Solution Design, Planning and Development, Testing and Improvement, and Presentation.

Table 2 The activity modules in the outdoor STEM-based extracurricular activities toolkit

Activities	Duration (hours)	Details
1. Salad shop member	1	Learning plant basics and youth entrepreneurship. Naming the vegetable shop and explaining the concept.
2. Seedling grower	2	Prepare materials, cultivate salad seedlings, and design a growth record chart.
3. Soil chef	4	Experimenting with organic materials (animal manure, rice husks) to create optimal soil mix formulas and solve soil quality issues.
4. Packaging designer	4	Designing eco-friendly packaging using natural materials like banana leaves. Practicing design thinking and cost calculation.
5. Salad vendor	4	Creating value-added food menus (e.g., vegetable pizza). Learning the 4Ps marketing concept, pricing strategies, and sales.

The formal intervention took place over a 5-week period and delivered a total intended intervention dosage of 15 hours. The activities were conducted during one student club session per week, with session lengths varying from 1 to 4 hours, depending on the specific module requirements detailed in Table 2. Attendance was recorded throughout the study, and students had zero absences. Consequently, students received the full 15-hour intervention dosage.

The schedule was structured through a strict week-by-week implementation: Week 1 introduced youth entrepreneurship via the "Salad Shop Member" module; Week 2 focused on agricultural basics in "Seedling Grower"; Week 3 engaged students in environmental problem-solving as the "Soil Chef"; Week 4 required design thinking for the "Packaging Designer" module; and Week 5 culminated in real-world sales during the "Salad Vendor" module. Students were organized into heterogeneous groups of 4 to 5 members to foster peer collaboration and distribute project responsibilities evenly. The teacher's role shifted from a traditional instructor to a facilitator, guiding students through the EDP rather than providing direct answers. The primary outdoor learning setting was the school's designated agricultural plot. Consequently, the team enforced strict safety procedures, including weekly briefings on proper handling of agricultural tools, weather precautions, and post-activity hygiene protocols.

The panel of 5 experts evaluated the toolkit and rated it "Excellent" for overall appropriateness ($M = 4.83$, $SD = 0.28$), with the safety aspect receiving the highest rating ($M = 5.00$, $SD = 0.00$), as shown in Table 3.

Table 3 Summary of the experts' rating on the appropriateness of the outdoor STEM-based extracurricular activities toolkit.

Components	<i>M</i>	<i>SD</i>	Description
1. The appropriateness of the activity toolkit for the students' age, interests, and ability levels.	4.55	0.50	Excellent
2. Clarity of the manual and accompanying materials	4.95	0.22	Excellent
3. Interest and creativity of the activities	4.80	0.40	Excellent
4. Safety aspect	5.00	0.00	Excellent
Overall rating	4.83	0.28	Excellent

Effectiveness on 21st-Century Entrepreneurial Skills

Students demonstrated statistically significant improvements in all three 21st-century entrepreneurial skills ($p < .05$). As shown in Table 4, post-test scores were significantly higher than pre-test scores across all domains.

Table 4 Descriptive statistics and t-test results of students' entrepreneurial skills pre- and post-learning activities. ($n = 33$)

21st-century Entrepreneurial Skills	Measurement period	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>t</i>	<i>p</i>
Problem-solving skills	Posttest	4.57	0.53	0.09	8.94	.001
	Pretest	3.90	0.68	0.12		
Creative thinking skills	Posttest	4.56	0.47	0.08	9.49	.001
	Pretest	3.70	0.66	0.11		
Collaboration Skills	Posttest	4.54	0.48	0.08	6.15	.001
	Pretest	3.92	0.73	0.13		

Note: $\alpha = .05$

To determine the practical significance of the toolkit, we calculated effect sizes using Cohen's d ; all domains showed large effect sizes ($d > 0.8$), confirming the substantial efficacy of the outdoor STEM activities (see Table 5).

Table 5 Mean differences and effect sizes of students' entrepreneurial skills pre- and post-learning activities. ($n = 33$)

21 st -century Entrepreneurial Skills	Mean Difference (<i>MD</i>)	SD of Differences (<i>SDD</i>)	<i>df</i>	<i>t</i> -value	<i>p</i> -value	Effect Size (<i>d</i>)	95% CI for the mean difference
Problem-solving skills	0.67	0.43	32	8.94	.001	1.56	[0.52, 0.82]
Creative thinking skills	0.86	0.52	32	9.49	.001	1.65	[0.68, 1.04]
Collaboration Skills	0.62	0.58	32	6.15	.001	1.07	[0.41, 0.83]

Based on the research findings, the outdoor STEM-based activity toolkit effectively enhances 21st-century entrepreneurial skills among primary school students, particularly in problem-solving, creative thinking, and collaboration. Large effect sizes across all domains ($d > 0.8$) confirm the intervention's substantial impact. A critical interpretation of the toolkit's modules, integrating quantitative outcomes with qualitative reflections, demonstrates how specific experiential activities directly catalyzed the cognitive and behavioral development of these skills rather than merely providing enjoyable experiences.

Theme 1: Systematic Problem Analysis and Material Experimentation For problem-solving skills, students improved significantly ($t = 8.94$, $p = .001$, $d = 1.56$) by actively engaging with authentic environmental constraints. During the "Soil Chef" module, students were challenged to diagnose soil quality issues and systematically experiment with organic materials, such as animal manure and rice husks, to formulate optimal soil mixes. Qualitative data from the reflective journals strongly supported this statistical improvement through the theme of *Systematic Problem Analysis and Material Experimentation*. Rather than just expressing enjoyment (e.g., "...The activity was fun. I learned about growing seedlings and solving problems..." - S04, March 25, 2025), students detailed their application of the Engineering Design Process (EDP) to evaluate and

iterate on physical results. For instance, one student demonstrated constraint analysis by noting, *"When we touched the soil in the garden plot, it was very hard and clay-like, which would make it difficult for our salad seedling roots to grow."* (S12, March 13, 2025). Furthermore, another student's ability to formulate and test alternative solutions was evident when they reflected, *"Our first soil mix held too much water and became muddy. We solved this by changing our formula and adding more rice husks to help the water drain faster."* (S08, March 13, 2025). This aligns with Raupp, who emphasized that meaningful STEM learning occurs when students apply hands-on experiences to solve authentic problems.

Theme 2: Cognitive Flexibility and Iterative Value Creation. For creative thinking skills, the toolkit successfully nurtured cognitive flexibility ($t = 9.49$, $p = .001$, $d = 1.65$), particularly through the "Packaging Designer" activity. Rather than passively absorbing information, students practiced design thinking by transforming local natural materials, like banana leaves and bamboo strips, into eco-friendly packaging. The qualitative theme of *Cognitive Flexibility and Iterative Value Creation* strongly corroborated these high scores. The iterative design and improvement process was clearly articulated by a student who focused on structural adaptation: *"Designing packaging using banana leaves to make a carry bag — at first it wasn't strong, but after reinforcing it with bamboo strips, it became sturdier"* (S03, March 19, 2025). Furthermore, this cognitive flexibility extended to recognizing market potential, as the necessity to add value to agricultural products directly stimulated their ability to design unique innovations. Another student noted the conceptual transformation of raw goods: *"... I liked this activity, especially adding value to salad vegetables by making food to sell ..."* (S02, March 26, 2025). To further illustrate the breadth of creative ideation, another group reflected on their conceptualization phase, stating, *"At first, our group thought about just wrapping the salad in a single banana leaf, but we realized the vegetables might get crushed. Then we brainstormed making a hard box out of bamboo, but it would take too long to weave. Finally, we decided to fold the banana leaves into a basket shape and use bamboo strips to make a strong handle, which is unique and makes it easy for customers to carry"* (S06, March 19, 2025). While prior studies highlight cognitive flexibility in general STEM design tasks, this study analytically demonstrates that linking design thinking directly to economic viability (e.g., adding value to agricultural products for a market) creates a specific pragmatic constraint that uniquely drives creative ideation, distinguishing it from purely artistic or theoretical STEM exercises.

Theme 3: Interdependence and Role Distribution in Team Enterprises. Finally, because entrepreneurial success inherently relies on teamwork, collaboration skills improved significantly ($t = 6.15$, $p = .001$, $d = 1.07$). This was systematically structured throughout the 5-week intervention by organizing students into heterogeneous groups of 4 to 5 members to distribute project responsibilities. In the culminating "Salad Vendor" module, students had to communicate effectively, share responsibilities, and work as a cohesive unit to execute pricing strategies and sell value-added menus, such as vegetable pizza. Qualitative reflections revealed the theme of Interdependence and Role Distribution in Team Enterprises. Navigating real-world applications—from soil preparation to final sales—inherently fostered a collaborative environment where peer reliance was essential. The need for shared responsibility became clear when one student noted, *"In our group, we divided the work so everything ran smoothly. Two friends made the vegetable pizzas, one person invited customers to our booth, and I was in charge of calculating the money and giving change"* (S05, March 26, 2025). Additionally, reflections showed growth in interpersonal communication and conflict resolution, such as, *"At*

first, we argued about the price of our salad because some wanted to sell it cheap to get more customers, but others said we wouldn't make a profit. We sat down, calculated our material costs together, and finally agreed on a fair price that everyone was happy with" (S18, March 19, 2025). Whereas prior research largely linked outdoor STEM to general community needs, our toolkit specifically operationalizes these activities into a structured collaborative business pipeline—from seedling cultivation to marketing concepts such as the 4Ps—thereby systematically bridging the gap between scientific inquiry and foundational business competencies.

Student Satisfaction

Students expressed "Very high satisfaction" with the toolkit overall ($M = 4.94$, $SD = 0.24$). The culminating "Salad Vendor" activity received the highest rating ($M = 4.94$), indicating it effectively addressed students' interests, as shown in Table 5.

Table 5 The satisfaction evaluation showing students' satisfaction levels toward the outdoor STEM-based extracurricular activities toolkit.

Question items	<i>M</i>	<i>SD</i>	Description
1. How satisfied are you with Activity 1 (Salad shop member)?	4.73	0.45	Very high satisfaction
2. How satisfied are you with Activity 2 (Seedling grower)?	4.73	0.62	Very high satisfaction
3. How satisfied are you with Activity 3 (Soil mix expert)?	4.73	0.62	Very high satisfaction
4. How satisfied are you with Activity 4 (Packaging designer)?	4.79	0.48	Very high satisfaction
5. How satisfied are you with Activity 5 (Salad vegetable seller)?	4.94	0.24	Very high satisfaction
6. How appropriate and suitable is the difficulty level of the activities for your grade level?	4.67	0.54	Very high satisfaction
7. Did you enjoy learning through this activity toolkit?	4.94	0.24	Very high satisfaction
8. Do you think this toolkit is helpful for your learning and real-life application?	4.82	0.46	Very high satisfaction
9. Are the workbook and materials in the activity toolkit appropriate for completing the activities?	4.76	0.50	Very high satisfaction
10. This activity increased my interest in gardening and agriculture.	4.58	0.70	Very high satisfaction
11. This toolkit benefits our school's "Doing Good Company" project.	4.70	0.63	Very high satisfaction

Table 5 The satisfaction evaluation showing students' satisfaction levels toward the outdoor STEM-based extracurricular activities toolkit. (*cont.*)

Question items	<i>M</i>	<i>SD</i>	Description
12. The activity period of the project was appropriate.	4.76	0.56	Very high satisfaction
13. Participating in this activity made me feel proud of myself.	4.67	0.59	Very high satisfaction
14. How satisfied are you with the overall content of the activity toolkit?	4.94	0.24	Very high satisfaction
15. How satisfied are you with the overall organization of the activities?	4.91	0.29	Very high satisfaction
Overall rating	4.77	0.33	Very high satisfaction

Regarding student satisfaction with the activity toolkit, the satisfaction survey revealed that students were highly satisfied, with average item ratings ranging from 4.67 to 4.94. Qualitative data gathered from student reflective journals further corroborated these quantitative scores, demonstrating that participants found the modules fun, engaging, hands-on, and directly applicable to real-life situations. Students frequently highlighted the practical and enjoyable nature of the experiential tasks through specific qualitative comments, such as:

"...The activity was fun. I learned about growing seedlings and solving problems..." (Student S04) *"...I liked this activity, especially adding value to salad vegetables by making food to sell..."* (Student S02)

These qualitative accounts illustrate that the toolkit successfully cultivated positive student engagement, fostering both enthusiasm for agricultural practices and a deeper appreciation for real-world entrepreneurial problem-solving.

Discussion

The findings indicate that participation in the outdoor STEM-based extracurricular toolkit is associated with preliminary changes in Grade 6 students' 21st-century entrepreneurial skills, specifically problem-solving, creative thinking, and collaboration. The large effect sizes ($d > 0.8$) suggest that the toolkit is positively correlated with students' developmental progress. However, these results should be interpreted by integrating quantitative and qualitative data to understand these preliminary changes, rather than concluding a direct causal relationship.

For analytical comparison with prior research, this study compares these findings with existing conceptual frameworks rather than treating them as mere validation of established literature. For instance, regarding problem-solving, while Raupp [34] emphasizes that meaningful STEM learning stems from solving authentic problems, this study advances this concept by operationalizing it under strict agricultural and economic constraints. In the "Soil Chef" module, students did not merely solve theoretical problems but were required to manage resources under empirical conditions. Similarly, while Arranz et al. [31] discuss the impact of

extracurricular activities on entrepreneurial attitudes, this study finds that linking design thinking processes to the "commercial viability" of agricultural products (e.g., value-added creation) critically drives cognitive flexibility. This distinguishes the process from purely artistic tasks or traditional classroom-based STEM exercises. Regarding collaboration, this toolkit moves students from general peer cooperation to a "structured collaborative business pipeline," aligning with the concepts of live project-based learning proposed by Chang and Rieple [25], while requiring more intensive role distribution than real-world work environments.

While the preliminary results show positive trends, interpreting the factors influencing skill development must account for several alternative explanations. First, testing effects suggest that the observed improvement in scores may reflect students' familiarity with the assessment rubrics after exposure to the measurement tools during the pre-test phase. Second, maturation suggests that the observed development could be attributed to the natural cognitive and social growth of Grade 6 students over the 5-week period, rather than the toolkit alone. Third, the novelty effect implies that the outdoor learning environment may have generated temporary motivation and excitement, which could potentially diminish as the activities become routine. Fourth, evaluator expectancy remains a factor: despite blinding procedures, evaluators' awareness of the project's objectives may have inadvertently led to unconscious bias in scoring post-intervention performance. Fifth, social desirability bias suggests that student reflective journals may be biased, as students might have written responses, they believed educators wanted to hear to conform to a positive learning environment. Finally, a ceiling effect could be present since pre-test scores were relatively high (e.g., 3.92 out of 5 for collaboration), meaning the outcome measurement may face statistical limitations; because the sample already possessed strong baseline skills, detecting further significant development becomes inherently more difficult. Consequently, the results of this study reflect preliminary changes associated with the activities, but do not permit definitive causal inference due to the limitations of a single-group research design. Future studies should address these factors by using experimental designs with control groups to substantiate these conclusions more reliably.

Recommendations

To implement the outdoor STEM-based extracurricular activity toolkit effectively, several practical steps are advised.

First, effective teacher preparation is crucial; educators must shift from traditional instructors to EDP facilitators. Schools should provide targeted professional development focused on experiential learning facilitation, training educators to guide student inquiry, manage group dynamics, and support problem-solving processes without supplying direct answers.

Furthermore, schools can adapt this agricultural toolkit to diverse local contexts by substituting salad seedlings with regionally relevant crops or local materials, ensuring the activities remain culturally and geographically appropriate.

Given the outdoor setting, schools must also establish and enforce strict safety and resource protocols. Schools must conduct mandatory briefings on the proper handling of agricultural tools, weather precautions, and post-activity hygiene. Additionally, administrators must secure adequate resources, such as designated garden plots and necessary raw materials, before implementation.

Finally, curriculum developers should embed these outdoor STEM entrepreneurial activities directly into existing science, mathematics, or basic vocational subjects. Integrating these modules into the formal curriculum, rather than treating them solely as peripheral extracurriculars, will help to significantly broaden students' perspectives on entrepreneurship.

To build on the preliminary associations identified in this study, future research must address several methodological limitations. Future studies should employ experimental or quasi-experimental designs with explicit comparison or control groups to establish definitive causality regarding the toolkit's effectiveness. Researchers should use larger sample sizes, address school-selection bias by recruiting across diverse urban and rural settings, and account for possible ceiling effects by using instruments sensitive to high baseline competencies. Moreover, future investigations must establish rigorous evaluation standards by explicitly reporting inter-rater reliability, mitigating evaluator bias through strict blinding and independent scoring, and providing clear, transparent evidence of intervention fidelity. Finally, longitudinal follow-up studies remain essential for evaluating the long-term retention and continued development of students' entrepreneurial skills, while incorporating externally validated, performance-based assessments to objectively measure 21st-century skills and reduce reliance on self-report measures.

Conclusion

This study concludes that the developed outdoor STEM-based extracurricular activity toolkit, centered on agricultural enterprise, provides preliminary, context-specific evidence of improvement associated with participation in enhancing primary school students' 21st-century entrepreneurial skills. The key findings show that participation in the five-module toolkit coincided with statistically significant improvements, characterized by large effect sizes, in Grade 6 students' problem-solving, creative thinking, and collaboration skills. Furthermore, quantitative and qualitative data revealed that students reported very high overall satisfaction ($M = 4.77$, $SD = 0.33$), which appeared linked to the engaging, hands-on nature of the real-world activities.

This research's primary contribution is successfully operationalizing entrepreneurial STEM education for younger learners in a specific outdoor agricultural context. While previous studies often treat entrepreneurship as peripheral, this research systematically bridges the gap between scientific inquiry and practical business competencies by embedding the EDP directly into a structured business pipeline—from seedling cultivation to marketing and sales. Ultimately, this study provides empirical evidence that integrating interdisciplinary STEM knowledge with authentic, contextualized extracurricular practices is a viable pedagogical approach associated with cultivating foundational entrepreneurial traits in primary education. However, given the study design, readers are explicitly reminded that alternative explanations—such as testing effects, maturation, novelty, evaluator expectancy, social desirability, and high initial scores—cannot be excluded. Successful, broader implementation still requires careful consideration of practical resources, teacher preparation, and safety protocols, alongside further rigorous experimental validation to establish causality.

Acknowledgements

The authors thank the Faculty of Education at Kasetsart University for academic support. We also thank the experts and participating schools in Nonthaburi province for their active involvement in the "Goodness Creation Company" project.

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