REIMAGINING HIGH SCHOOL ENTREPRENEURSHIP EDUCATION IN THAILAND: AN AGILE, DATA-DRIVEN, AND HUMAN-CENTERED APPROACH

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Highlights

The 5-stage PDTPE model successfully integrates Agile Learning, Data Science Processes, and Design Thinking into upper secondary STEM education, achieving high expert-validated utility and pedagogical quality. In a six-week quasi-experimental evaluation, Grade 11 students using the framework demonstrated significantly higher academic achievement and enhanced multidimensional entrepreneurial competencies—specifically in leadership, execution skills, and innovative adaptability—compared to those receiving conventional instruction.

Abstract

This study developed, validated, and evaluated an integrated Agile Learning model to enhance academic achievement and entrepreneurial competency in Thai secondary STEM (Science, Technology, Engineering, and Mathematics) education. Grounded in Social Constructivism and Experiential Learning Theory, the quasi-experimental design research used a two-phase developmental design. Phase 1 evaluated model quality (incorporating Data Science Processes and Design Thinking—designated as the Problem Framing, Data-Driven Ideation, Team-Based Development, Presentation and Feedback, Evaluation and Scaling (PDTPE) Model), via a nine-expert panel. Phase 2 employed a quasi-experimental pretest-posttest control group design with 75 Grade 11 students (experimental = 38; control = 37) over six weeks. Tools used were a quality evaluation form ("IOC" = 0.60-0.90), a 36-item entrepreneurial competency scale (α = 0.98), and a 40-item achievement test ("KR-20" = 0.94). The data gathered were tested using t-tests and effect sizes. Results showed that the experts' assessment of the overall model (M=4.45; SD=0.41) was at a high level. Among the factors being assessed, the one with the highest evaluation was utility (M=4.56). At post-intervention, the experimental group demonstrated substantial gains in learning ($t = 20.97$, $p < .01$), significantly higher posttest achievement than the control group ($t = 2.19$, $p < .01$), and greater entrepreneurial competency ($M = 4.01$ vs. 3.58, $t = 6.50$, $p < .01$). The PDTPE model offers an empirically validated framework for fostering 21st-century entrepreneurial capabilities in secondary schools.

Keywords

agile learning, data science processes, design thinking, entrepreneurial competency, secondary technology education, upper secondary school students.

Introduction

Driven by the Fourth Industrial Revolution (4IR), secondary education has evolved its pedagogical approach to meet the needs of future work readiness in the 21st-century economy. In light of this fast-changing technological environment, which has contributed to the elimination of jobs, the education system in the world now faces the dilemma of producing secondary education graduates with not only technological proficiency but also problem-solving capabilities, leadership skills, and entrepreneurship traits (Bacigalupo et al., 2016; Thelma et al., 2024).

Fortunately, there is international recognition of the importance of developing an entrepreneurial mindset in adolescence as an accelerator of socio-economic mobility, innovation, and resilience (Chen, 2025). Moreover, smart learning environments combine advanced technologies with adaptive teaching to provide personalized learning experiences (Nguyen et al., 2026). This issue has support in Thailand due to policies being implemented through the 20-Year National Strategy of Thailand (2018-2037) and the National Education Standards, where it is stated that secondary school curricula now need to focus on turning students into innovative co-creators with digital skills, financial understanding, and leadership skills (Chen, 2025; Wannapiroon & Pimdee, 2022).

Despite these ambitious national mandates, traditional secondary STEM (Science, Technology, Engineering, and Mathematics) education is often associated with numerous teaching challenges (Angmani et al., 2025; Sumarno et al., 2023). Traditional secondary classes, such as Thailand's required upper secondary STEM class Technology 3 (Design and Technology), have largely used traditional teacher-led methods of delivery (Institute for the Promotion of Teaching Science and Technology, 2019). As such, classroom instruction delivery usually involves step-by-step laboratory exercises, individual coding lessons, or theory lessons that shield the learners from challenging and uncertain problem environments (Pimdee et al., 2024).

Although direct instruction may promote the immediate recall of basic computer concepts, it often provides students with limited opportunities to participate in authentic problem-solving, learn from failure, make independent decisions, or apply user-centered design principles (Parsons & MacCallum, 2019). Consequently, students may enter tertiary education or the workforce with limited practical experience, confidence, and adaptability in addressing real-world technological challenges (Sumarno et al., 2023).

To overcome the above-mentioned gaps, the teaching approach used in STEM education at the secondary level must go beyond the mere use of software and embrace an integrated model of entrepreneurial competency (Sumarno et al., 2023). Generally speaking, entrepreneurship competency at the secondary education level is more than just making and marketing a product (Ndjama & Mokoena, 2026); rather, it is the set of various qualities that include tactical entrepreneurial competence, team-based execution of leadership, and innovative adaptation under changing limitations (Angmani et al., 2025; Bacigalupo et al., 2016). Therefore, the development of the above-mentioned diverse qualities requires an interactive approach that includes project management and data analysis along with empathic creativity.

Therefore, this paper addresses this pedagogical demand by combining three distinct yet complementary approaches into a single instructional framework. These include Agile Learning, Data Science Processes, and Design Thinking (Promsiri et al., 2022). Agile Learning is an approach that draws on the flexible software development practice in which project implementation is divided into short, repetitive work periods known as "sprints" (Aljehani & Qureshi, 2025). It deconstructs the classroom-based power relationship by replacing the teacher-centered learning process with learner-centered team responsibility, self-regulation, and iterative prototyping cycles (Fitsilis et al., 2025; Parsons & MacCallum, 2019; Hlazunova et al., 2026). In the ever-changing environment of software development, Agile methods, such as Scrum, Kanban, and Extreme Programming (XP), have become revolutionary practices (Aljehani & Qureshi, 2025).

The Data Science Process is essential when fast and flexible thinking is not enough, as evidence-based decision-making is a key ingredient in today's entrepreneurship (Arora et al., 2025). Utilizing Data Science Processes, students have systematic procedures (for instance, the Cross Industry Standard Process for Data Mining (CRISP-DM) that help learners form empirically testable questions (Jaggia et al., 2020), collect digital data, clean data sets, and conclude (Raza et al., 2026). Using data-driven criteria helps students eliminate guesswork and confirm market demand with facts.

Design Thinking is employed to integrate human experience with quantitative analytics. Design Thinking suggests using an innovative approach that involves stages, including empathy, definition, ideation, prototyping, and testing (Laowongsee et al., 2025; Promsiri et al., 2022), where user empathy plays a central role within the approach known as Design Thinking and allows creating problem-solving skills in real-life conditions (Kim et al., 2023; Mehddi et al., 2025). Although there have been studies on Agile project management (Parsons & MacCallum, 2019), data science literacy, and design thinking concepts (Mehddi et al., 2025), there is not much empirical evidence on how these areas can be integrated into secondary STEM (Science, Technology, Engineering, and Mathematics) classes. Each concept used in isolation creates its own shortcomings in terms of pedagogy because design thinking devoid of data science might end up with unfounded ideas, data science without design

thinking may end up with analysis paralysis with no user consideration, and both of these in isolation without Agile project management will have no team collaboration and missed deadlines (Mehddi et al., 2025).

To address these gaps, this study proposes, develops, validates, and empirically tests the PDTPE model, which is a five-stage pedagogical strategy involving Problem Framing (P), Data-Driven Ideation (D), Team-Based Development (T), Presentation and Feedback (P), and Evaluation and Scaling (E). The proposed 6-week intervention program in an upper secondary STEM class setting will test the validity of the PDTPE model, based on expert opinion, and its effect on students' performance and multidimensional entrepreneurial skills vis-à-vis conventional instructional approaches. The main objective of this study is to propose an empirically based approach for teaching entrepreneurship skills to secondary school STEM teachers and educators, as well as curriculum makers and policymakers.

Literature Review

Social Constructivism

Vygotsky's Social Constructivism suggests that both the acquisition of knowledge and the development of cognition are socially constructed through interactions, discussions, and the use of cultural resources and discourse within ZPD'S learning process (Taber, 2025). Rather than passively gaining knowledge, learners build their own knowledge through interactions and problem-solving tasks with peers. In secondary school STEM lessons, social constructivism helps explain why group activities may be preferable to individual work in the computer lab. By engaging in peers' problem-solving, learners help each other develop their cognitive and technical skills to construct algorithms.

Experiential Learning Theory

Figure 1 shows the Experiential Learning Theory (ELT) by Kolb (Kong, 2021). This cyclical process comprises four stages: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE) (Javahery & Bavandi, 2026). The learner goes through various recursive cycles, uses abstract thought, and tests them against actual experiences. In entrepreneurship and technology, passive lectures become ineffective because they limit the learning process to abstract conceptualization, without the learner experiencing its practical aspects. Using experiential circles helps secondary school STEM learners test theories, make observations, and modify prototypes.

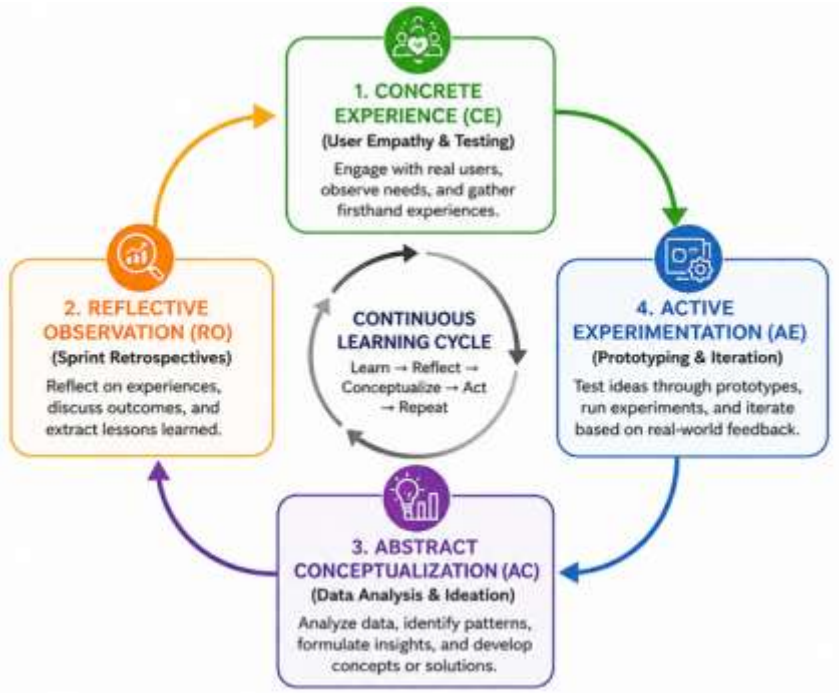

Figure 1. Kolb's Experiential Learning Theory (ELT)
Remark: Adapted from Kolb's Experiential Learning Theory (ELT) (Kong, 2021).

Synthesized Pedagogical Domains

Entrepreneurial competency in secondary education

Entrepreneurial competency involves the practical application of knowledge, skill sets, and behavioral patterns to recognize opportunities, gather resources, and navigate uncertainty (Bacigalupo et al., 2016). Most educational programs emphasize economics, but the modern secondary education framework, such as the European Entrepreneurship Competence Framework (EntreComp), views entrepreneurial competence as a flexible mindset required for 21st century citizenship (Bacigalupo et al., 2016; Seikkula-Leino et al., 2021).

To guide this study, we drew on two key frameworks: the entrepreneurial skills outlined by EntreComp (Bacigalupo et al., 2016) and the flexible, learn-as-you-go approach of Agile principles (Silva et al., 2020). With these in mind, the researchers broke down 'entrepreneurial competency' into three hands-on dimensions that were then observed and measured These included Entrepreneurial Skills (technical skills, resource utilization, opportunity recognition, and tactics planning), Leadership Skills (interpersonal communication, team goal setting, role negotiation, and team coordination), and Innovative Adaptability (cognitive ability to receive constructive criticism, implement pivoting amid market uncertainty, and adopt failure as a sign of iteration). Therefore, the development of these dimensions in secondary schools calls for real-world learning environments that involve decision-making with risk and ambiguity (Sumarno et al., 2023). Direct-instruction approaches do not promote these behaviors because they rely on predictable, unambiguous outcomes, pose no ambiguity or risk, and do not require adaptive leadership.

The Agile learning framework

Adapted from the Agile Manifesto for Software Development (Hanser, 2026), the Agile framework is focused on valuing human interactions over processes, working software over comprehensive documentation, and responding to change over following a plan (Briggs, 2014; Parsons & MacCallum, 2019). Agile methodology helps to turn the chaotic collaboration process of students into a planned process by breaking down the tasks into smaller segments or sprints, which can be organized via the use of Kanban boards and brief stand-up meetings (Aljehani & Qureshi, 2025; Parsons & MacCallum, 2019). The incorporation of the ongoing interactions within the work process makes it highly compatible with Vygotsky's Social Constructivism (Taber, 2025). While the method is useful in terms of project management and adaptability, it doesn't provide any tools for the development of user empathy or empirical analysis.

General Education Data Science Processes

Incorporating Data Science Processes in secondary schools expands basic computational skills into empirical data literacy (Raza et al., 2026), standardized approaches, like CRISP-DM (Cross-Industry Standard Process for Data Mining) and OSEMN (Obtain, Scrub, Explore, Model, iNterpret), create frameworks for empirical investigation (Leavy et al., 2026; Mendes & Farinha, 2026).

Working with raw data, designing surveys, cleaning up dirty data, and discovering statistical patterns helps secondary students base their decisions on facts rather than guesses (Arora et al., 2025). In entrepreneurial ventures, data science processes ensure that proposed solutions meet real market demands. However, if data processes are used independently from each other, there is a chance that a problem of "data paralysis" may appear – analyzing numbers regardless of human needs and building prototypes.

The design thinking paradigm

Design Thinking is a problem-solving process for design, which consists of five iterative steps: Empathize, Define, Ideate, Prototype, and Test. Based on Experiential Learning Theory (Javahery & Bavandi, 2026), Design Thinking helps people increase their emotional intelligence, observe user problems, and learn to prototype ideas and build creative confidence (Mehddi et al., 2025). Though Design Thinking allows individuals to come up with empathic and innovative ideas, secondary school learners normally find it difficult to proceed further towards implementation since the process involves transitioning from low-fidelity prototype stages to high-fidelity technology implementation stages (Mehddi et al., 2025). Therefore, Design Thinking lacks technical or empirical verification without data science and Agile-based management applications.

Methodological Synthesis and the Gaps in Literature

Although there is extensive research on how Agile Learning, Data Science Processes, and Design Thinking are used effectively as teaching tools independently, there has not been sufficient research on integrating all three methods into an educational framework in secondary education. There are three major gaps in existing literature: Earlier works analyze Agile execution loops (Parsons & MacCallum, 2019), Data Science processes, or Design Thinking empathy loops (Mehddi et al., 2025) independently. No existing work the authors are aware of focuses

on the educational opportunities provided by integrating all three frameworks into a single learning model. Most integrated frameworks are designed for higher-education software engineering or MBA courses. Technology courses in secondary education remain largely based on linear laboratory work conducted under teacher guidance.

Even as academic theories call for fostering an entrepreneurial mindset among students enrolled in STEM/technology classes at the secondary school level, there is no empirical study using a quasi-experimental design to test the effects of a structured iterative model on measurable performance and multifaceted entrepreneurial skills (leadership, execution, and innovative adaptation). To address gaps in the literature, this study proposes the PDTPE Model (Problem Framing, Data-Driven Ideation, Team-Based Development, Presentation and Feedback, Evaluation and Scaling).

Research Objectives and Explicit Research Questions

To test the PDTPE model, this research will have two research objectives (ROs) based on the following three formal research questions (RQs):

RO1: To develop and validate the expert quality (utility, feasibility, propriety, accuracy) of an integrated Agile Learning model that integrates Data Science Processes and Design Thinking (PDTPE).

RO2: To test the effect of the PDTPE model on the academic performance and entrepreneurial competence of upper secondary students in comparison to the conventional mode of teaching.

RQ1: Is the developed PDTPE model able to meet expert criteria of instructional quality in terms of utility, feasibility, propriety, and accuracy?

RQ2: Do the upper secondary students taught using the PDTPE model exhibit significant improvement in learning achievements after instruction in comparison to pre-instruction levels and in comparison, to those students who are taught using conventional approaches?

RQ3: Does the application of the PDTPE model result in significant improvement in overall and dimensional entrepreneurial competence (Entrepreneurial Skills, Leadership Skills, Innovative Adaptability)?

Methods

Research Design and Conceptual Framework

The research in this study used a two-stage Type 1 developmental research design, combining expert judgment with a quasi-experimental, nonequivalent control group pretest-posttest design (Takona, 2024). Moreover, school and student administration scheduling precluded the disruption of each classroom. Therefore, cluster random assignment of existing courses was used in place of individual random assignment (Takona, 2024).

Phase 1: Model Development & Expert Quality Assessment (n = 9 Experts)
Systematic Literature Synthesis (Agile, Data Science, Design Thinking, EntreComp)
Expert Focus Group & Quality Assessment (utility, feasibility, propriety, and accuracy)

Phase 2: Empirical Quasi-Experimental Implementation (n = 75 Grade 11 Students)
Experimental Group (n = 38): PDTPE Model (12 Hours / 6 Weeks)
Control Group (n = 37): Traditional Instruction (12 Hours / 6 Weeks)

Phase 1: Model Formulation and Expert Quality Assessment

Theoretical synthesis and architecture

The architecture of the PDTPE model was developed through a synthesis of the literature on Agile Learning, Data Science Process, Design Thinking (Promsiri et al., 2022), and other competencies required for entrepreneurship (Bacigalupo et al., 2016). The synthesis process involved discovering areas of procedural overlap where short Agile learning cycles could be applied to realize the empathy cycles of Design Thinking and feedback processes of Data Science.

Expert panel selection and validation

The draft framework's construct validity, pedagogical utility, and feasibility were assessed by a nine-member expert panel using purposive sampling. The expert panel consisted of individuals who qualified as experts in Computer Education (n=3), with PhDs in Computer Education and more than 10 years' experience researching educational technology. Moreover, three additional individuals were specialists in Curriculum and Instruction, experienced senior academic researchers in secondary STEM and technology curricula. Finally, another group of three Educational Measurement & Evaluation Specialists who were Psychometricians specializing in instrument design and educational statistics joined the group. Expert reviews were conducted via an online focus group discussion (Zoom platform). The participants read the model manual, the activity guide for students, and the scoring rubrics before rating an 18-item evaluation tool based on the Program Evaluation Standards: utility, feasibility, propriety, and accuracy (Yarbrough et al., 2010). The content validity was confirmed using the Item-Objective Congruence (IOC) index, which yielded scores ranging from 0.60 to 0.90.

Phase 2: Empirical Quasi-Experimental Implementation

Population, sample, and baseline equivalence

The study's target population consisted of 456 Grade 11 students in 14 intact classes taking up the Compulsory Technology 3 (Design and Technology) subject in Kanthararom School in Kanthararom district of Sisaket province in the 1st semester of the 2025 academic year. Cluster random sampling was performed, with clusters (classrooms) as sampling units, and two sections of the subject were randomly selected that had similar academic backgrounds, teacher experience, and demographic patterns ($n = 75$).

The experimental Group ($n = 38$) was taught via the PDTPE model, while the control group ($n = 37$) was taught via traditional lecture-demonstration-practice instruction. To control for selection biases and internal threats associated with the quasi-experimental research design, baseline equivalence was evaluated prior to instruction. An independent-samples t-test on pretest learning achievement revealed no statistically significant difference between the experimental group ($M = 12.68, SD = 4.17$) and the control group ($t(73), p > .05$), confirming baseline comparability prior to the intervention.

Instructional intervention and implementation fidelity

Both interventions were conducted by the same certified secondary computer science teacher to rule out confounding factors that might arise from differences among teachers. The intervention period was 6 weeks (for 2 hours every week for a total of 12 hours) (Table 1). Both interventions covered the same topics required by the national curriculum for Technology 3 (Project Initiation, Project Development, and Project Presentation).

Table 1. Weekly implementation matrix for experimental (PDTPE) vs. control conditions

Week / Hours	Unit Phase	Experimental Group (PDTPE Model)	Control Group (Traditional Model)
Week 1 (2 hrs)	Problem Framing & User Empathy	Phase 1 (Problem Framing): Teams (4-5 students) did fieldwork to observe community settings, performed qualitative interviews with users, and created empathy maps and problem statements.	The instructor delivers a direct lecture on project selection. Students individually select project topics from a list in a textbook.
Week 2 (2 hrs)	Data Collection & Ideation	Phase 2 (Evidence-based Ideation): Participants created plans for data collection, conducted digital surveys and observations, analyzed data in spreadsheets, and developed evidence-based solutions.	Classroom lectures focus on methods of data collection. Students fill out typical project proposal templates without conducting empirical data collection.

Week 3 (2 hrs)	Sprint Planning & Prototyping	Phase 3 (Team-Based Development): The teams created the Agile Kanban board, the team roles (Sprint Master, Developer, Pitcher), and implemented Sprint 1 to create low-fidelity prototypes (Aljehani & Qureshi, 2025).	The instructor shows the tool and hardware operation through the projector. Students create specified components by following step-by-step worksheets.
Week 4 (2 hours)	Sprint Iterations and Refinement	Phase 3 (Team-based development): The teams carried out Sprint 2, usability testing, refinement of the prototype's features, and re-estimation of task velocity.	Students continue individual/pair project building in the computer laboratory under direct, teacher-led supervision.
Week 5 (2 hrs)	Pitching & Constructive Feedback	Phase 4 (Presentation and Feedback): Teams gave 5-minute presentations to their classmates, answered questions, and received feedback based on rubric criteria (Bacigalupo et al., 2016).	Students' group work, presented as finished projects, is displayed sequentially at the front of the classroom; the instructor provides numerical grades and written feedback.
Week 6 (2 hrs)	Data Analysis and Scaling	Phase 5 (Data analysis and Scaling): Teams collected user feedback measures, analyzed their prototypes' performance, planned scaling, and completed team reviews.	The instructor summarizes the class performance of all projects. Students fill out standard course reflection forms.

Research Instruments and Psychometric Validation

Entrepreneurial competency scale

Post-intervention entrepreneurial competency assessment used a 36-item questionnaire which assessed each response using a 5-point Likert scale adapted from EntreComp (Bacigalupo et al., 2016). The instrument measured three operationalized sub-constructs. These included:

Entrepreneurial Skills (12 items): Opportunity recognition, financial literacy, and resource mobilization.

Leadership Skills (12 items): Team coordination, goal setting, and strategic negotiation.

Innovative Adaptability (12 items): Creative problem solving, pivot execution under uncertainty, and constructive feedback integration.

Instrument Validity: Items from the instrument were analyzed by 5 experts in the field, resulting in an IOC of 1.00. Reliability Testing through Field testing on a non-sample group (n=30 students in class 11) yielded an internal consistency reliability of Cronbach's Alpha (α) = 0.98.

Learning achievement test

Academic achievement was measured using a 40-item, 4-option multiple-choice test aligned with Bloom's Revised Taxonomy across four cognitive domains: understanding, application, analyzing, and evaluating (Khoy, 2025).

Psychometric validation

Content Validity: Expert evaluation $(n = 5)$ confirmed IOC indices ranging from 0.60 to 1.00 for all items.
Item Analysis: Pilot testing $(n = 30)$ confirmed item difficulty indices (p) between 0.21 and 0.79 (optimal moderate difficulty) and item discrimination indices (r) between 0.35 and 0.76 (strong discrimination capacity.
Reliability: Internal consistency, evaluated using the Kuder-Richardson Formula 20 ("$KR-20$"), yielded a reliability coefficient of 0.94, confirming high test reliability.

Data Collection Procedure

Pre-Test: During Week 1, the experimental group ($n = 38$) and the control group ($n = 37$) took part in the 40-item Learning Achievement Test.
Intervention: The intervention period lasted 6 weeks, as outlined in the matrix in Table 1. Implementation fidelity was tracked weekly using an observation checklist from an independent curriculum evaluator.
Posttest: During Week 6, the participants (from both groups) took part in the posttest 40-item Learning Achievement Test and 36-item Entrepreneurial Competency Scale.

Data Analysis and Statistical Testing

Quantitative analysis was performed using IBM SPSS Statistics Version 28.0. Descriptive statistics including the means (M) and standard deviations (SD) were computed for expert evaluations, test scores, and competency dimensions. A paired-samples t-test was used to evaluate pre- to post-intervention gains in learning achievement within the experimental group. Independent-samples t-tests were used to evaluate post-intervention differences in learning achievement and entrepreneurial competency between the experimental and control groups. Cohen's d was calculated for parametric mean comparisons and interpreted as small ($d = 0.20$), medium ($d = 0.50$), and large ($d \geq 0.80$). Normality was verified via Shapiro-Wilk tests ($p > .05$), and homogeneity of variance was confirmed via Levene's test ($p > .05$), satisfying assumptions for parametric testing.

Results

Participant Demographics and Baseline Characteristics

To assess whether there are any demographic similarities between the groups at baseline, demographic factors such as gender composition and academic performance (GPA) were examined in the experimental and control groups. In all, there were 75 students in this study, 38 in the experimental group and 37 in the control group. On the whole, there was gender balance across the groups, with females comprising 57.90% (n=22) in the experimental group and 54.05% (n=20) in the control group. On the other hand, regarding GPA, the majority of students in both the experimental and control groups were in the 2.51-3.00 range: 47.37% (n=18) and 54.05% (n=20), respectively. Baseline demographic data for the participants in both instructional conditions are illustrated in Table 2.

Table 2. Baseline demographic characteristics of students across instructional conditions

Demographic Characteristic	Experimental (n=38)	Experimental (%)	Control (n=37)	Control (%)
Gender				
Male	16	42.10	17	45.95
Female	22	57.90	20	54.05
Total	38	100.00	37	100.00
Cumulative GPA				
< 2.50	11	28.95	10	27.03
$2.51 - 3.00$	18	47.37	20	54.05
> 3.00	9	23.68	7	18.92
Total	38	100.00	37	100.00

Structural Architecture and Expert Quality Assessment of the PDTPE Model

The created pedagogical model—which is termed the PDTPE Model—is a combination of Agile delivery, Data Science analysis cycle, and Design Thinking empathy, and consists of 5 phases of instruction (Figure 2):

Step 1: Problem Framing (P)—the learners practice their empathic skills, examine the problem from the end-user perspective, obtain initial qualitative findings, and create problem statements.
Step 2: Data-Driven Ideation (D)—students prepare a plan for data collection, collect and process data via digital means, examine trends, and create evidence-based solutions.
Step 3: Team-Based Development (T)—student groups assign tasks to one another, plan short Agile sprints, create physical or digital prototypes, and refine them through group feedback.
Step 4: Presentation and Feedback (P)—students demonstrate their prototypes to external audiences and participate in feedback discussions.
Step 5: Evaluation and Scaling (E)—participants evaluate empirical performance data, review the results of their efforts, identify flaws in the structure itself, and plan for the future scalability of their efforts.

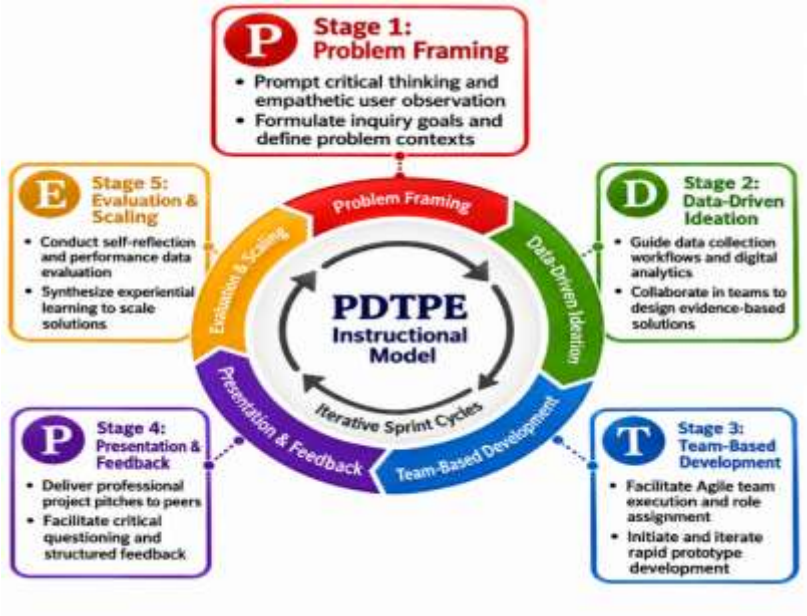

Figure 2. The 5-Stage PDTPE instructional framework

Expert evaluation results ($n = 9$) confirmed that the overall model quality was high ($M = 4.45, SD = 0.41$). As detailed in Table 3, utility achieved the highest rating ($\overline{M} = 4.56, SD = 0.45$).

Table 3. Expert quality evaluation of the PDTPE Model ($n = 9$)

Evaluation Dimension	Mean (M)	Standard Deviation (SD)	Quality Level
Utility	4.56	0.45	Highest
Propriety	4.47	0.39	High
Feasibility	4.42	0.47	High
Accuracy	4.36	0.37	High
Overall	4.45	0.41	High

Empirical Instructional Effectiveness

Within-group achievement comparison

The students in the experimental group showed marked improvements in their performance on achievement measures after employing the PDTPE model (see Table 4). This resulted in a rise in their mean (*M*) score from 12.68 ($SD = 4.17$) during the pretest period to 30.89 ($SD = 4.82$) during the posttest period, out of a total score of 40. From the dependent-samples t-test, this increase is statistically significant ($t = 20.97, p < .01$).

Table 4. Pretest vs. posttest learning achievement of the experimental group ($n = 38$)

Assessment Stage	Total Score	Mean (M)
Pretest	40	12.68
Posttest	40	30.89

Note: $p < .01$

Entrepreneurial competency assessment

Evaluation of the experimental group's post-intervention entrepreneurial competency indicated high performance across all three target dimensions ($M = 4.01, SD = 0.24$) (Table 5). Leadership skills received the highest rating ($M = 4.07, SD = 0.31$), followed by Entrepreneurial skills ($M = 4.00, SD = 0.23$) and innovative adaptability ($M = 3.93, SD = 0.42$).

Table 5. Experimental group entrepreneurial competency dimensions ($n = 38$)

Competency Dimension	Mean ($\boldsymbol{M}$)	Standard Deviation (*SD*)	Interpretation Level
Leadership Skills	4.07	0.31	High
Entrepreneurial Skills	4.00	0.23	High
Innovative Adaptability	3.93	0.42	High
Overall Competency	4.01	0.24	High

Between-group comparative analyses

Post-intervention comparative analyses confirmed the superior efficacy of the experimental model over conventional instruction. As shown in Table 6, the experimental group achieved significantly higher posttest learning achievement scores ($M = 30.89, SD = 4.82$) compared to the control group ($M = 28.27, SD = 5.55$), with $t = 2.19, p < .01$.

Table 6. Posttest achievement comparison between experimental and control groups

Group	n	Total Score	Mean (M)
Experimental	38	40	30.89
Control	37	40	28.27

Note: $p < .01$

Similarly, the experimental group demonstrated a statistically higher post-intervention entrepreneurial competency ($M = 4.01, SD = 0.24$) than the control group ($M = 3.58, SD = 0.32$), yielding a significant difference ($t = 6.50, p < .01$) (Table 7).

Table 7. Post-intervention entrepreneurial competency comparison between groups

Group	n	Max Score	Mean (M)
Experimental	38	5	4.01
Control	37	5	3.58

Note: $p < .01$

Discussion

This research created, verified, and empirically tested the PDTPE Model to increase the academic success and entrepreneurial skills of upper secondary school technology students. From the investigation, it was determined that the model is more effective when compared to traditional teaching methods.

Pedagogical Quality and Structural Synergy of the PDTPE Model (RQ1)

The expert evaluation of the PDTPE model showed that it had excellent pedagogical quality ($M = 4.45$; $SD = 0.41$), with the highest mean in the utility domain ($M = 4.56$). Practical difficulties often accompany abstract models; Design Thinking without empirical evidence leads to superficial ideation (Mehddi et al., 2025), and the same is true for Data Science without it – it makes it cumbersome. The PDTPE model solves such problems, providing empathy in Problem Framing (Design Thinking) (Promsiri et al., 2022), empiricism in Data-Driven Ideation (Data Science), and teamwork in Team-Based Development (Agile). They are similar to the ELT approach (Javahery & Bavandi, 2026) and the social constructivism theory (Taber, 2025).

Effects on Learning Achievement (RQ2)

The PDTPE-model students exhibited significant pre- and post-test performance improvements ($M_"pre" = 12.68$ $vs.$ $M_"post" = 30.89$; $p < .01$) and performed significantly better than the control group on post-test achievement ($t = 2.19, p < .01$). Contrary to direct teaching, which imparts knowledge of abstract theoretical concepts, the PDTPE model involves students in applying their knowledge through practical data collection and analysis, and in creating a physical representation via hardware/software prototyping.

Improvement in Entrepreneurial Competencies (RQ3)

There was an improvement in entrepreneurial competencies among participants in the experimental group ($M = 4.01$), compared to those in the control group ($M = 3.58$; $t = 6.50, p < .01$). These improvements were attributed to the authentic sprinting process in three aspects:

Leadership Competencies ($M = 4.07$): Due to the role allocation (Sprint Masters, developers), students had to bargain for roles, velocity, and peer accountability (Rigas et al., 2026).
Entrepreneurial Competencies ($M = 4.00$): Through the application of Data Science, participants learn to use market data as evidence rather than assumptions to support business plans.
Adaptability to Innovation ($M = 3.93$): By engaging in sprint reviews and pitch forums (Aljehani & Qureshi, 2025), the students will be well-versed in turning their prototype weaknesses to beneficial criticism, which is an important trait in entrepreneurship (Bacigalupo et al., 2016).

Practice Implications

Change in the Teacher's Role: Successful implementation requires instructors to shift from conventional educational techniques to roles that serve as facilitators or coaches. The major areas of focus should entail sprinting bottlenecks, data ethics, and peer reviews.

Modular Curriculum Integration: The 5-stage PDTPE process can be embedded into existing secondary STEM courses without requiring new subject tracks.

Limitations and Future Research

Several limitations can be noted in the study. These include a sample size of 75 11th-grade students from a single high school, which may not provide sufficient generalizability across demographic factors. Second, although the 6-week/12-hour period was sufficient to assess skill and cognitive gains, it was inadequate to assess behavioral change over a longer period. Finally, the design of an intact classroom setting prevented random allocation of participants to conditions.

Conclusion

The PDTPE model provides an empirically tested framework that can successfully incorporate entrepreneurial thinking, evidence-based decision-making, and iterative design into STEM education at the secondary level. Moreover, expert evaluation indicated that the PDTPE model exhibited excellent structural quality across utility, feasibility, propriety, and accuracy ($M = 4.45$). Also, it was empirically established that the PDTPE Model significantly improved learning outcomes ($p < .01$) and developed entrepreneurial competencies, such as leadership implementation, competence implementation, and innovation under uncertainty, compared to the traditional model ($p < .01$).

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Ethics declaration: This study involved Grade 11 secondary school students. Written informed consent was obtained from the school administration, and informed assent was gathered from all participating students prior to study commencement. Participation was voluntary, and no sensitive personal data or physical risks were involved. The study complies with the ethical principles outlined in the Declaration of Helsinki (revised in 2013) and aligns with Thailand's National Policy and Guidelines for Human Research, which exempts minimal-risk educational and behavioral research from formal institutional review. Accordingly, the study received an official ethics exemption certificate from the university ethics committee (Exemption No. EC_KMITL_68_105).

AI statement: During the preparation of this manuscript, the authors used ChatGPT to assist with translating the original Thai content into English. The authors used Grammarly Premium to refine language for clarity and consistency. ChatGPT was also used in a limited capacity to assist with the visual refinement and redesign of figures to improve clarity and presentation. They did not use any AI tools to generate the study's conceptual framework, data, analysis, or interpretations. All content, including figure accuracy and underlying academic meaning, was reviewed and verified by the authors, who take full responsibility for the integrity of the work.

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