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Development and Preliminary Evaluation of a Creative micro:bit-Based Learning Model to Support Computational Thinking and Technological Design in Small Rural Schools

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Abstract

Limited access to digital technologies, instructional resources, and specialized computing expertise constrains learning opportunities in small rural schools. This study aimed to (1) design and develop a creative micro:bit-based learning model for Grade 4 students, (2) evaluate its process and outcome efficiency and compare students' learning achievement before and after participation, and (3) assess its appropriateness and feasibility through expert evaluation. A multi-phase Research and Development approach with a one-group pretest–posttest design was employed. The development group included 10 in-service teachers and 20 pre-service teachers, and the implementation group included 30 Grade 4 students from five small rural schools. The model comprised four two-hour modules: Fun Thinking, Traffic Light, Micro Servo, and the Meow Cat Project. Three experts evaluated content congruence using the Index of Item-Objective Congruence (IOC). Efficiency was assessed using the E1/E2 criterion, and pretest–posttest scores were compared using paired-samples t-tests. IOC values ranged from 0.94 to 1.00. The main implementation yielded E1/E2 values of 91.74/79.00, exceeding the 75/75 criterion. Posttest scores were significantly higher than pretest scores in all modules ($p < .001$). Experts rated overall appropriateness and feasibility highly ($M = 3.65$, $SD = 0.49$). The findings provide preliminary support for the model as a context-sensitive approach for technology-enhanced learning in small rural schools.

Keywords: Computational Thinking, Micro:bit, Creative Learning, Technological Design Skills, small rural schools, learning achievement, Research and Development

1. Introduction

In the 21st century, competencies in Computational Thinking (CT) and Technological Design Skills have become indispensable prerequisites for fostering innovation, advancing scientific literacy, and ensuring equitable participation in the rapidly evolving digital economy (Li et al., 2025). These skills are increasingly recognized not only as technical abilities but also as essential cognitive and problem-solving capacities that enable

individuals to adapt to emerging technologies, drive innovation, and engage meaningfully in society. Previous evidence from the local teacher-education context has also revealed persistent gaps in fundamental and mechanical physics understanding, highlighting the need for learning experiences that strengthen conceptual reasoning and higher-order thinking skills (Sarapak et al., 2025). Yet, persistent educational inequities—most notably the "digital divide"—continue to restrict access to these opportunities, particularly for students in rural areas and small schools. Learners in these contexts frequently face a combination of infrastructural limitations, insufficient access to technological resources, and a shortage of specialized educators equipped to deliver computationally rich learning experiences (Chisag Guaman et al., 2025; Kim et al., 2022). The consequences of these inequities are far-reaching, reinforcing cycles of educational and economic disadvantage. Addressing this gap through cost-effective, scalable, and contextually adaptive educational strategies has therefore emerged as a critical global priority. Recent evidence in physics education has likewise demonstrated that technology-supported laboratory environments can provide learning outcomes comparable to conventional laboratory approaches while improving accessibility and reducing dependence on costly physical equipment in resource-constrained settings (Sarapak et al., 2025). Within this landscape, low-cost, high-impact technologies such as the Micro:bit provide a powerful lever for enabling hands-on, experiential learning opportunities that foster both computational thinking and technological design capabilities in resource-constrained educational settings (Amenyo & Kpo, 2023).

Extensive research underscores the pedagogical potential of physical computing platforms, including the Micro:bit, in enhancing CT competencies when integrated with active learning methodologies such as Project-Based Learning (PBL) and Constructionism (Kastner-Hauler et al., 2022; Philbin, 2024). Engaging students in the creation of tangible artifacts to address real-world problems has been shown to improve motivation, creativity, and comprehension of abstract computational concepts (Cápay & Klimová, 2019; Manikutty et al., 2020). Moreover, the interdisciplinary nature of Micro:bit-based activities allows for seamless integration of coding, technological design, and contextualized problem-solving (Zhang et al., 2025), making it especially suitable for resource-constrained educational environments.

Despite these promising outcomes, a notable research gap remains. Evidence from Surin Province further indicates that students favor technology-integrated instructional approaches, emphasizing the importance of appropriately combining technology, pedagogy, and content to enhance learner engagement and meaningful learning experiences (Sarapak et al., 2025). Existing studies often emphasize short-term interventions rather than the systematic development of sustainable learning models tailored to the unique characteristics of small rural schools (Vásquez Gómez et al., 2025). These contexts require learning frameworks that address critical factors such as teacher support, cultural and environmental relevance, and flexible implementation strategies. To meet this need, there is an urgent call to design a context-sensitive, creative learning model that simultaneously fosters CT and technological design skills while adapting to the real constraints of rural classrooms. This study aimed to design and develop a Creative micro:bit-based Learning Model for Grade 4 students in small rural schools. Specifically, the objectives were: (1) to design and develop a creative micro:bit-based learning model appropriate for the context of small rural schools; (2) to evaluate the process and outcome efficiency of the developed model and compare students' learning achievement before and after participating in the learning activities; and (3) to evaluate the appropriateness and feasibility of the developed model through expert assessment. The findings are expected to provide preliminary evidence regarding the practical use of micro:bit-based learning activities in resource-constrained rural school contexts.

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2. Methodology

2.1 Research Design

This study employed a multi-phase Research and Development (R&D) approach adapted to the development, iterative refinement, and preliminary evaluation of an educational intervention (Gall et al., 2007). For the present study, the R&D process was operationalized into four phases: (1) exploration and model design, (2) model development and validation, (3) main implementation, and (4) final evaluation and refinement. The development process began with contextual exploration, in which relevant literature, curriculum standards, and classroom conditions in small rural schools were examined to identify instructional needs and constraints. This was followed by a participatory design phase, in which in-service teachers and pre-service teachers collaboratively contributed to the design of learning activities, ensuring that the model reflected authentic classroom practices and resource limitations. Subsequently, expert content validation was conducted to evaluate the congruence, accuracy, and appropriateness of the learning model, learning materials, and assessment instruments. Based on expert feedback, revisions were made prior to the pilot implementation phase, which was used to test the practicality, clarity of instructions, and preliminary efficiency of the model in a small-scale setting. The findings from the pilot phase informed further refinement of the instructional design and assessment procedures. After revision, the main implementation phase was conducted using a one-group pretest–posttest design to examine changes in students' module-related learning achievement following participation in the four structured learning modules. Because the study did not include a control or comparison group, the statistical analysis was intended to provide only preliminary evidence of learning improvement associated with the implementation of the model, rather than to establish causal relationships or definitive effectiveness. Finally, a post-implementation expert evaluation was conducted to assess the overall appropriateness and feasibility of the finalized model for use in small rural school contexts. In addition, classroom observations were carried out throughout the implementation process to monitor instructional flow, student engagement, and practical issues during activities. These observations were used only for formative support, instructional reflection, and implementation monitoring, and were not subjected to formal qualitative data analysis or treated as a separate research dataset.

2.2 Participants

The participants were selected purposively from small schools under the Surin Primary Educational Service Area Office. Selection criteria included the availability of basic information and communication technology infrastructure, institutional willingness to participate, and the feasibility of organizing the micro:bit-based activities. Participants were organized into the following groups:

Development group: 10 in-service teachers and 20 pre-service teachers participated as co-design contributors. They assisted with contextual analysis, activity design, and formative review of the draft learning model.

Pilot group: a separate group of Grade 6 students (n = 12) who were not included in the main implementation participated in the try-out of the draft model. The pilot was used to examine usability and preliminary E1/E2 values before revision. The participants were selected from area and had prior exposure to basic computer use but no formal experience with micro:bit-based programming.

Implementation group: 30 Grade 4 students from five small rural schools participated in the four-module implementation. Students worked collaboratively in groups of three to four per micro:bit-based kit. The distribution of participants across schools was as follows: School 1 (n = 8), School 2 (n = 5), School 3 (n =5), School 4 (n = 8), School 5 (n = 4). All 30 Grade 4 students completed both the pretest and posttest for all four modules. There

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were no missing data in the main implementation phase, as all participants attended every instructional session and completed all required assessments under supervised conditions.

2.3 Developed Learning Model

The creative micro:bit-based learning model was developed through literature review, contextual analysis, and participatory workshops with the development group. The model combined creative learning, project-based learning, collaborative learning, and physical computing. It included four sequential modules delivered over eight instructional hours, with approximately two hours allocated to each module:

1. Fun Thinking: an introductory module focusing on familiarization with the micro:bit-based environment and basic block-based programming;
2. Traffic Light: an activity involving sequencing and the control of light outputs;
3. Micro Servo: an activity involving the control of servo movement through programmed commands; and
4. Meow Cat Project: a culminating creative project in which students applied previously introduced programming and physical computing concepts to construct and test an artifact.

The sequence progressed from introductory tool use to guided device control and then to a more open project task. During each module, students worked collaboratively, tested their programs, observed physical outputs, identified errors, and revised their solutions with facilitator support.

2.4 Research Instruments

1. Learning management plans: four plans specified the objectives, learning materials, activity sequence, instructional time, facilitator roles, group organization, and assessment procedures for the four modules.
2. Content-validation forms: Three experts evaluated the congruence between the learning model, learning plans, assessment instruments, and research objectives using the Index of Item-Objective Congruence (IOC).
3. Learning achievement assessments: Module-based assessments were administered before and after each corresponding learning activity to examine changes in students' knowledge and application of concepts addressed within each module. These assessments measured module-related learning achievement rather than separate components of computational thinking or technological design performance. A final outcome score with a maximum of 20 points was used for the E2 calculation.
4. Expert evaluation rubric: three experts evaluated eight dimensions of the finalized model, including curriculum alignment, content appropriateness, process flexibility, technology integration, use of the micro:bit, promotion of 21st-century skills, assessment diversity, and sustainability and budget feasibility.

2.5 Research Procedures

Consistent with the R&D framework described above, the study was conducted in four phases:

1. Exploration and model design: relevant literature, curriculum documents, and studies concerning computational learning and physical computing were reviewed. Contextual information from small schools was considered, and workshops with the development group were used to co-design the initial model.
2. Model development and validation: the draft model, learning plans, and assessment instruments were reviewed by three experts using IOC. The materials were revised in response to expert feedback and implemented with the Grade 6 pilot group to examine usability and preliminary efficiency.

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3. Main implementation: the revised model was implemented with 30 Grade 4 students from five schools. The four modules required eight instructional hours in total. Students worked in groups of three to four per kit, while facilitators provided procedural guidance and supported testing and revision.

4. Final evaluation and refinement: students completed the post-activity assessments, efficiency values were calculated, and the complete model was submitted to three experts for final evaluation of appropriateness and feasibility. The model was then refined for future implementation.

2.6 Data Collection and Analysis

IOC values were used to summarize the experts' judgments of item-objective congruence. Values of 0.50 or higher were treated as acceptable for retaining or revising an item. Descriptive statistics, including mean, standard deviation, and percentage, were used to summarize the efficiency and expert-evaluation data.

Process efficiency (E1) represented the percentage of the cumulative process scores obtained during the learning activities relative to the maximum possible process score of 48 points. Outcome efficiency (E2) represented the percentage of the final outcome scores relative to the maximum possible score of 20 points. The obtained values were compared descriptively with the predetermined 75/75 criterion; no inferential test against the criterion was performed.

For each module, pretest and posttest scores were compared using a paired-samples *t*-test at the .05 significance level. The analysis also reported the mean difference, a 95% confidence interval for the mean difference, and Cohen's d_z for paired observations. Because the 30 students were drawn from five schools, the results were interpreted as preliminary. A multilevel analysis was not conducted because only five school clusters were represented. Expert evaluation scores were summarized using the mean (M) and standard deviation (SD). The evaluation represented expert judgments of perceived appropriateness and feasibility; it was not treated as evidence of long-term implementation sustainability.

3. Results and Discussion

3.1 Design and Development of the Creative micro:bit-Based Learning Model

The participatory development process produced a creative micro:bit-based learning model with four sequential modules and supporting learning plans. The model was structured around four components: principles, objectives, learning components, and the four-module learning process. In-service teachers and pre-service teachers contributed to the contextual analysis and formative review, helping align the activity sequence with the practical conditions of small rural schools.

Table 1. Content validity of the developed instruments

Instrument	IOC value	Interpretation
Learning management plans (overall)	0.94	Appropriate
Learning achievement assessments	1.00	Appropriate
Expert evaluation instruments	1.00	Appropriate

As shown in Table 1, the IOC values ranged from 0.94 to 1.00 and exceeded the criterion used in the study. These results indicate that the experts judged the content of the learning plans and assessment instruments to be congruent with their intended objectives. The IOC findings support content congruence, but they should not be interpreted as evidence of score reliability or of student learning effects. The participatory involvement

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of teachers and pre-service teachers also strengthened the contextual grounding of the model by incorporating practitioner perspectives into its development.

3.2 Efficiency and Learning Achievement Outcomes

3.2.1 Process and Outcome Efficiency of the Developed Model

The model was evaluated against the predetermined 75/75 efficiency criterion during the pilot and main implementation phases. The pilot results are presented in table 2, and the main implementation results are presented in table 3.

Table 2 Efficiency of the learning model during the pilot study

Item	Full score	M	SD	Efficiency	Criterion	Result
Process (E1)	48	44.77	1.99	93.27	75	Exceeded
Outcome (E2)	20	16.81	1.47	84.03	75	Exceeded

Table 3 Efficiency of the learning model during the main implementation

Item	Full score	M	SD	Efficiency	Criterion	Result
Process (E1)	48	44.03	1.63	91.74	75	Exceeded
Outcome (E2)	20	15.80	1.97	79.00	75	Exceeded

The pilot values were E1 = 93.27 and E2 = 84.03. During the main implementation, the process and outcome efficiency values were E1 = 91.74 and E2 = 79.00, respectively. Both values descriptively exceeded the predetermined 75/75 criterion. The high process score indicates that students obtained a large proportion of the available scores during the planned learning activities, while the outcome score indicates that the final assessment mean remained above the predetermined criterion.

These findings suggest that the activity sequence was workable under the implementation conditions and that students were generally able to complete the planned tasks. The hands-on construction of visible outputs may have supported engagement by connecting programming commands to observable device responses, consistent with constructionist and physical-computing perspectives (Cápay & Klimová, 2019; Philbin, 2024). Nevertheless, E1/E2 values depend on the design and scoring difficulty of the process tasks and final assessment. They therefore provide descriptive information about performance relative to a local criterion and should not be treated as causal or stand-alone evidence of instructional effectiveness.

3.3 Comparison of Pre- and Post-Learning Achievement

Paired-samples *t*-tests indicated that the reported posttest means were higher than the pretest means for all four modules. Table 4 presents the reported scores together with mean differences, 95% confidence intervals, and paired-samples effect sizes calculated from the reported summary statistics.

Table 4 Comparison of pretest and posttest achievement scores (N = 30)

Module	Pretest M (SD)	Posttest M (SD)	Mean difference	95% CI	t(29)	d_z	p
Fun Thinking	2.76 (1.41)	7.27 (1.40)	4.51	[3.96, 5.06]	16.81	3.07	< .001
Traffic Light	2.63 (1.54)	7.68 (1.37)	5.05	[4.53, 5.57]	19.73	3.60	< .001
Micro Servo	2.66 (1.43)	7.90 (1.12)	5.24	[4.73, 5.75]	21.05	3.84	< .001
Meow Cat Project	2.76 (1.40)	7.76 (1.22)	5.00	[4.50, 5.50]	20.48	3.74	< .001

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The mean differences ranged from 4.51 to 5.24 points, and all reported comparisons had p values below .001. The calculated d_z values ranged from 3.07 to 3.84, indicating very large standardized differences based on the reported paired t statistics. Because these effect sizes are unusually large, verification from the raw student-level dataset is particularly important.

The consistent direction of change across the four modules suggests that students demonstrated higher immediate achievement after participation in the activities. A possible explanation is the progression from introductory block-based programming to guided physical outputs and a culminating project. Physical computing can make abstract programming structures more observable by allowing students to test commands and immediately see the consequences in lights, movement, or other device behavior (Kastner-Hauler et al., 2022; Philbin, 2024). Project-oriented tasks may also promote active participation and provide meaningful reasons to revise a program or artifact (Manikutty et al., 2020). A similar pattern has been observed in hands-on science learning conducted in Surin Province. Sreejivungsa et al. (2025) reported significant improvements between pretest and posttest scores across multiple physics laboratory activities, suggesting that direct interaction with observable physical phenomena can support immediate conceptual learning. However, the achievement assessments reported in this study do not provide separate scores for decomposition, abstraction, pattern recognition, algorithmic thinking, or debugging, nor do they provide a distinct performance measure of technological design. The results should therefore be interpreted as changes in learning achievement related to the four introductory computing and micro:bit modules, rather than as direct evidence that the model developed all components of computational thinking or technological design skills. In addition, the one-group design does not exclude testing effects, facilitator support, maturation, or other influences on score change.

3.4 Appropriateness and Feasibility of the Model Based on Expert Assessment

Three experts evaluated the finalized model across eight criteria. The results are presented in table 5.

Table 5 Expert evaluation of the developed model (N = 3)

Evaluation criterion	M	SD
1. Alignment with creative learning principles and the Core Curriculum	3.64	0.50
2. Accuracy, currency, and appropriateness of content	3.73	0.47
3. Flexibility and appropriateness of the learning process	3.73	0.47
4. Integration of computer science, design, and technology	3.73	0.47
5. Appropriateness of using the micro:bit board	3.64	0.50
6. Promotion of 21st-century skills	3.73	0.47
7. Diversity of measurement and evaluation methods	3.55	0.52
8. Sustainability and budget feasibility	3.45	0.52
Overall	**3.65**	**0.49**

The overall expert rating was M = 3.65 (SD = 0.49). The highest mean ratings were obtained for content accuracy and appropriateness, process flexibility, integration of computer science with design and technology, and promotion of 21st-century skills (M = 3.73 for each criterion). The lowest mean was obtained for sustainability and budget feasibility (M = 3.45, SD = 0.52), followed by diversity of measurement and evaluation methods (M = 3.55, SD = 0.52). The findings indicate that the experts viewed the model positively overall, particularly in relation to its instructional structure and content integration. At the same time, the comparatively lower rating for sustainability and budget feasibility indicates that resource requirements warrant further attention. The use of a

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shared-kit arrangement, with three to four students per micro:bit, may reduce initial equipment costs, but expert judgments alone cannot establish long-term sustainability. A stronger feasibility assessment would require actual cost data, replacement and maintenance requirements, teacher-training time, frequency of reuse, and comparisons among different student-to-kit ratios.

3.5 Summary of Practical Implications in Resource-Constrained Contexts

From a practical perspective, the findings suggest that the developed model can provide a structured and context-sensitive approach for introducing physical computing activities in small rural schools. The involvement of in-service and pre-service teachers was a notable strength because it connected the model-development process to authentic classroom constraints. This participatory approach may be particularly relevant for rural schools, where teacher support and implementation flexibility are essential (Vásquez Gómez et al., 2025).

Nevertheless, the evidence supports a preliminary evaluation rather than a definitive conclusion about causal effectiveness, computational thinking development, or long-term scalability. The study provides a useful foundation for subsequent research using direct CT measures, technological-design performance rubrics, comparison groups, school-level analysis, delayed posttests, and transfer tasks in which students create unfamiliar micro:bit projects independently.

4. Limitations

This study has several limitations. First, the one-group pretest–posttest design did not include a comparison group; consequently, the observed score changes cannot be attributed exclusively to the developed model. Second, the implementation group comprised only 30 students from five purposively selected schools. Students within the same school may have shared instructional and contextual characteristics, but the small number of school clusters limited the use of multilevel analysis. Third, the achievement assessments did not report separate component-level scores for computational thinking or a direct performance measure of technological design. Fourth, the study assessed immediate post-activity performance and did not examine retention or transfer to unfamiliar tasks. Fifth, expert ratings provided evidence of perceived appropriateness and feasibility but did not establish actual long-term sustainability or cost-effectiveness. Finally, classroom observations were used only for formative monitoring and were not analyzed as a systematic qualitative dataset.

5. Conclusion

This study developed a creative micro:bit-based learning model consisting of four sequential modules for Grade 4 students in small rural schools. The model was created through a participatory process involving in-service and pre-service teachers and was reviewed by three experts. The developed instruments obtained acceptable IOC values, the pilot and main implementations exceeded the predetermined E1/E2 criterion, and the reported posttest achievement means were higher than the pretest means across all four modules. Expert evaluation also indicated positive perceptions of the model's appropriateness and feasibility, although sustainability and budget feasibility received the lowest mean among the evaluated criteria. The findings provide preliminary support for the potential use of structured, hands-on micro:bit activities to promote immediate learning achievement related to introductory computing and physical computing in small rural school contexts. They should not be interpreted as definitive evidence that the model caused the observed changes or directly developed all components of computational thinking and technological design skills. Future studies should include larger and more

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diverse samples, comparison groups, delayed posttests, direct CT and design-performance measures, school-level analysis, and systematic cost and implementation data.

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Declaration

The authors declare that Generative AI (ChatGPT/Gemini) was only used to help improve the English language and for minor translation tasks. The AI was not used to create any scientific content, conduct data analysis, or interpret results. All ideas, experimental design, data collection, analysis, and conclusions were solely carried out by the authors. Following ethical research standards and academic integrity policies, the authors confirm that AI tools were used openly, ethically, and under the full supervision of the authors to ensure the manuscript's accuracy and appropriateness.

Ethics Statement

This research was reviewed and approved by the Human Research Ethics Committee of Surindra Rajabhat University, Thailand, under research project approval number HE 672023, dated November 29, 2024. Prior to data collection, all participants were informed of the objectives, procedures, and details of the study, including the voluntary nature of participation and their right to withdraw from the study. All participant information was kept confidential and used solely for research purposes. Informed consent was obtained from all participants prior to their participation in accordance with the procedures approved by the Human Research Ethics Committee.

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