

Evaluating the effect of the B-CompThinkT Modules on Students' Computational Thinking in Lower Secondary Education

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Abstract— This study aimed to examine the effects of the B-CompThink module integrated with technology on students' computational thinking skills in the topic Basic Concepts of Computational Thinking. A quasi-experimental design was employed, involving three groups: the B-CompThinkT group, the B-CompThink group, and the control group. The study sample consisted of 90 first-year secondary school students enrolled in the subject. The research instruments included pre-tests, post-tests, and delayed post-tests developed based on the format of the Academic Session Final Examination (UASA). Data were analyzed using MANCOVA, and the results showed that the B-CompThinkT group demonstrated a significant improvement in achievement scores compared to the other groups in both the post-test and delayed post-test. The findings suggest that integrating the B-CompThinkT module into teaching and learning enhances students' computational thinking skills.

Index Terms— Computational Thinking, Module, Technology-Integrated, Fundamentals of Computer Science, Basic Concepts of CT, Achievement

I. INTRODUCTION

The Fourth Industrial Revolution (IR4.0) has reshaped the way humans live, work, and interact. Emerging technologies such as artificial intelligence (AI), the Internet of Things (IoT), automation and big data analytics have created new demands on education systems to equip students with 21st-century skills, including problem-solving, digital literacy and computational thinking (CT) [1]. CT emphasizes systematic problem such as decomposition, pattern recognition, abstraction and algorithmic thinking [2]. Globally, countries such as the United States, United Kingdom, Estonia and Finland have embedded CT into their K-12 curricula to strengthen student's readiness for future digital economies [2][3].

In Malaysia, the Ministry of Education introduced the Fundamentals of Computer Science (Asas Sains Komputer, ASK) subject in the 2017 Standard Curriculum for Secondary Schools (KSSM) to integrate CT at the lower secondary level [4].

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The subject aims to develop students' understanding of fundamental concepts such as data representation, algorithms, and basic programming. However, implementation challenges persist, including limited teacher training, unequal access to technology and students' difficulties in mastering abstract concepts [5][6]. Studies have also shown that students' CT levels remain moderate with weak correlations to academic achievement [7].

While these findings highlight the urgency of effective teaching modules that are systematic, engaging, and supported by technology, existing solutions remain inadequate. Most available CT modules emphasize procedural programming drills, lack motivational design, and provide minimal scaffolding for higher-order skills [8][9][10]. Furthermore, local research has largely focused on teachers' perceptions rather than empirical evidence of students' learning outcomes, leaving a gap in the design and evaluation of pedagogically structured and technology-enhanced CT interventions [7][11].

To date, no dedicated CT module has been systematically developed for the Malaysian lower secondary context, particularly one that integrates technology to support motivation and scaffolding for higher-order skills. In Malaysia, the topic of Basic Computational Thinking Concepts in the Form One Computer Science Fundamentals (ASK) curriculum specifically emphasizes the development of decomposition, pattern recognition, abstraction and generalization skills [4].

Existing CT teaching approaches in Malaysia largely rely on conventional instruction. These methods often lack interactivity and fail to sustain students' motivation in learning complex concepts [7][11][12]. While international studies demonstrate that technology-enhanced strategies such as gamification, mobile learning and interactive visualizations improve CT skills and engagement [13][14], similar empirical evidence in the Malaysian context remains scarce. This raises critical question: Why are existing CT teaching approaches less effective in helping students master abstract concepts? How can technology integration specifically address these challenges?

To address these gaps, the B-CompThink module was developed for the topic Basic Concepts of Computational Thinking in Form One ASK. A technology-integrated version, B-CompThinkT embeds QR codes that link to fast-response reinforcement exercise (immediate feedback) and gamified assessment activities. This design aims to reinforce CT elements through active engagement, immediate feedback and motivational reward systems. Importantly, the module aligns with internationally recognized CT frameworks that emphasize the explicit development of CT dimensions through curriculum design and technology integration [15][16].

This study evaluates the effects of B-CompThinkT on students' CT achievement compared with the B-CompThink module and conventional teaching. It also examines the sustainability of learning outcomes through delayed post-tests providing theoretical and practical insights into CT instruction in secondary education.

II. LITERATURE REVIEW

A. Computational Thinking in K-12 Education: Global Trends and Challenges

Although Computational Thinking (CT) has been widely embedded into K-12 curricula worldwide, research consistently highlights ongoing challenges in its implementation. Studies report that 30-50% of students in introductory programming courses struggle to progress, often due to difficulties in transferring abstract CT concepts into problem-solving contexts [17][18]. For example, students frequently rely on memorizing syntax rather than applying CT principles to analyze and decompose problems [19][20][21]. These challenges are not limited to higher education; they are also evident at the school level, where students face obstacles in mastering decomposition, abstraction and generalization across different subjects [7].

International research further suggests that the integration of CT requires more than curriculum inclusion; it demands innovative pedagogical approaches, teacher readiness and adequate learning resources [5][23]. Without systematic support, CT risks being taught as isolated programming tasks rather than as a transferable problem-solving competency. This indicates that while global policy efforts have advanced CT integration, practical classroom implementation still faces limitation that require new models of teaching and learning.

B. Technology-Enhanced CT Instruction: What Works?

The integration of technology into CT instruction has shown significant promise in addressing students' difficulties with abstract concepts and sustaining motivation. Empirical studies demonstrate that interactive and gamified approaches can transform passive learning into active problem-solving experiences [24]. For instance, mobile application development module improved students' CT achievement through contextualized tasks that encouraged collaboration and creativity [12]. Similarly, gamified graphic organizers not only enhanced elementary students' programming skills but also facilitated their ability to generalize problem-solving strategies across contexts [25].

Other innovations include the use of QR codes, which allow students to access multimedia content such as videos and quizzes instantly. QR-code-based learning increased motivation by providing immediate feedback and reward systems that reinforced mastery [26]. Such findings align with international frameworks that emphasizes the need to explicitly develop CT dimensions-decomposition, pattern recognition, abstraction and algorithmic thinking through active and technology supported pedagogy [8][9].

Despite these advances, critical analysis reveals two key limitations. First, many technology-enhanced interventions remain context-specific, often tested in small-scale or short-term studies, raising concerns about their scalability and sustainability. Second, while international evidence highlights strong potential, the Malaysian context has yet to fully capitalize on such innovations. Most local studies still emphasize conventional instruction with limited empirical work on gamification, mobile learning or QR code integration. These gaps reinforce the need for localized research that adapts proven international practices to Malaysia's unique educational context.

C. The Malaysian Context: Gaps in Curriculum and Pedagogy

In Malaysia, Computational Thinking (CT) was formally embedded in the curriculum through the introduction of the Fundamentals of Computer Science (Asas Sains Komputer, ASK) subject under the 2017 Standard Curriculum for Secondary Schools (KSSM) [10]. ASK was designed to build students' understanding of data representation, algorithms and programming while strengthening CT skills as part of national STEM education goals. Despite these policy efforts, several

studies reveal persistent challenges in implementation.

First, teacher readiness remains limited. Many teachers report inadequate professional development opportunities, insufficient teaching resources and difficulties in applying innovative pedagogical approaches [11]. Without adequate training, CT instruction often defaults to conventional teaching methods such as lectures and textbook-based exercises, which do not actively engage students.

Second, student continue to face obstacles in mastering abstract CT concepts. Empirical studies show that Malaysian students generally achieve only moderate levels of CT with weak correlations to academic achievement [12]. This suggests that current teaching strategies fail to sufficiently support students in developing higher-order CT dimensions such as abstraction and generalization.

Third, while some local initiatives have produced CT-related teaching modules [27], most remain limited in scope, focusing on printed or non-interactive activities. These modules lack integration of technology, immediate feedback mechanisms and gamification strategies that international research has shown to be effective. Consequently, they are less successful in sustaining students' motivation and long-term retention of CT concepts.

Collectively, these challenges highlight a gap between curriculum aspirations and classroom realities. Although ASK provides a platform for CT instruction, limitations in pedagogy, resources and teacher readiness continue to hinder its effectiveness. This underscores the need for contextually relevant, technology supported modules that can bridge policy intentions and actual learning outcomes.

D. Research Gap: Why B-CompThinkT?

Although Malaysia has made progress in integrating CT through the ASK curriculum, existing teaching approaches and modules remain inadequate to meet students' learning needs. Conventional classroom practices are often teacher-centered emphasizing textbook exercises with minimal interactivity. Meanwhile, locally developed CT modules largely adopt traditional, print-based formats that fail to incorporate multimedia, gamification or mechanisms for immediate feedback [12]. These shortcomings limit their ability to engage students particularly when dealing with abstract CT dimensions such as abstraction and generalization.

International research shows that technology-enhanced interventions- including mobile learning, gamification and QR-code-based activities- can increase motivation, improve achievement and help students transfer CT skills across contexts [13] [28]. However, such approaches are rarely implemented or empirically validated within the Malaysian secondary school context. This creates a significant research gap: while the effectiveness of technology-enhanced CT teaching has been demonstrated globally, its localized adaption and impact in Malaysian classrooms remain underexplored.

The B-CompThink module was developed to address these issues by structuring CT learning systematically for the topic Basic Concepts of Computational Thinking in Form One in ASK subjects. Its technology-integrated version, B-CompThinkT incorporates QR codes that link to interactive quizzes and gamified reward systems, designed to strengthen students' engagement and mastery of CT components.

A further contribution of this study lies in its use of delayed post-tests which provide theoretical and practical insights often absent in prior CT research. Delayed post-tests measure not only immediate gains but also the sustainability of learning outcomes over time. In CT education, retention is critical because it demonstrates whether students can consolidate abstract concepts and continue to apply them beyond the intervention period. Yet, few Malaysian studies have adopted this design, making the present study both novel and significant.

In summary, this study addresses three critical gaps:

- 1) The lack of technology-enhanced CT modules tailored to the Malaysian secondary school context.
- 2) The limited alignment of existing teaching materials with international CT frameworks.
- 3) The absence of research on long-term retention of CT skills, addressed through the use of delayed post-tests.

By filling these gaps, the study contributes new evidence on how technology-integrated modules can enhanced both the immediate and sustained development of CT in secondary education.

III. METHODOLOGY

This study employed a quasi-experimental design with three groups: (i) B-CompThinkT, (ii) B-CompThink and (iii) conventional instruction. A total of 90 Form One students from a secondary school in Selangor, Malaysia were purposively sampled and assigned to intact classed (n = 30 per group). The intervention lasted ten weeks, beginning with a pre-test in week one, followed by a five week intervention and concluded with a post-and delayed post-test in week six and ten, respectively.

To ensure comparability, classes selected had similar academic performance levels. Pre-test scores were used as covariates in subsequent analyses and MANCOVA was employed to control baseline differences between groups.

A. Intervention Material: The B-CompThinkT Module

The instructional materials used in this study consisted of two modules: B-CompThink and B-CompThinkT. Both were developed for the Form one Fundamentals of Computer Science (Asas Sains Komputer, ASK) curriculum, specifically the topic Basic Concepts of Computational Thinking. The B-CompThink module was designed as a structured print-based resource containing explanations, worked examples and practice exercises aligned with CT dimensions provided structured explanations, worked examples and exercises targeting CT dimensions (decomposition, pattern recognition, abstraction and generalization).

The B-CompThinkT module extended this design by integrating technology through QR codes embedded in the printed module (Figure 1). Each QR code directed students to the B-CompThink application which provided two types of activities:

1) Reinforcement activities

Students accessed interactive exercises with immediate feedback. These tasks were designed to consolidate understanding of CT concepts such as decomposition and pattern recognition, by guiding students step by step (Figure 2).

2) Assessment activities

Students engaged in gamified quizzes with star-based reward systems. If a student did not achieve the minimum score, they were required to repeat the activity until mastery was demonstrated. Successful completion unlocked access to the next level, promoting persistence and mastery learning (Figure 3).

A typical learning sequence in B-CompThinkT follows these steps:

The teacher introduced the concept (e.g., Decomposition) using the notes provided in the module and guided students through pair or group activities.

Students scanned a QR code embedded in the module related to the topic.

They were directed to the B-CompThink application and completed a short interactive reinforcement activity with immediate feedback.

Students subsequently attempted a gamified assessment quiz, earning stars for correct answers. If necessary, they repeated the quiz until they reached the required score.

Upon successful completion, students progressed to the next stage of the module.

The design ensured that the module combined teacher explanation (supported by notes in the module), collaborative learning and self-directed digital activities, providing balanced approach to both guided and independent learning.



Fig. 1. Technology-Integrated B-CompThink Module with QR Codes

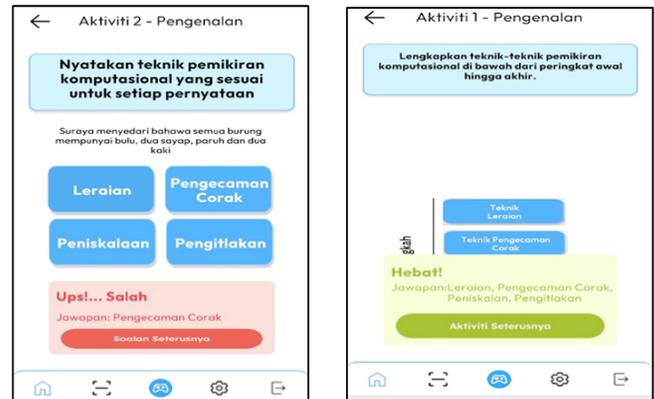


Figure 2. Real-time feedback interface from reinforcement activities, showing students' responses and corrections.

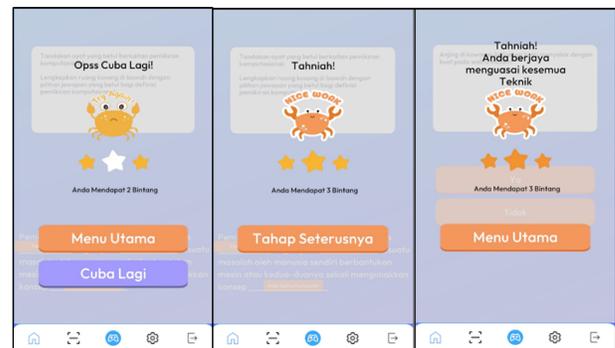


Fig. 3. Game-Based Assessment Activities with a Star Reward System

B. Conventional Teaching

The control group received instruction through conventional methods commonly practiced in Malaysian ASK Classrooms. Lessons were delivered primarily through teacher-led lectures using the official textbook. Student completed written tasks individually. No supplementary modules or technology integration were used. This approach reflected the standard pedagogical practice in ASK focusing on teacher explanation and textbook exercises rather than interactive or gamified learning.

C. Research Design and Sample

The research instrument was a structured achievement test developed in accordance with the Academic Session Final Examination (UASA) format [4]. It comprised three types of questions: multiple-choice objective, multiple-response objective, and subjective. The items were designed based on the Revised Bloom’s Taxonomy, encompassing six cognitive levels, and were distributed according to a 5:3:2 difficulty ratio (low, medium, high) to assess four components of computational thinking: decomposition, pattern recognition, abstraction, and generalization. Content validity was established through expert review, while reliability was determined through a pilot test. Data were analyzed using MANCOVA, with pre-test scores as covariates to control for initial differences in the dependent variables, thereby ensuring a more valid assessment of the intervention effects.

D. Ethical Considerations

Ethical approval was obtained from the Ministry of Education Malaysia and the school administration. Informed consent was secured from parents and students prior to participation. Students’ identities were anonymized, and all data were treated confidentially. Importantly, intact classes were maintained throughout the study and no restructuring of class composition was conducted to ensure fairness. Students were assured that their participation would not affect their grades and they were free to withdraw at any stage.

IV. FINDINGS

A. Computational Thinking Skills in the Post-Test

Descriptive analysis (Table 2) shows that the B-CompThinkT group achieved the highest mean scores across all five CT components compared with B-CompThink and the conventional group. For example, in abstraction, students in the B-CompThinkT group (M = 18.83, SD = 2.15) significantly outperformed both the B-CompThink (M = 17.50, SD = 2.54) and the conventional groups (M = 7.00, SD = 2.82). Similarly, the B-CompThinkT group also led in basic concepts, decomposition, pattern recognition and generalization.

The largest performance gap was observed in abstraction, a dimension often considered most challenging for novices (Brennan & Resnick, 2012; Grover & Pea, 2018). This result can be explained by the design of the B-CompThinkT module, where QR-linked activities provided immediate feedback for reinforcement and gamified assessments with a star-reward system. Students had to achieve a minimum score of 80% to unlock the next stage, ensuring mastery learning and repeated practice until the concept was fully consolidated. Such mechanisms provided retrieval practice and spaced repetition [22], which strengthened abstraction and facilitated transfer to novel contexts.

Importantly, the B-CompThink group also outperformed the conventional group in most CT components. This indicates that the pedagogical design of the module itself is effective even without technology. The print-based module contained scaffolded explanations and step-by-step worked examples that guided students through decomposition and problem-solving systematically. This finding is consistent with previous research showing that structured scaffolding enhances problem-solving skills [29], and that graphic organizer-based instruction significantly improved CT outcomes compared to conventional teaching [25]. Thus, both the modular approach and technology integration contribute to improved CT achievement, with the technology-enhanced version offering the strongest gains.

TABLE I

MEANS AND STANDARD DEVIATIONS OF POST-TEST SCORES FOR COMPUTATIONAL THINKING SKILL COMPONENTS ACROSS GROUPS

Computational Thinking Component	Group	Mean	SD	n
Basic Concepts of CT	<i>B-CompThinkT</i>	17.83	2.520	30
	<i>B-CompThink</i>	15.00	2.936	30
	Conventional	9.17	2.960	30
	Total	14.00	4.572	90
Decomposition	<i>B-CompThinkT</i>	19.33	1.729	30
	<i>B-CompThink</i>	16.17	2.520	30
	Conventional	10.17	3.075	30
	Total	15.22	4.554	90
Pattern Recognition	<i>B-CompThinkT</i>	18.50	2.330	30
	<i>B-CompThink</i>	16.00	2.421	30
	Conventional	9.17	2.960	30
	Total	14.56	4.719	90
Abstraction	<i>B-CompThinkT</i>	18.83	2.151	30
	<i>B-CompThink</i>	17.50	2.543	30
	Conventional	7.00	2.816	30
	Total	14.44	5.875	90
Generalization	<i>B-CompThinkT</i>	17.00	2.491	30
	<i>B-CompThink</i>	15.67	2.537	30
	Conventional	6.83	2.780	30
	Total	13.17	5.217	30

The multivariate Pillai’s trace test (Table 3) confirmed significant differences between groups, $F(5, 78) = 75.35, p < .001$, while pre-test covariates were not significant. This means that the observed differences in post-test achievement were not due to initial student ability but rather to the type of instruction received. The significant multivariate effect demonstrates that structured and technology-supported approaches addressed CT challenges more effectively than conventional textbook-based teaching. In particular, the reinforcement and gamified activities in B-CompThinkT consistently provided advantages across CT components.

TABLE II
MULTIVARIATE TEST RESULTS (PILLAI’S TRACE) FOR POST-TEST SCORES

Effect	Value	F	Hypothesis df	Error df	p
Intercept	.828	75.347 ^b	5.000	78.000	<.001
Pre_BasicConcepts	.017	.268 ^b	5.000	78.000	.929
Pre_Decomposition	.061	1.017 ^b	5.000	78.000	.414
Pre_PatternRecog.	.038	.608 ^b	5.000	78.000	.694
Pre_Abstraction	.040	.643 ^b	5.000	78.000	.668
Pre_Generalization	.071	1.186 ^b	5.000	78.000	.324
T&L Group	.951	14.318	10.000	158.000	<.001

This means that the observed differences in post-test achievement were not due to initial student ability but rather to the type of instruction they received.

B. Computational Thinking Skills in the Delayed Post-Test

Descriptive analysis of the delayed post-test (Table 4) shows that students in the B-CompThinkT group maintained the highest mean scores across most CT components: basic concepts (M = 16.50, SD = 2.33), abstraction (M = 14.33, SD = 2.54), and generalization (M = 14.33, SD = 2.17). Interestingly, the B-CompThink group recorded the highest mean in decomposition (M = 18.67, SD = 2.25), while the conventional group achieved the highest mean in pattern recognition (M = 17.83, SD = 2.52).

Although all groups declined slightly from the post-test, the retention advantage is evident where the B-CompThinkT design enforced mastery learning. The QR-linked reinforcement activities (with immediate feedback) and gamified assessments that required students to repeat quizzes until reaching a minimum score created retrieval practice and spaced repetition, mechanisms known to

strengthen long-term memory [30]. This explains why abstraction and generalization - two CT dimensions typically difficult to sustain - were retained better in the B-CompThinkT group.

TABLE III
MEANS AND STANDARD DEVIATIONS OF DELAYED POST-TEST SCORES FOR COMPUTATIONAL THINKING SKILL COMPONENTS ACROSS GROUPS

Computational Thinking Component	Group	Mean	SD	n
Basic Concepts of CT	<i>B-CompThinkT</i>	16.50	2.330	30
	<i>B-CompThink</i>	15.00	2.626	30
	Conventional	9.33	2.537	30
Decomposition	<i>B-CompThinkT</i>	13.61	3.968	30
	<i>B-CompThink</i>	18.67	2.249	30
	Conventional	15.33	2.249	30
Pattern Recognition	<i>B-CompThinkT</i>	9.00	3.051	30
	<i>B-CompThink</i>	14.33	4.752	30
	Conventional	17.83	2.520	30
Abstraction	<i>B-CompThinkT</i>	14.33	2.537	30
	<i>B-CompThink</i>	9.17	2.960	30
	Conventional	13.78	4.454	30
Generalization	<i>B-CompThinkT</i>	14.33	2.171	30
	<i>B-CompThink</i>	5.67	3.144	30
	Conventional	12.56	5.720	30

The strong performance in decomposition within the B-CompThink group can be explained by the print module's scaffolded, step-by-step worked examples, which provided clear guidance for breaking down complex problems. Even without technology, the structured sequencing of examples and exercises enhanced problem-solving strategies [29]. This finding demonstrates that the design of the module itself, not only the technological features contribute substantially to improve CT skills.

Interestingly, the conventional group scored highest in pattern recognition. This may be attributed to repetitive textbook drills that reinforce surface-level pattern recall [30]. However, such rote practice is less effective for developing higher-order CT skills, which require abstraction and transfer beyond immediate contexts.

Overall, the B-CompThink group, while lacking technological features, still outperformed the conventional group in most delayed post-test components. This indicates that structured modules alone provide a stronger foundation for long-term CT retention than textbook-based instruction, a result consistent with finding showing that structured graphic organizer-based interventions promoted CT more effectively than conventional teaching [25].

The multivariate Pillai's trace test (Table 5) indicated significant differences among groups in delayed post-test scores, $F(10, 158) = 12.06, p < .001$, while pre-test covariates did not significantly influence the outcomes. These findings confirm that the B-CompThinkT module contributed to sustaining long-term gains in CT skills, particularly in abstraction and generalization, while the B-CompThink module demonstrated robustness in decomposition.

TABLE IV
MULTIVARIATE TEST RESULTS (PILLAI'S TRACE) FOR DELAYED POST-TEST

Effect	Value	F	Hypothesis df	Error df	p
Intercept	.899	138.29	5.000	78.000	<.001
Pre_BasicConcepts	.055	.901 ^b	5.000	78.000	.485
Pre_Decomposition	.098	1.687 ^b	5.000	78.000	.147
Pre_PatternRecog.	.017	.268 ^b	5.000	78.000	.929
Pre_Abstraction	.061	1.017 ^b	5.000	78.000	.414
Pre_Generalization	.031	.503 ^b	5.000	78.000	.773
T&L Group	.866	12.060	10.000	158.000	<.001

V. DISCUSSION

The results of this study highlight the differentiated impact of modular and technology-enhanced instruction on students' computational thinking (CT). A central finding is that the B-CompThinkT module led to the most substantial gains in abstraction. This can be explained by the design of QR-linked reinforcement tasks and gamified quizzes that required students to reach mastery thresholds before progressing. Such design elements created opportunities for retrieval practice and space repetition [31], two well-established mechanisms that strengthen long-term retention. Because abstraction requires learners to distinguish essential features from irrelevant details; a skill typically regarded as the most demanding CT dimensions [32]; the interactive and feedback-driven nature of the B-CompThinkT activities appears to have directly targeted this ability. This interpretation is also supported by students' written responses. As illustrated in Figure 4, students in the B-CompthinkT group were able to represent abstraction by identifying core principles and omitting irrelevant details, a feature less evidence reinforces that the QR-linked reinforcement and mastery-based tasks explicitly fostered abstraction skills.

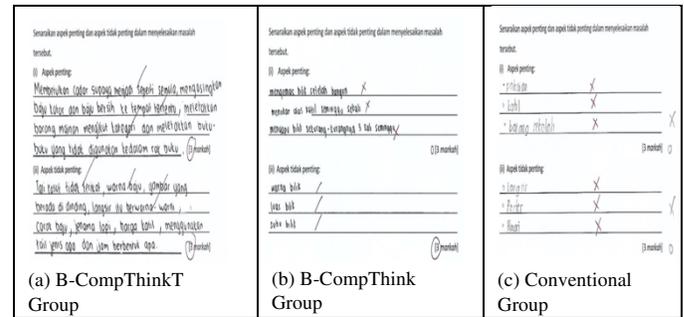


Fig. 4. Example of student response from the B-CompThinkT group demonstrating abstraction by identifying core principles and omitting irrelevant details.

Equally important, the findings show that the B-CompThink module, even without technology, significantly outperformed traditional teaching. This suggests that the pedagogical design of the module itself is inherently effective. The print-based version employed structured scaffolding and worked examples, which reduced cognitive load [31] and allowed students to decompose and solve problems systematically. These results are consistent with previous research showing that scaffolding through worked examples enhanced students' problem-solving strategies [29] and that structured graphic organizer-based instruction significantly improved CT outcomes [25]. Such consistency underscores that the strength of the B-CompThink module lies not only in its technological features but also in its pedagogical foundation. Figure 5 based examples from student work further showed how decomposition skills were fostered through the systematic sequencing of problems in the print module.

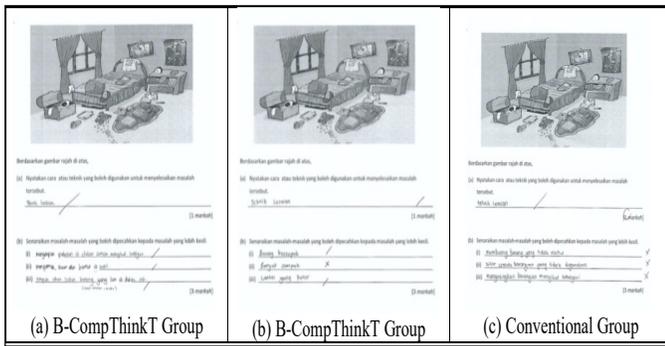


Fig. 5. Example of student response from the B-CompThink group showing systematic decomposition through step-by-step problem breakdown guided by scaffolded instructions.

From a theoretical perspective, the study contributes to understanding CT instruction by integrating several complementary frameworks. Distributed Cognition [32] explains how learning in the B-CompThinkT group extended beyond the individual to interactions with peers, teachers, and digital tools. The constructivist perspective is reflected in students’ active engagement with scaffolded tasks that allowed them to build knowledge progressively [33]. The use of a mastery learning approach, in which students were required to achieve at least 80% before moving on, ensured that knowledge gaps were addressed prior to progression [34]. At the same time, cognitive load theory provides insight into why scaffolding and worked examples in the print module improved performance even without technology, as they helped learners focus on essential cognitive processes without being overwhelmed by extraneous details [31].

The implications are twofold. Practically, the findings indicate that the teachers in resource-constrained schools can still benefit from the print-based B-CompThink module, which provides systematic scaffolding to support CT. For schools with greater access to digital tools, the B-CompThinkT module offers additional advantages through gamification and technology-enabled feedback, particularly for difficult to master skills like abstraction and generalization. Theoretically, the study contributes to CT education by showing that technology is not the sole driver of improvement; rather, it is the integration of scaffolding, mastery-based progression and distributed learning environments that underpins effective CT instruction.

In sum, the discussion underscores that both modular design and technology integration are critical but in complementary ways. The print module establishes a strong foundation through structured pedagogy while technology-enhanced features amplify practice opportunities and retention mechanisms. Together, these insights advance the understanding of how CT skills especially abstraction can be more effectively cultivated in secondary education.

VI. LIMITATIONS AND FUTURE RESEARCH

While the results are promising, several limitations should be acknowledged. First, the study was conducted in only one secondary school, which restricts the generalizability of the findings. Future research should replicate the study across schools in different regions to account for variation in teaching contexts and student backgrounds.

Second, the study did not directly measure student motivation or cognitive load, both of which may have influenced the effectiveness of the intervention. Including validated motivation scales or cognitive load measures would provide a more comprehensive understanding of how the modules impact learning processes.

Third, the fidelity of teacher implementation was not systematically monitored. Differences in how teachers delivered the modules could have influenced student outcomes. Future studies should incorporate

classroom observations or fidelity checklists to ensure consistent delivery.

Finally, the study examined CT achievement over a relatively short period. Longer-term studies are needed to determine whether the benefits of the B-CompThinkT module persist beyond the immediate and delayed post-test. Expanding the intervention to include other digital tools such as adaptive learning systems, artificial intelligence tutors, or AR/VR environments could further strengthen its impact.

VII. CONCLUSION

This study provides empirical evidence that the B-CompThinkT module a technology-integrated, mastery-oriented instructional design—significantly improves lower secondary students’ computational thinking skills compared with both a print-based module and conventional teaching. The integration of QR-linked reinforcement, immediate feedback, and gamified assessments requiring mastery before progression was especially effective in strengthening abstraction and generalization, skills that are typically the hardest to sustain.

At the same time, the B-CompThink print module also proved superior to conventional teaching, demonstrating that structured, scaffolded modules alone can substantially improve decomposition and problem-solving skills. This highlights that effective pedagogical design, not only technology, is central to advancing CT.

The findings support theoretical perspectives from constructivism, distributed cognition and mastery learning, while also aligning with recent research emphasizing the role of scaffolding and technology-supported practice in CT education [29][25][35].

Practical implications include the recommendation that ASK teachers adopt structured modules with scaffolded worked examples as a baseline, and enhance them with gamified and feedback-driven features where possible. For policymakers, the study underscores the importance of investing in blended learning resources that integrate pedagogy and technology to support Malaysia’s KSSM reforms and broader digital education goals.

Future work should broaden the sample, integrate motivational and cognitive load measures, and test additional digital enhancements. By doing so, researchers and educators can build a stronger evidence base for scalable, sustainable CT instruction in Malaysia and beyond.

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