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Developing Higher-Order Thinking Skills in Physics: Association of a Structured Concept-Mapping Intervention and Student's Problem-Solving Self-Report Perception

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Abstract

Higher-order thinking skills (HOTS) are increasingly emphasised in science education, yet physics instruction often remains dominated by formula-based problem solving and rote application, providing limited opportunities for students to analyse relationships, construct reasoning, and apply conceptual knowledge to unfamiliar problems. This study examined

changes in secondary school students' physics self-report perception following the implementation of a HOTS-oriented instructional approach and explored students' perceptions of HOTS-based learning. The study involved 84 students from a secondary school in Selangor, Malaysia, selected through purposive sampling. The instructional intervention incorporated structured derivation concept maps in the teaching of Newton's law of gravitation to encourage students to connect physical concepts, mathematical relationships, and problem-solving processes. The findings showed a statistically significant increase in critical thinking performance mean scores from pre-test (M = 2.61) to post-test (M = 4.15), with $p < .001$. Students also reported positive perceptions of HOTS-oriented instruction (M = 4.21), particularly in supporting independent learning and conceptual understanding, while recognising the role of conventional instructional approaches (M = 3.99) in establishing foundational knowledge. These findings suggest that structured HOTS-oriented learning activities have potential to support students' transition from procedural application toward more analytical and conceptually grounded physics problem solving. The study provides preliminary evidence for integrating explicit higher-order reasoning strategies into secondary physics instruction, while highlighting the need for further controlled studies to establish their comparative effectiveness.
keywords: HOTS skills, Critical Thinking, Problem Solving and Physics Learning

Introduction

Background of Study

Contemporary education increasingly extends beyond the development of basic literacy and numeracy toward the cultivation of higher-order thinking, independent problem solving, and the ability to apply knowledge in unfamiliar situations (Yanti & Thohir, 2024; Rasyid et al., 2024). Within this broader shift toward higher-order competencies, national education policy has placed explicit emphasis on these skills; in Malaysia, such competencies are particularly important in preparing students to respond effectively to the increasingly complex demands of science, technology, and future employment. Consequently, science education is expected not only to develop students' content knowledge but also to strengthen their capacity to analyse information, evaluate alternative solutions, and solve problems independently.

Translating this policy emphasis into subject-specific classroom practice remains uneven, and physics offers a particularly instructive case, since the subject inherently requires students to integrate conceptual understanding, mathematical relationships, and procedural reasoning simultaneously. In physics education, however, instructional practices may still place considerable emphasis on formula application and routine problem-solving procedures, potentially limiting opportunities for students to analyse unfamiliar situations and articulate conceptual reasoning (Ubaidillah et al., 2023; Rasyid et al., 2024). Such approaches may help students reproduce previously learned procedures but may provide limited opportunities for them to develop Higher Order Thinking Skills (HOTS), particularly when dealing with complex or unfamiliar problems. Previous research has indicated that students require learning experiences that actively engage them in exploring concepts, constructing explanations, and solving problems rather than merely recalling information (Lismaya, 2019). These learning experiences are important because meaningful physics understanding requires students to connect conceptual principles with mathematical relationships and apply them across different problem contexts.

The development of HOTS therefore requires deliberate instructional strategies that encourage students to analyse relationships, justify reasoning, and construct solutions independently. Susanto & Retnawati (2016) suggests that thinking skills can be strengthened through systematic learning activities that train students' cognitive processes and promote meaningful understanding. Nevertheless, the effective integration of HOTS into physics instruction remains challenging, particularly when students are accustomed to conventional approaches that emphasise formula application and memorisation. This highlights the need for structured pedagogical approaches that explicitly support higher-order reasoning during physics learning.

Accordingly, the present study investigates the integration of HOTS-oriented instruction in physics learning, with particular emphasis on the use of structured derivation concept maps in teaching Newton's law of gravitation. The study examines whether such an approach can support students' physics self-report perception and encourage a shift from procedural problem solving toward more analytical and conceptually grounded reasoning.

Statement of Problem

Building on this background, the discussion is now narrowed from the general policy and disciplinary context to the specific pedagogical gap motivating the present study: the lack of structured, classroom-ready strategies for operationalising HOTS during physics problem solving. Physics requires students not only to understand scientific concepts and mathematical relationships but also to analyse information, connect multiple representations, justify reasoning, and apply knowledge to unfamiliar problems. However, classroom instruction may still emphasise memorisation of formulas and routine procedures, providing limited opportunities for students to engage in higher-order reasoning. Consequently, students may be able to reproduce familiar solutions while having trouble when required to interpret abstract concepts or solve non-routine physics problems.

This challenge is particularly important because physics concepts frequently involve abstract relationships that require students to integrate conceptual understanding with mathematical reasoning. Passive learning and formula-based instruction may therefore be insufficient for developing the analytical and problem-solving abilities required for more complex tasks. Previous research has highlighted the need for learning approaches that actively involve students in constructing knowledge and applying concepts in meaningful contexts (Rannikmäe, 2016). Nevertheless, there remains a need for structured instructional strategies that explicitly guide students through the reasoning processes involved in solving physics problems rather than expecting higher-order thinking to develop implicitly.

Although the importance of HOTS has been widely acknowledged, its classroom implementation may remain inconsistent because teachers require practical pedagogical approaches that can be incorporated into existing physics lessons. Factors such as reliance on conventional teaching practices, assessment-oriented instruction, limited opportunities for independent problem solving, and inadequate emphasis on higher-level cognitive processes may restrict students' development of HOTS. Astrid et al. (2022) further emphasise the importance of considering students' learning characteristics when developing higher-order thinking abilities. Therefore, the challenge is not merely whether HOTS should be included in physics education, but how HOTS can be operationalised through structured classroom

activities that support students in developing more analytical and independent approaches to problem solving.

One potential approach is the use of structured derivation concept maps, which can guide students in identifying relationships among physical concepts, equations, and sequential reasoning processes. Such an approach may help students move beyond memorising formulas toward understanding how physical relationships are derived and applied. However, evidence is still required to determine whether the integration of structured HOTS-oriented activities can improve students' self-report perception in solving physics problems and how students perceive such learning approaches.

Accordingly, this study investigates the implementation of a HOTS-oriented instructional approach using structured derivation concept maps in the teaching of Newton's law of gravitation among high school physics students. Specifically, the study examines changes in students' physics self-report perception following the intervention and explores their perceptions of HOTS-oriented learning. Through this investigation, the study seeks to provide empirical evidence regarding the potential of structured HOTS-based pedagogy to support more analytical, conceptually grounded, and independent problem solving in secondary physics education.

The novelty of this study lies in its integration of structured derivation concept mapping — a technique that explicitly visualises the mathematical derivation sequence underlying a physics law (Newton's law of gravitation) — within an authentic secondary classroom, rather than applying concept mapping solely to conceptual or terminological relationships as in much of the prior literature (e.g., Barta et al., 2022). By simultaneously examining change in students' critical-thinking performance and their self-reported perceptions of HOTS-oriented instruction, the study offers an integrated quantitative–perceptual account of how a structured pedagogical tool translates national HOTS policy (Ministry of Education Malaysia, 2013) into classroom-level outcomes. In doing so, the study contributes to the broader social science literature on education reform by providing context-specific empirical evidence from a Malaysian secondary school setting — a context that remains underrepresented relative to higher-education and Western-based HOTS research — and by offering a pedagogical model that classroom teachers can adapt without extensive additional training or resources.

Objective of the Study and Research Questions

This study is done to evaluate changes in students' critical-thinking performance following the implementation of HOTS-focused learning in secondary physics instruction. This study also aims to investigate students' perceptions of HOTS-focused learning in supporting conceptual understanding, independent learning, and problem-solving. Specifically, this study is done to answer the following questions:

- How do students' critical-thinking performance change following the implementation of HOTS-focused learning in secondary physics instruction?
- How do students perceive HOTS-focused learning in supporting conceptual understanding, independent learning, and problem-solving?

Literature Review

Stimulating Higher-Order Thinking Skills in Learning

Higher-Order Thinking Skills (HOTS) refer to cognitive processes that extend beyond the recall and reproduction of information. Within Bloom's taxonomy, higher-order thinking is commonly associated with the more advanced cognitive processes of analysis, synthesis, and evaluation, which require learners to manipulate, reorganise, interpret, and judge information rather than simply remember it (Bloom, 1956; Forehand, 2010). HOTS therefore involves the ability to examine relationships among ideas, construct arguments, solve unfamiliar problems, evaluate evidence, and generate meaningful conclusions. Lewis and Smith (1993) further describe higher-order thinking as occurring when newly acquired information is integrated with existing knowledge and reorganised to achieve a particular purpose or generate a reasoned response.

The development of HOTS is closely associated with active cognitive engagement. Learners are more likely to exercise higher-order thinking when they are required to question information, analyse relationships, justify their reasoning, evaluate alternatives, and apply existing knowledge to unfamiliar situations. Such cognitive processes differ from lower-order learning activities that primarily require students to recall facts or reproduce predetermined procedures. Higher-order thinking is therefore particularly important in learning situations where problems are complex, non-algorithmic, and capable of producing multiple possible solutions (Zohar & Dori, 2003). These characteristics require learners to exercise greater autonomy and to select, monitor, and evaluate appropriate strategies during problem solving. Several pedagogical approaches have been identified as capable of stimulating these cognitive processes. Inquiry-based learning encourages students to formulate questions, investigate relationships, and construct explanations through exploration, whereas problem-based learning requires students to apply knowledge to unfamiliar or authentic situations. Constructivist approaches similarly position students as active participants who build understanding through prior knowledge and learning experiences. Graphic organisers, particularly concept maps, can support higher-order cognition by externalising conceptual relationships, organising information hierarchically, and encouraging learners to integrate previously fragmented knowledge. Meta-analytic evidence indicates that concept mapping can produce meaningful improvements in both critical-thinking ability and critical-thinking disposition compared with conventional instruction (Barta et al., 2022).

Metacognition also plays an important role in developing HOTS. Metacognitive processes involve learners' awareness of their own thinking and their ability to plan, monitor, evaluate, and regulate cognitive activities. These processes support higher-order thinking because students must not only determine how to solve a problem but also evaluate whether their chosen strategy is appropriate and modify it when necessary. Accordingly, HOTS development is strengthened when instruction provides explicit opportunities for questioning, reasoning, explanation, evaluation, reflection, and problem solving rather than relying primarily on teacher-centred transmission of information.

In Malaysia, the development of HOTS has been embedded within national educational reform through the Malaysia Education Blueprint 2013–2025. HOTS implementation has been promoted across curriculum, pedagogy and assessment, including through inquiry-based, problem-based, project-based and STEM-oriented learning approaches (Ministry of Education

Malaysia, 2013). The integration of HOTS into the curriculum reflects a broader aim to develop students who are capable of critical thinking, creativity, problem solving, and independent learning. Nevertheless, classroom implementation continues to face challenges, including teachers' reliance on conventional instructional approaches, limited resources and training, and concerns regarding students' readiness to engage in higher-level cognitive activities. These challenges suggest that the inclusion of HOTS in curriculum policy alone may be insufficient; teachers also require practical instructional approaches that translate HOTS principles into observable learning activities.

Within this context, structured learning tools such as concept maps offer a potential mechanism for making higher-order reasoning more explicit. Rather than requiring students to memorise isolated formulas or procedural steps, concept-based representations can encourage learners to identify relationships, connect theoretical principles with mathematical expressions, and organise the sequence of reasoning needed to solve a problem. Such structured cognitive support may therefore provide an appropriate mechanism for embedding HOTS within physics instruction.

Importance of Critical Thinking in Physics Learning

Critical thinking represents an important dimension of higher-order cognition and is particularly relevant to physics learning. It involves the deliberate analysis and evaluation of information, arguments, evidence, and possible solutions before reaching a justified conclusion. Critical thinkers are expected not merely to accept information but to question assumptions, consider alternative explanations, evaluate evidence, and revise their reasoning when necessary. These abilities are closely associated with the broader HOTS processes of analysis, evaluation, problem solving, reasoning, argumentation, and metacognition.

Critical thinking is particularly relevant to physics because successful problem solving requires students to coordinate conceptual knowledge, mathematical representation and strategic reasoning rather than merely retrieve equations. Students must identify relevant variables, select appropriate principles, establish mathematical relationships and evaluate whether a resulting solution is physically plausible (Ubaidillah et al., 2023; Rasyid et al., 2024). Many physics problems require learners to interpret a physical situation, identify relevant variables, select appropriate concepts, establish mathematical relationships, and evaluate whether the resulting solution is physically meaningful. Consequently, students who rely primarily on memorised formulas may experience difficulty when presented with unfamiliar or complex problems that differ from previously practised examples.

The ability to apply knowledge in unfamiliar contexts therefore represents a key distinction between procedural learning and higher-order physics reasoning. Application at a higher cognitive level requires learners to transfer conceptual understanding to new situations rather than simply reproduce a familiar procedure. Analysis enables students to decompose a physics problem into its relevant components, while evaluation requires them to determine whether assumptions, strategies, and resulting answers are appropriate. Synthesis further enables learners to integrate multiple concepts or representations into a coherent solution. These processes are particularly important when physics questions involve several stages of reasoning rather than straightforward substitution into an equation.

Problem solving in physics is also closely related to reasoning and metacognition. Students must determine what information is relevant, identify an appropriate strategy, execute the strategy, and evaluate the resulting solution. This requires both cognitive and metacognitive regulation. When students monitor their reasoning, identify errors, and reconsider inappropriate strategies, they engage in processes that are characteristic of critical thinking. Developing such capabilities can therefore help students progress from passive recipients of information toward more independent and reflective problem solvers.

Despite the importance of these abilities, traditional teacher-centred approaches may provide limited opportunities for students to explicitly demonstrate higher-order reasoning. Instruction that emphasises the reproduction of formulas and standard solution procedures may support performance on familiar exercises but does not necessarily ensure that students understand the conceptual relationships underlying those procedures. Previous literature has therefore emphasised the need for teaching approaches that encourage questioning, inquiry, problem solving, explanation, and reflection. These approaches can create opportunities for students to articulate their reasoning and strengthen the connections between conceptual understanding and mathematical problem solving.

This issue is particularly relevant to secondary physics education, where students are frequently introduced to abstract concepts that require simultaneous conceptual and mathematical reasoning. Newton's law of gravitation, for example, requires students to understand relationships among mass, distance, gravitational force, and mathematical proportionality. If the associated equation is learned only as a formula to be memorised, students may have difficulty explaining its derivation or applying it meaningfully in unfamiliar contexts. A structured HOTS-oriented approach that makes relationships and reasoning processes visible may therefore help students develop a more conceptually grounded understanding of physics problems.

Past Studies on Developing Critical Thinking in Physics Learning

The development of critical thinking in physics education has received increasing attention because physics requires students to interpret phenomena, connect conceptual and mathematical representations, evaluate possible solutions, and apply principles to unfamiliar situations. Consequently, previous studies have explored instructional approaches that move students beyond memorising formulas and reproducing standard procedures. Among the most frequently investigated approaches are problem-based learning, problem-solving instruction, inquiry-oriented learning, and the use of visual or conceptual representations. Collectively, these approaches share an emphasis on active engagement, reasoning, and the application of knowledge rather than passive reception of information.

Problem-Based Learning (PBL) has been particularly prominent in research on critical thinking in physics. Nurhayati et al. (2021) investigated the relationship between PBL, critical-thinking ability, and higher-order thinking among prospective physics teachers and reported that PBL was associated with the development of HOTS in physics learning. More recent synthesis studies have reached similar conclusions. Kamaluddin et al. (2024), for example, conducted a meta-analysis of ten studies examining PBL in physics education and reported an overall positive effect on students' critical-thinking abilities. Likewise, a meta-analysis of PBL-based student worksheets found a large overall effect on critical thinking and physics problem-

solving outcomes, suggesting that structured problem-oriented learning materials can support the development of higher-level reasoning. These findings indicate that critical thinking is more likely to develop when students are required to interpret problems, formulate possible solutions, justify decisions, and evaluate their reasoning.

Empirical studies at the secondary-school level also demonstrate the potential of problem-centred approaches. A recent quasi-experimental study involving high-school physics students reported improvements in critical-thinking performance after the implementation of PBL in the topic of dynamic fluids compared with conventional instruction. Similarly, studies of problem-solving-based physics instruction have highlighted the value of requiring students to analyse information, identify relevant concepts, construct solution strategies, and evaluate the validity of their answers. One recent quasi-experimental study employing a problem-solving-based physics model reported positive effects on both critical thinking and learning independence. These results support the view that critical thinking in physics develops through repeated engagement with reasoning processes rather than through direct transmission of factual content alone.

Beyond broad instructional models, concept mapping provides a more targeted form of cognitive scaffolding by requiring learners to externalise, organise and connect conceptual relationships. A meta-analysis by Barta et al. (2022) found that concept mapping produced significant improvements in students' critical-thinking abilities and dispositions compared with conventional instruction. Similarly, meta-analytic evidence from elementary and secondary science education indicates positive effects of concept mapping on science achievement, including physics-related learning. These findings provide an empirical rationale for examining whether a derivation-oriented form of concept mapping can support the simultaneous integration of conceptual and mathematical reasoning in physics.

Concept maps and related graphic organisers allow students to externalise relationships among concepts, organise information hierarchically, and identify connections that may not be immediately evident through conventional note-taking. This is consistent with the literature reviewed in the present study, which identifies concept maps, flow maps, and other graphic organisers as tools for visualising relationships and organising thought during higher-order learning. Recent research examining digital concept maps in Grade 10 physics found stronger development of critical-thinking dimensions among students exposed to concept-map-supported instruction compared with students receiving conventional teaching. Such findings are particularly relevant to physics because students must frequently coordinate conceptual explanations with equations, variables, diagrams, and mathematical derivations.

The effectiveness of these approaches may be explained by the cognitive demands they impose on learners. Rather than simply identifying an equation and substituting numerical values, students are required to determine what a problem represents, identify relevant concepts, explain relationships among variables, justify the selected procedure, and evaluate whether the obtained solution is reasonable. These activities correspond closely to higher-order cognitive processes such as analysis, evaluation, reasoning, problem solving, and metacognition. The existing literature therefore suggests that critical thinking develops most effectively when such processes are explicitly embedded within instructional activities rather than expected to emerge automatically from exposure to physics content.

Despite encouraging findings, several limitations remain in the existing literature. Much of the research has concentrated on broad instructional models such as PBL or inquiry-based learning, whereas fewer studies have examined how a specific structured cognitive tool can guide students through the reasoning and mathematical derivation involved in physics problem solving. Furthermore, studies frequently report overall improvements in critical-thinking scores without explaining how students connect conceptual knowledge to mathematical procedures during the learning process. This distinction is important in physics, where students may successfully reproduce formulas while lacking a sufficiently integrated understanding of how those formulas originate and when they should be applied.

Accordingly, there is value in investigating instructional strategies that explicitly structure the relationship between physics concepts, mathematical derivation, and higher-order reasoning. The present study addresses this need by incorporating a structured derivation concept map within HOTS-focused instruction on Newton's law of gravitation. Rather than treating concept mapping solely as a tool for organising information, the intervention is intended to guide students through the conceptual and mathematical relationships underlying the derivation and application of physics principles. In doing so, the study examines whether a structured HOTS-oriented approach can support students in progressing from formula-based problem solving toward more analytical and conceptually grounded reasoning.

Conceptual Framework: HOTS, Critical Thinking, and Physics Learning.
The conceptual framework of this study is grounded primarily in Bloom's taxonomy of the cognitive domain. Bloom's taxonomy provides a hierarchical representation of cognitive processes ranging from lower-order activities such as remembering and understanding to more advanced processes involving application, analysis, synthesis, and evaluation. Within the context of this study, HOTS represents the cognitive processes that require students to move beyond factual recall and procedural reproduction toward the analysis of relationships, evaluation of information, construction of reasoning, and solution of complex physics problems.

The framework proposes that HOTS-oriented instruction acts as the instructional stimulus through which higher-level cognitive processes are activated. Learning activities that require students to identify conceptual relationships, justify problem-solving steps, analyse information, connect mathematical expressions with physical principles, and evaluate solutions are expected to promote deeper engagement with physics content. Critical thinking is therefore conceptualised not as a separate instructional strategy but as an important cognitive outcome associated with the activation of higher-order thinking processes.

Structured derivation concept maps represent the principal pedagogical mechanism through which HOTS is operationalised in the present study. Concept mapping can support students in organising knowledge and visualising relationships among physical concepts, while the structured derivation component requires students to follow and understand the logical progression from fundamental principles to mathematical relationships. In this way, students are encouraged to understand not only which equation should be used but also why the equation is appropriate and how its components are related.

The proposed framework therefore assumes a sequential relationship in which HOTS-oriented instructional activities stimulate higher-order cognitive processes, which subsequently support critical thinking and physics problem-solving self-report perception. Rather than treating learning as the memorisation of isolated facts and formulas, the framework positions students as active learners who analyse information, establish conceptual relationships, evaluate reasoning, and apply knowledge to solve problems.

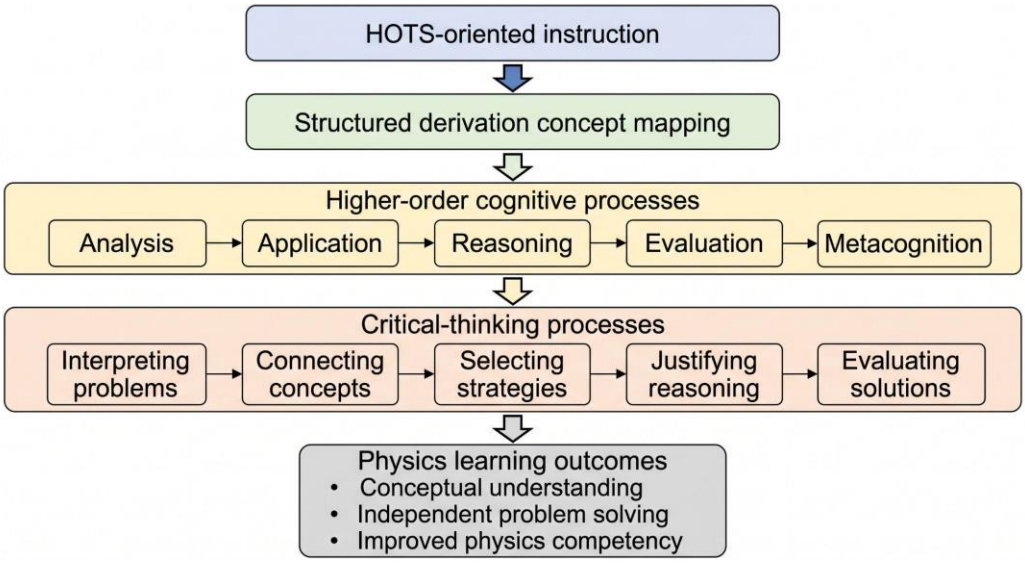


Figure 1 Conceptual Framework of the Study - Learning Strategies Components

Methodology

This quantitative study is done to evaluate changes in students' critical-thinking performance after the implementation of HOTS-focused learning in secondary physics instruction. A purposive sample of 84 participants responded to the survey. The instrument used is a 5 Likert-scale survey and was delivered to the participants before and after the intervention. The intervention employed a Structured Derivation Concept Map, which visually represented the derivation of physics relationships from fundamental concepts rather than presenting formulas in isolation. The approach guided students through the logical connection of variables such as mass, radius, linear velocity, and orbital period, with the aim of encouraging analytical reasoning and conceptual understanding.

A questionnaire was administered after intervention to enable assessment on students' perceptions of HOTS-focused learning in supporting conceptual understanding, independent learning, and problem-solving. In addition, a Likert-scale instrument was used to capture students' responses toward the instructional approach. Further analysis using SPSS is done to present findings to answer the research questions for this study.

Findings

Findings for Demographic Profile

A total of 84 students agreed to have their responses gathered. The demographic data in Figure 2 show a relatively imbalanced gender distribution among the respondents, with 69 (82.3%) identifying as male and 15 (17.7%) as female, drawn from three secondary schools in Selangor, Malaysia (Sekolah Tinggi Klang, n = 54; SMK Dato' Hamzah, n = 30; SMK Sultan Sulaiman, n = 18). All participants were Form Four students enrolled in the physics stream.

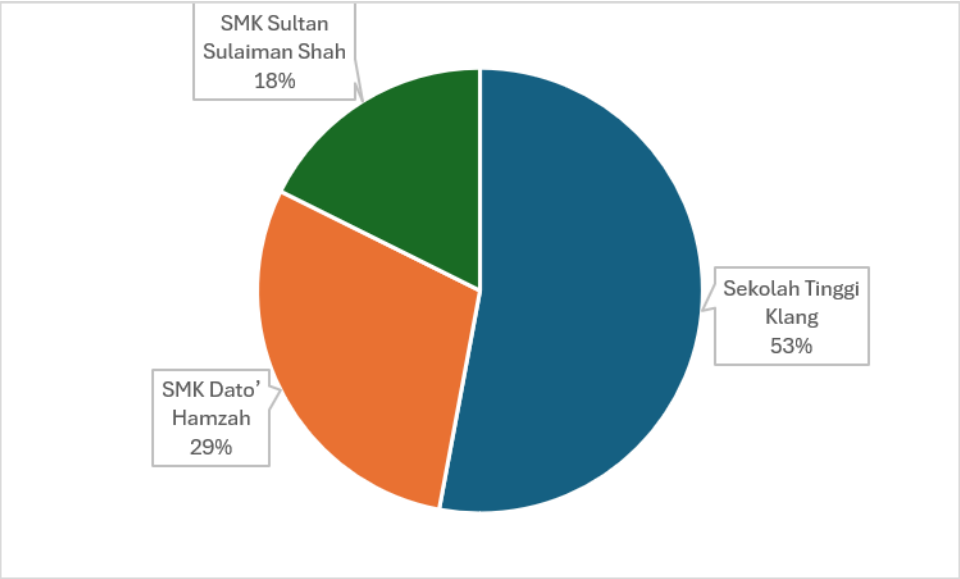


Figure 2 Percentage for Demographic Profile

The choice of these schools was based on their Gred Purata Sekolah (GPS) scores in the 2024-Year SPM's. The 3 selected schools have an average GPS of more than 3.50, indicating that these 3 schools would fall into the category of low achiever. The GPS scoring range for all 3 selected schools ranged from 4.18 (Sekolah Tinggi Klang), 4.22 (SMK Dato' Hamzah), to 4.49 (SMK Sulaiman Shah).

The similarity of the schools provides a relatively uniform sample of students who have similar academic backgrounds. Therefore, the use of these three schools as study sites provides a homogenous group of students who come from similar academic environments. Thus, by clustering the students' academic performance, the researcher will reduce the amount of variation due to environmental factors and concentrate on understanding the internal variables that impact the academic outcomes of students who were all within one level of academic performance.

Findings for impact of HOTS-focused learning in developing critical thinking skills among Physics Students

This section presents data to answer research question 1- How do students' critical-thinking performance change following the implementation of HOTS-focused learning in secondary physics instruction? The questionnaire has 5 items.

Table 1
Mean for Pre-Test

ITEM	MEAN	STD. DEVIATION	RANK
Physics learning activities involving HOTS help me think deeper.	2.75	0.512	1
HOTS questions help me view a problem from multiple perspectives	2.67	0.567	2
The use of HOTS in learning Physics increases my confidence in making decisions.	2.57	0.607	4

I can apply the knowledge learned in Physics to solve real-life problems because of HOTS-based learning.	2.58	0.542	3
I have the opportunity to solve HOTS questions in Physics class.	2.48	0.630	5

Table 1 shows the mean for students' critical-thinking performance before the implementation of the intervention. From the table, it is observed that the lowest mean score is 2.48 indicates the students agree that they have limited opportunity to solve HOTS questions in Physics class. The highest mean score reported is 2.75 which indicated most students very much agreed that Physics learning activities involving HOTS help them think deeper. Overall, these five items indicate that students perceived their critical thinking skills to be limited prior to the intervention.

Table 2
Mean for Post-Test

ITEM	MEAN	STD. DEVIATION	RANK
Physics learning activities involving HOTS help me think deeper.	4.17	0.556	2
HOTS questions help me view a problem from multiple perspectives	4.31	0.559	1
The use of HOTS in learning Physics increases my confidence in making decisions.	4.02	0.537	5
I can apply the knowledge learned in Physics to solve real-life problems because of HOTS-based learning.	4.13	0.636	4
I have the opportunity to solve HOTS questions in Physics class.	4.14	0.604	3

Table 2 shows the mean for students' critical-thinking performance after the implementation of the intervention. From the table, it is observed that all the items recorded a high mean score. The highest mean score is 4.31 indicates the students went through the intervention was recorded for students' ability to view problems from multiple perspectives, while the lowest mean score 4.02 was recorded for students feeling more confidence in making decisions using HOTS in Physics learning. Overall, Structured Derivation Concept Map intervention did give impact to students perceived critical thinking skills.

Table 3
Paired-Samples t Test Comparing Pre-Impact and Post-Impact Scores

Measure	M	SD	Mean Difference	95% CI for Difference	t	df	p
Pre-impact	2.61	0.39					
Post-impact	4.15	0.41	-1.55	[-1.65, -1.44]	-28.66	83	< .001

To further examine the impact of the intervention, a paired-samples t-test was conducted based on Table 3 to compare pre-test and post-test scores. Students' self-reported perception of their critical-thinking engagement in physics increased significantly from pre-test ($M = 2.61$, $SD = 0.39$) to post-test ($M = 4.15$, $SD = 0.41$), $t(83) = -28.66$, $p < .001$, with a mean difference of -1.55, 95% CI [-1.65, -1.44]. Because this change was observed in a single group without a comparison condition, and the instrument explicitly referenced HOTS-labelled activities, this result should be interpreted as evidence of increased perceived engagement with HOTS-

oriented learning rather than demonstrated gains in physics problem-solving self-report perception. Therefore, Research Objective 1 is achieved.

The substantial increase in mean scores suggests that students' perceived engagement with critical-thinking processes was responsive to the structured instructional intervention. This interpretation is consistent with evidence that explicit, student-centred instructional strategies can support critical-thinking development (Abrami et al., 2015; Barta et al., 2022). Nevertheless, because the present outcome was self-reported and the study lacked a comparison condition, the observed increase should not be interpreted as direct evidence of equivalent gains in objectively measured critical-thinking competency.

Findings for students' perceptions of HOTS-focused learning in supporting conceptual understanding, independent learning, and problem-solving

Table 4

Student's perception on effectiveness of HOTS intervention in enhancing critical thinking

ITEM	MEAN	STD. DEVIATION	RANK
HOTS-based teaching makes me actively engaged in class compared to traditional methods.	4.12	0.589	3
Traditional methods such as copying notes and listening to lectures, does not help me develop critical thinking skills.	3.99	0.549	5
I understand Physics concepts more effectively when I have opportunities to explore and solve problems independently	4.21	0.582	1
I gain a better understanding of Physics through HOTS-focused teaching methods compared to traditional methods.	4.14	0.541	2
The HOTS approach increases my independence and confidence levels in solving Physics problems compared to traditional methods.	4.12	0.524	4

This section presents data to answer research question 2. The questionnaire has 5 items. Table 4 shows the mean score of students' perception on how HOTS based learning intervention improves their critical thinking skills. Across the five items, mean agreement ranged from 3.99 (SD = 0.55) for the statement that traditional methods do not support critical thinking to 4.21 (SD = 0.58) for valuing independent problem exploration (grand M = 4.12, SD = 0.56). From the table, it is observed that item 3 has the highest mean at 4.21 which indicates that most students made a good agreement of comprehension towards the Physics concept effectively when they were given the opportunity to explore themselves. This is followed by items 4 and 1 with the mean score of 4.14 and 4.12 respectively. This suggests that students gained better understanding of the topics and gave them active engagement in class after being approached by using HOTS intervention rather than traditional teaching methods.

Research Objective 2 demonstrates convincingly that students perceive the drawbacks of traditional "chalk-and-talk" classroom delivery methods. In particular, students rated "independence when investigating/solving problems" (M=4.21) higher than "note copying"

(M=3.99). These perceptions are consistent with the broader shift toward student-centred approaches in science education, in which learners actively construct, test and refine conceptual understanding through problem solving, inquiry and collaborative reasoning (Yanti & Thohir, 2024; Ubaidillah et al., 2023). The feedback from the intervened students suggests that they were more engaged intellectually when permitted to take ownership of their exploratory efforts rather than remain passive recipients of information. Stanberry & Payne (2018) indicate that the types of active learning methodologies provided by the research are beneficial in improving students' retention of course content and their ability to use critical thinking skills, thereby increasing their interest and persistence in pursuing STEM (science, technology, engineering, mathematics) degrees when compared to standard lecture delivery models.

Conclusion

Summary of Findings and Discussions

A paired-samples t-test was employed to examine Research Objective 1. The analysis revealed a statistically significant increase in students' self-reported critical-thinking engagement. Scores rose from a pre-test mean of 2.61 (SD = 0.39) to a post-test mean of 4.15 (SD = 0.41), $t(83) = -28.66$, $p < .001$, 95% CI [−1.65, −1.44]. The effect size was large (Cohen's $d_z = 3.13$).
This magnitude of change exceeds what is typically reported for single-session instructional interventions. Several explanations are possible. The increase may reflect genuine engagement with the Structured Derivation Concept Map. Alternatively, it may partly reflect participants' awareness of the HOTS-oriented framing of the lesson. The questionnaire items explicitly referenced HOTS-based activities. The present design cannot distinguish between these explanations.

The pre-test results indicated limited prior exposure to HOTS-oriented tasks. Several items recorded mean scores below 2.60, suggesting students perceived few opportunities for higher-order questioning before the intervention. This pattern is consistent with Bloom's taxonomy. Learners who lack deliberate practice tend to remain within the Remembering and Understanding categories. The post-test increase is consistent with Battaglia (2020), who reported positive changes in critical-thinking perceptions following explicit instruction.

However, the present study did not include a comparison group taught through conventional methods. The observed change cannot be attributed to the intervention alone. Alternative explanations, including practice effects and demand characteristics, cannot be ruled out with the current design.

The lowest-rated item across both perception scales concerned traditional note-copying. This finding is consistent with the view that passive transcription activities may occupy students physically without engaging them cognitively. Belouahem (2020) described rote learning as a cycle of memorising and practising that leads to forgetting. The present findings are consistent with this distinction. The self-report nature of the measure means the result reflects students' perceptions rather than directly observed learning outcomes.

Pedagogical Implications and Suggestions for Future Research

The findings are consistent with Revised Bloom's Taxonomy. This framework holds that higher-order thinking skills (HOTS) can develop through structured support. This appears true

even among students with limited lower-order thinking skills (LOTS). The findings also raise a question for curriculum design. It remains unclear why mastery of the Remembering level is typically treated as a prerequisite for Analysing or Creating tasks. This question is not resolved by the present data. It is noted here as a direction for future theoretical work.

The study has several limitations that should guide future research. Data collection and the HOTS-based activity were completed within a single day. This short timeframe limited the amount of practice available to students. It also restricts the strength of any causal interpretation. The absence of a comparison group further limits confidence in attributing the observed change to the intervention. Alternative explanations include testing effects and increased familiarity with the assessment items. In addition, both outcome measures relied on student self-report. No objective scored measure of physics problem-solving competency was administered.

Future studies are encouraged to adopt a quasi-experimental design with a comparison group taught through conventional instruction. Longitudinal studies should be implemented across a full semester or academic year. Such studies would help establish whether gains in perceived critical-thinking engagement are retained over time. Future work should also employ an objective competency measure alongside the self-report questionnaire. The reliability of all instruments should be reported in subsequent studies.

The present study offers preliminary evidence that a Structured Derivation Concept Map may support students' engagement with HOTS-oriented physics tasks. Replication with a controlled design is needed before stronger claims about instructional effectiveness can be made. An objective competency measure should also be included in future replications. The findings nonetheless suggest that explicit, structured scaffolding deserves further attention. This includes the link between physical concepts and mathematical derivation in physics education.

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