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Computational Thinking Proficiency among Pre-Service Teachers at Universiti Putra Malaysia

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***Abstract* — This paper investigates the computational thinking proficiency of pre-service teachers at the Faculty of Educational Studies, Universiti Putra Malaysia, through a multi-methods research design. The primary objective is to assess the understanding and perceptions of computational thinking among pre-service teachers and its implications for problem-solving proficiency in various academic disciplines. The study reveals that pre-service teachers possess above midpoint computational thinking proficiency. It emphasizes the importance of integrating computational thinking into teacher training programs to adequately prepare pre-service teachers for the digital era. The role of prior knowledge and experience in shaping computational thinking proficiency among individuals entering the teaching profession is highlighted. The findings underscore the necessity of incorporating computational thinking into teacher education curricula to meet the evolving demands of the digital landscape. Despite challenges related to varying levels of prior knowledge and limited exposure, there is a growing recognition of the significance of computational thinking in education. Teacher training initiatives are progressively integrating computational thinking into their programs, offering practical experiences and interdisciplinary approaches to empower pre-service teachers with essential proficiency for contemporary educational practices. Continuous learning and collaborative efforts are identified as crucial components in shaping the future of computational thinking in teacher education, ensuring educators remain at the forefront of educational advancements. Ultimately, the aim is to equip future generations with the computational thinking proficiencies necessary for navigating a dynamic and ever-changing world.**

Keywords: Computational thinking, pre-service teachers, computational thinking understanding, proficiency, teacher education

I. Introduction

The integration of computational thinking (CT) into teacher education programs has emerged as a pivotal issue in Malaysia, particularly as the nation strives to equip future educators with the skills needed to meet the demands of the 21st-century educational landscape. Despite the recognized importance of CT, the Malaysian education system faces numerous challenges in embedding it effectively within teacher training curricula. One of the primary hurdles lies in the educators' limited proficiency in computational thinking concepts, compounded by difficulties in implementing CT within education contexts [1]. This issue is further exacerbated by the constraints of resources, teacher engagement, and systemic preparedness, which hinder the development of a comprehensive model for integrating CT across diverse subject areas [2].

In a developing country like Malaysia, where educational reform is ongoing, pre-service teachers often struggle to grasp the complexities of CT due to insufficient exposure and training [3]. Although the 2017 curriculum revision marked a significant step toward prioritizing CT integration, the lack of specialized modules in many teacher education programs presents a major limitation [1]. Educators require not only familiarity with computational thinking but also pedagogical strategies to teach it effectively across disciplines, yet many pre-service teachers remain underprepared for this task [4]. Additionally, the existing curriculum often emphasizes programming as the primary medium for teaching CT, limiting the broader conceptual understanding of CT as a versatile tool for problem-solving across all educational domains [5].

While initiatives like robotics programming and mobile learning have been introduced to enhance computational proficiency, there remains a significant gap in training teachers to implement these technologies and concepts in real-world classroom settings [6], [7]. Teacher preparation programs, therefore, must address these gaps by providing pre-service educators with robust, structured CT modules that not only build technical skills but also foster positive

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attitudes toward integrating CT into future teaching practices [8], [9]. Globally, many education systems have already integrated CT into K-12 curricula, recognizing the need for systemic change and teacher training as essential to fostering critical thinking and problem-solving skills in students [10].

In Malaysia, however, the integration of CT remains limited by resource availability and systemic readiness, raising concerns about the country's ability to compete on a global scale in delivering quality education [11]. As the educational landscape continues to evolve, addressing the challenges of CT integration within teacher education programs will be critical to ensuring that pre-service teachers are equipped with the tools and knowledge necessary to foster computational thinking proficiency in their future classrooms [12]. Overcoming these limitations requires a concerted effort from policymakers, educational institutions, and teachers alike to prioritize CT as a core component of teacher training programs, ensuring that Malaysia's future educators are fully prepared to navigate and contribute to the complexities of an increasingly digital world [2].

A. Research question:

RQ1: How do pre-service teachers in the Faculty of Educational Studies, Universiti Putra Malaysia understand about computational thinking?

RQ2: How do pre-service teachers in the Faculty of Educational Studies, Universiti Putra Malaysia perceive the integration of computational thinking into teaching and learning practices?

RQ3: What is the extent of computational thinking proficiency among pre-service teachers in the Faculty of Educational Studies, Universiti Putra Malaysia?

II. Methodology

The multi-method approach employed in this study integrates both qualitative and quantitative methods to provide a comprehensive understanding of the research topic. This design involves the collection, analysis, and integration of multiple forms of either quantitative or qualitative data, distinguishing it from mixed methods research [13]. In this study, qualitative data collection and analysis are prioritized, followed by quantitative data. The secondary method complements and enriches the findings from the primary method, providing deeper insights [13]. While multi-method designs offer valuable perspectives, they can be time-consuming and resource-intensive. Given the complexities of the educational landscape in Malaysia, including disparities in access to quality education and varying outcomes across demographic groups, this approach is particularly relevant. By integrating different data sources, this methodology captures the multifaceted nature of educational environments, enhancing the credibility of the findings through data triangulation [14], [15]. This is crucial in a developing country like Malaysia, where addressing socio-economic and cultural factors requires a thorough, multidimensional research approach.

A. Qualitative phase:

In this study, qualitative methods are employed initially to gather in-depth insights into pre-service teachers' understanding and perceptions of computational thinking and its integration into teaching and learning. Qualitative data is collected through face-to-face interviews, allowing participants to express their thoughts, experiences, and perspectives in detail [16]. Thematic analysis is then conducted to identify recurring themes, patterns, and meanings within the qualitative data. This qualitative phase lays the foundation for the subsequent quantitative phase. Purposive sampling is the chosen strategy for the qualitative phase of this study. In this case, pre-service teachers enrolled at the Faculty of Educational Studies at Universiti Putra Malaysia are targeted. Purposeful sampling ensures that participants can provide valuable insights into computational thinking and its integration into teaching and learning practices. Data collection will continue until data saturation is achieved, meaning that no new information or themes emerge from the interviews, ensuring comprehensive coverage of perspectives.

B. Quantitative phase:

Following the qualitative phase, quantitative methods are utilized to quantify and validate the findings obtained from the qualitative analysis. A structured questionnaire is administered to collect quantitative data on the computational thinking proficiency among pre-service teachers. All 25 items in the questionnaire were content validated by experts. A pilot test was conducted with 30 samples to assess reliability, yielding a Cronbach's alpha value of .97. The collected data is then analysed using Statistical Package for the Social Sciences (SPSS), to calculate descriptive statistics such as mean, median, and standard deviation. This quantitative phase provides numerical evidence to complement and corroborate the qualitative findings, enhancing the rigor and validity of the study [17]. For the quantitative phase, a random sampling method was employed within the population of pre-service teachers enrolled at the Faculty of Educational Studies, UPM. Random sampling ensures that each member of the population has an equal chance of being selected, thereby enhancing the representativeness of the sample. Based on the Cochran’s formula for continuous data, a sample size of 182 participants was targeted to achieve adequate statistical power and precision in the analysis. This sample size is determined to provide reliable estimates of the population parameters and to ensure the generalizability of the findings to the larger population of pre-service teachers at UPM's Faculty of Educational Studies.

C. Integration of Data:

Once both qualitative and quantitative data have been collected and analysed, the findings from both phases are integrated and compared. This integration allows for a deeper understanding of the research topic by providing multiple perspectives and insights [13]. Researchers look for convergence or divergence in the results, considering how qualitative themes align with quantitative data patterns. Any inconsistencies or discrepancies between the qualitative and quantitative findings are explored and discussed, contributing to a more nuanced interpretation of the results. This synthesis allows for a deeper understanding of the research topic by integrating diverse perspectives and shedding light on complex phenomena. Figure 1 shows the procedure of this study.

Fig. 1. Research procedure.

III. Result

A. Qualitative Findings

The interview protocol explored the understanding and perspectives of pre-service teachers in the Faculty of Educational Studies, Universiti Putra Malaysia, on computational thinking. Table 1 details the information pertaining to the interview respondents.

TABLE I
INTERVIEW PROTOCOL PARTICIPANTS BACKGROUND INFORMATION.

Demography information	Respondent 1	Respondent 2
Gender	Female	Male
Age	22 years old	23 years old
Semester	4	5
Course	TESL	Sport Science

1) How do pre-service teachers in the Faculty of Educational Studies, Universiti Putra Malaysia understand about computational thinking?

Interview question 1: How would you define computational thinking in your own words?

Respondent 1: “I am not that familiar with computational thinking however I have heard this term before but that’s it. For me, after reading the definition maybe some sort of higher-level critical learning skill to develop in order to solve more complex problem in a very systematic way.”

Respondent 2: “Uhm I am familiar with the concept of computational thinking because I was once a science computer student back in matriculation, most of the time I studied algorithms and programming. We also studied that, most of the time I break down logical steps in smaller bits in any kind of programming so a computer would understand better, basically teaching our brain to think in a way like machines can follow or vice versa. For me, computational thinking is basically about finding a solution, but not just finding any kind of a solution to a problem but it is also about finding the most efficient way to solve a problem. It must be logical and planned out carefully when solving the problems.”

Both respondents demonstrate a basic grasp of computational thinking. However, Respondent 2 exhibits a deeper understanding, likely due to their background in computer science. Respondent 1 defines computational thinking as a higher-level critical thinking skill for solving complex problems systematically. This demonstrates a general awareness of computational thinking as a problem-solving approach, but lacks specific examples to support their understanding. Respondent 2, however, provides a more detailed explanation, drawing connections between computational thinking and their experience in studying algorithms and programming. They emphasize breaking down logical steps into smaller and more manageable parts.

Interview question 2: Can you provide examples of how computational thinking can be applied in your everyday life or in educational settings?

Respondent 1: “I am not sure if it can be applied in real daily life but in educational settings maybe we can apply it for lesson planning. Lesson planning is a very detailed and intricate process for teacher to do when they need to teach in class. Therefore, using computational skill teacher can plan thoroughly on what they should do in class whether the lesson is effective or not, the time to teach, strategy with students that are weaker in certain area and many more.”

Respondent 2: “As a Student, I would plan out my daily schedule or routine, from waking up early, catching the bus and go to class early, Critical thinking also can be integrated if there is a quiz/presentation in the class, problem-solving proficiency on tutorials that are given by the lecturers, after classes, during my lunch break, I often find myself managing my finances when deciding what to buy for lunch.”

Respondent 1 suggests applying computational thinking in educational settings, particularly in lesson planning for teachers. While this example demonstrates an understanding of how computational thinking can be applied in an educational context, it lacks specificity and depth. Respondent 2, however, offers a range of examples illustrating how computational thinking can be applied in everyday life, such as planning daily schedules, problem-solving in tutorials, and managing finances. These examples showcase a practical understanding of how computational thinking can inform decision-making processes and problem-solving strategies beyond just academic settings. Both respondents grasp the essence of computational thinking as a problem-solving approach emphasizing logic, efficiency, and systematic analysis.

2) How do pre-service teachers in the Faculty of Educational Studies, Universiti Putra Malaysia perceive the integration of computational thinking into teaching and learning practices?

Interview question 1: How important do you believe computational thinking proficiency are for pre-service teachers like yourself?

Respondent 1: "I think it is pretty important to me as pre-service teacher is also a student and students need to think a lot. Hence, using these skills, our thinking process will have a structure and we do not stray away from our learning objective. Plus, pre service teacher is new to educational world so we need to do a lot of studying in order to be familiar with it and using this kind of thinking will definitely help I think."

Respondent 2: "Uhm, computational thinking proficiency are absolutely important for pre-service teachers like myself, We as teachers. We do more than just give or teach knowledge; we get students ready to succeed in a world that depends more and more on technology. Learning how to think like a computer gives us the right way of thinking and the tools we need for dealing with this digital environment well. Computational thinking improves how we solve problems, creating lesson plans, adjusting to the different needs of students."

Both respondents recognize the value of computational thinking proficiency for pre-service teachers, acknowledging its potential to enhance teaching and learning experiences. Respondent 1 emphasizes the importance of computational thinking proficiency for pre-service teachers, highlighting the benefits of a structured and systematic learning process while Respondent 2 expands on this viewpoint by highlighting the broader perspective, emphasizing CT's importance in preparing students for a tech-dependent world, enhancing problem-solving skills, creating lesson plans, and adapting to diverse student needs.

Interview question 2: How do you think computational thinking can enhance teaching and learning experiences?

Respondent 1: "Hmm I think thinking in systematic way can help any experience in general. It can help in teaching experience since computational thinking can contribute to solving complex issues in classroom settings. It also can help students in their learning experience as it involves many useful skills that certainly can help students whether they are inside or outside school for better learning experience overall"

Respondent 2: "Yes, of course. Certainly! adding computational thinking to educational methods can improve the experiences of teaching and learning a lot more. Uhm, it is like similar to giving teachers and students a strong lens that they use to see and handle the process of learning. So, by that it gives students the proficiency they will need for their future, helps them comprehend ideas more thoroughly and inspires creativity together with innovation."

Both respondents agree that computational thinking can enhance teaching and learning experiences. Respondent 1 suggests that computational thinking contributes to solving complex issues in the classroom and improves students' learning experiences by developing useful proficiency. Respondent 2 expands on this by likening computational thinking to a lens that enables teachers and students to better understand and handle the learning process. They argue that computational thinking fosters proficiency essential for the future, deepens comprehension, and fosters creativity and innovation. Both respondents recognize the value of computational thinking in education, but Respondent 2 provides a more comprehensive perspective, emphasizing its broader impact on teaching, learning, problem-solving, and preparation for the digital age.

B. Quantitative Findings

1) What is the extent of computational thinking proficiency among pre-service teachers in the Faculty of Educational Studies, Universiti Putra Malaysia?

The percentage and frequency of background information among study participants are covered in Table 2. The survey included 182 students from the Faculty of Educational Studies at UPM. There were 104 female and 78 male participants.

TABLE 2

BACKGROUND INFORMATION AMONG STUDY PARTICIPANTS.

	Demography information	Frequency	Percentage (%)
Gender	Male	78	42.8
	Female	104	57.2
Age years	20 – 22 years	97	53.2
	23 – 25 years	85	46.8

Table 3 shows the mean score of 3.41 with a standard deviation of 0.66, which indicates that, on average, pre-service teachers in the Faculty of Educational Studies possess computational thinking proficiency well above the midpoint level of 3.00. This suggests that pre-service teachers generally possess above-average computational thinking proficiency. This means that they generally understand the concepts of computational thinking and its relevance to education, but there may be variability in their proficiency levels. A standard deviation of 0.66 indicates that the scores are fairly close to the mean, meaning there is a moderate consistency in the computational thinking proficiency among the pre-service teachers. Table 3 also shows that decomposition and pattern recognition proficiency are slightly lower compared to other components of computational thinking, with a mean of 3.18 and 2.99, respectively.

TABLE 3

DESCRIPTIVE ANALYSIS RESULT

Items	N	Mean	Std. Deviation
Abstraction	182	3.60	0.85
Decomposition		3.18	0.58
Pattern Recognition		2.99	0.47
Algorithm		3.59	0.71
Generalization		3.70	0.73
Computational Thinking		**3.41**	**0.66**

Figure 2 shows the frequency and percentage of 25 items that measure pre-service teachers' computational thinking proficiency. The data indicates that respondents generally perceive themselves as highly proficient in computational thinking, with most individuals feeling confident in their ability to identify key ideas, simplify problems, recognize commonalities, and adapt techniques to new situations. However, there are still areas where some respondents feel challenged, particularly in identifying patterns that can simplify solving different problems.

Construct	Items	Strongly disagree		Disagree		Natural		Agree		Strongly agree	
		frequency	%	frequency	%	frequency	%	frequency	%	frequency	%
Abstraction	I find it easy to identify fundamental ideas from complex problems	1.00	0.55	13.00	7.14	69.00	37.91	66.00	36.26	33.00	18.13
	I can simplify complex problems to focus on the most important aspects.	7.00	3.85	23.00	12.64	72.00	39.56	59.00	32.42	21.00	11.54
	I am skilled at recognizing commonalities among seemingly different problems.	1.00	0.55	10.00	5.49	57.00	31.32	83.00	45.60	31.00	17.03
	I can extract key information from a problem to solve it more effectively	0.00	0.00	15.00	8.24	68.00	37.36	73.00	40.11	26.00	14.29
	I am confident in isolating essential details from a problem to understand its core concept.	1.00	0.55	9.00	4.95	75.00	41.21	66.00	36.26	31.00	17.03
Decomposition	I can break down complex problems into smaller, manageable parts effectively.	3.00	1.65	9.00	4.95	76.00	41.76	83.00	45.60	11.00	6.04
	I find it challenging to handle complex problems by dividing them into smaller tasks.	11.00	6.04	32.00	17.58	57.00	31.32	66.00	36.26	16.00	8.79
	I am skilled at identifying the individual steps needed to solve a larger problem.	8.00	4.40	27.00	14.84	79.00	43.41	55.00	30.22	13.00	7.14
	I feel comfortable splitting a problem into smaller components for easier problem-solving.	10.00	5.49	18.00	9.89	74.00	40.66	69.00	37.91	11.00	6.04
	I am confident in breaking a problem into smaller tasks that are easier to manage.	11.00	6.04	37.00	20.33	63.00	34.62	60.00	32.97	11.00	6.04
Pattern Recognition	I easily identify similarities among different problems.	3.00	1.65	22.00	12.09	81.00	44.51	68.00	37.36	8.00	4.40
	I struggle to notice patterns that can simplify solving different problems.	7.00	3.85	59.00	32.42	87.00	47.80	25.00	13.74	4.00	2.20
	I am adept at identifying similarities between seemingly unrelated problems.	9.00	4.95	29.00	15.93	113.00	62.09	29.00	15.93	2.00	1.10
	I confidently recognize patterns that help in solving diverse problems.	1.00	0.55	9.00	4.95	97.00	53.30	63.00	34.62	12.00	6.59
	I can quickly recognize recurring patterns in various problem solving situations.	5.00	2.75	13.00	7.14	102.00	56.04	49.00	26.92	13.00	7.14
Algorithm	I feel confident in creating step-by-step instructions to solve problems.	1.00	0.55	4.00	2.20	53.00	29.12	89.00	48.90	35.00	19.23
	I can easily outlining clear and precise steps to solve a problem.	3.00	1.65	16.00	8.79	45.00	24.73	95.00	52.20	23.00	12.64
	I am skilled at designing algorithms to address various problems.	0.00	0.00	3.00	1.65	68.00	37.36	101.00	55.49	10.00	5.49
	I feel comfortable translating problem-solving strategies into detailed instructions.	2.00	1.10	9.00	4.95	73.00	40.11	85.00	46.70	13.00	7.14
	I find it easy to convert problem-solving strategies into specific steps.	0.00	0.00	11.00	6.04	79.00	43.41	82.00	45.05	10.00	5.49
Generalization	The skills I've learned in problem-solving can be applied to different scenarios.	1.00	0.55	7.00	3.85	63.00	34.62	78.00	42.86	33.00	18.13
	I am confident that the problem-solving techniques I've learned are transferable.	0.00	0.00	8.00	4.40	57.00	31.32	88.00	48.35	29.00	15.93
	I am skilled at adapting problem-solving techniques to new and unfamiliar scenarios.	2.00	1.10	5.00	2.75	63.00	34.62	92.00	50.55	20.00	10.99
	I can easily apply problem-solving skills to new situations.	3.00	1.65	2.00	1.10	51.00	28.02	93.00	51.10	33.00	18.13
	I believe the problem-solving methods I've learned have broader applications beyond their initial context.	0.00	0.00	3.00	1.65	72.00	39.56	86.00	47.25	21.00	11.54

Fig 2. Frequency and percentage of pre-service teachers' computational thinking proficiency

C. *Data integration*

Qualitative data enriches the understanding of how pre-service teachers perceive and apply computational thinking. Both respondents demonstrated a basic grasp of CT, but the depth of understanding varied significantly. With a mean score of 3.41 (on a scale where 3.00 is the midpoint) and a standard deviation of 0.66, it is evident that these teachers-in-training are confident in their ability to solve problems using CT strategies. This above-average proficiency suggests a solid foundational understanding of CT concepts, which is essential for applying these skills in educational contexts. Qualitative findings recognised the value of CT proficiency for pre-service teachers, acknowledging their potential to enhance teaching and learning experiences. There is moderate consistency in computational thinking proficiency among pre-service teachers. However, specific areas, such as decomposition and pattern recognition, are slightly weaker and could benefit from targeted educational interventions.

IV. Discussion and Conclusion

Pre-service teachers at the Faculty of Educational Studies, Universiti Putra Malaysia, demonstrate an above-average understanding of computational thinking (CT), which enables them to simplify problems and apply solutions broadly, thus enhancing their overall problem-solving capabilities. However, their slightly lower scores in decomposition and pattern recognition suggest areas for improvement [3]. Curriculum design in teacher training programs may not fully integrate CT concepts, leaving pre-service teachers without a structured pathway to develop these critical skills. While computational thinking is increasingly recognized as a crucial component of modern education, its inclusion in Malaysia's educational framework is still evolving. Many teacher education programs may focus on general problem-solving skills without providing targeted training on decomposition and pattern recognition, which are vital for solving more intricate, real-world problems in data analysis and other fields. Strengthening these proficiencies could significantly improve their ability to handle complex issues, especially in data analysis and problem-solving contexts. This is particularly important in a developing country like Malaysia, where teachers are expected to guide students through the increasing complexities of the digital era.

CT proficiency among pre-service teachers is largely influenced by their prior knowledge and experience in STEM fields, coding, and problem-solving-based learning [2]. Those with a background in these areas often transition more smoothly into understanding computational thinking principles. However, many teacher training programs still lack effective integration of CT concepts, leading to limited exposure and training for pre-service teachers [7]. This limitation is particularly pronounced in low-resource settings, where inadequate access to technology and a lack of infrastructure further hamper efforts to provide comprehensive CT education. In Malaysia, these technological and infrastructural challenges have created disparities in CT proficiency among pre-service teachers, particularly between urban and rural areas, highlighting the need for targeted interventions that bridge this gap [1]. To address these gaps, teacher training programs must integrate CT concepts more comprehensively, equipping pre-service teachers with the necessary proficiency through dedicated training and resources. Initiatives such as pre-enrolment courses, workshops, and mentorship programs can help bridge gaps in prior knowledge and experience, enabling all students, regardless of background, to develop foundational CT proficiency. Specialized modules focusing on CT can significantly enhance pre-service teachers' comprehension of computational principles and improve their ability to integrate these skills into their future classrooms [9].

Moreover, addressing the infrastructural challenges in low-resource settings requires a concerted effort from educational institutions and policymakers to provide the necessary technological tools and access, ensuring that pre-service teachers from all backgrounds have equal opportunities to develop CT proficiency. The broader technological and infrastructural challenges faced by pre-service teachers in Malaysia underscore the need for a systemic overhaul of teacher education programs [18]. Limited access to digital tools and internet connectivity, especially in rural areas, poses significant obstacles to fostering CT proficiency among pre-service teachers [2]. Addressing these challenges is crucial for ensuring that Malaysia's future educators can effectively integrate CT into their teaching practices, particularly as the demand for digital literacy and problem-solving skills continues to grow in the global workforce. Therefore, government initiatives and educational reforms must prioritize resource allocation to improve technological infrastructure in schools and teacher training institutions. Furthermore, emphasizing the real-world relevance of computational thinking can help pre-service teachers understand its broader implications beyond the classroom, especially in fields like technology, engineering, and data science [12].

By incorporating CT into lesson planning and instructional design, pre-service teachers can be empowered to integrate these concepts into their teaching practices effectively. However, the success of such initiatives will largely depend on the ability of teacher education programs to adapt to the evolving demands of the digital age. The ongoing technological evolution requires agile and responsive teacher training programs that not only provide CT knowledge but also foster critical thinking, creativity, and problem-solving skills [19]. In low-resource settings, where technological access is limited, teacher education programs must also focus on innovative pedagogical approaches that do not rely solely on digital tools. Blended learning models, which combine face-to-face teaching with minimal technology use, can help pre-service teachers in these environments develop CT skills even with limited resources. The growing recognition of CT's significance in preparing educators for the demands of the digital age highlights a paradigm shift in teacher education [8].

Overcoming the challenges posed by resource constraints and systemic limitations requires collaborative efforts between educational institutions, policymakers, and industry stakeholders to provide sustainable solutions that support CT integration. By fostering a culture of lifelong learning and innovation, teacher education institutions can ensure that educators remain at the forefront of pedagogical practice, equipped to empower future generations with the skills they need to thrive in an ever-changing world [19]. Collaboration across disciplines, particularly between STEM and non-STEM fields, is also essential in shaping the future of CT in teacher education. Such interdisciplinary approaches enrich learning experiences and prepare students to tackle complex challenges using holistic problem-solving and critical thinking skills [3]. Ultimately, the evolving nature of CT in teacher education represents a transformative shift towards a more dynamic, inclusive, and forward-thinking approach, ensuring that future educators are well-prepared to meet the challenges and opportunities of tomorrow. While this study provides valuable insights into the understanding and application of CT among pre-service teachers at the Faculty of Educational Studies, Universiti Putra Malaysia, it is limited by its focus on a single institution. The findings may not fully capture the diverse experiences and challenges faced by pre-service teachers across different regions of Malaysia, particularly in rural or low-resource settings. Additionally, the study does not extensively address the broader contextual challenges impacting CT proficiency, such as disparities in technological access and curriculum integration across various teacher training programs. Therefore, the generalizability of the findings may be constrained, and further research is needed to explore how these contextual factors influence CT education on a national scale.

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