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Assessing creative problem-solving competencies in primary school educators: A confirmatory factor analysis approach

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Abstract: This study aimed to examine and analyze the second-order confirmatory factor structure of creative problem-solving for primary school teachers. The sample consisted of 150 teachers and educational supervisors from the Office of the Basic Education Commission, selected through multi-stage random sampling. The data collection tool was a creative problem-solving questionnaire evaluated for item-objective congruence (IOC) values between 0.60 and 1.00, with discriminant power ranging from 0.68 to 0.88 and reliability coefficients between 0.77 and 0.92. Data were analyzed using means, standard deviations, and second-order confirmatory factor analysis (CFA). The results revealed that teachers and educational supervisors had a high level of agreement on creative problem-solving in general and for each component. The second-order CFA creative problem-solving model demonstrated a good fit with the empirical data and consisted of five components and 15 indicators. The components, ranked by weight from highest to lowest, were Truth Discovery (TD), reflecting the emphasis teachers place on understanding the nature and context of problems. This was followed by Knowledge Creation (KC), which highlights the importance of applying knowledge to real-world challenges, and Problem Identification (PI). Idea Generation (IG) and Solution Discovery (SD) received slightly lower scores, though still within the high range. This suggests that while teachers value these components, they may require further development in fostering innovation and evaluating solutions critically.

Keywords: *Computational thinking, Creative problem solving, Educators, Primary school teachers, Thailand.*

1. Introduction

Developing the ability to solve problems creatively has become an essential skill in the modern era. This capability requires well-structured learning methods like Phenomenon-Based Learning (PhBL). PhBL encourages learners to explore real-world phenomena, such as global issues or natural disasters, fostering the integration of interdisciplinary knowledge for effective problem-solving. When combined with computational thinking (CT)—a framework emphasizing analysis and problem-solving design—this approach can significantly enhance creative problem-solving skills (CPS) [1, 2]. CT focuses on analytical thinking, while PhBL promotes hands-on experience and situational analysis, cultivating innovation and creativity [3].

Moreover, Artificial Intelligence (AI) tools hold great potential for fostering students' cognitive skills [4]. AI can personalize learning experiences, monitor progress, and assess learning outcomes, enabling better retention and understanding. Integrating computational thinking and AI into education improves learning efficiency and prepares students with 21st-century skills such as critical thinking, productivity, and creativity [5]. This alignment ensures that education remains relevant and responsive to societal changes and challenges [6].

In professional education, particularly for teacher trainees, problem-solving creatively is crucial [7]. Modern educators are not merely knowledge transmitters but facilitators encouraging students to

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analyze, innovate, and solve problems. Teachers frequently face dynamic and complex challenges, requiring creative problem-solving skills to manage these situations effectively [8]. They also serve as role models, demonstrating analytical thinking, creativity, and innovative problem-solving to students.

Traditional problem-solving methods are often insufficient in addressing the multi-faceted challenges of today's world. Teachers need new approaches to innovate solutions and create engaging, effective learning environments [8]. However, research indicates that many students in education technology courses struggle to apply innovative methods or use technology effectively in problem-solving, limiting their alignment with expected learning outcomes [9].

This gap underscores the importance of examining creative problem-solving components within Thai education professionals' context. The study focuses on using a second-order confirmatory factor analysis (CFA) to identify key factors that can enhance teacher trainees' capabilities [10] enabling them to perform their roles effectively in the future [11].

In the Thai education system, educational supervisors are pivotal as academic advisors, guiding teachers in instructional strategies and classroom management. According to various studies, supervision is a vital yet challenging aspect of school administration [12, 13]. Adequate supervision ensures adherence to Ministry of Education standards, aligns with institutional and national goals and improves teacher competencies through continuous evaluation and constructive feedback. Supervisors can implement timely corrective measures by detecting instructional issues through observation and appraisal, supporting professional growth, and enhancing teaching effectiveness.

However, challenges remain in educational supervision. As Abdulla [14] highlights, supervisors often lack time, training, or resources. Many supervisors are expected to fulfill their roles with minimal preparation or interest, treating it as an add-on responsibility to existing commitments. Addressing this issue requires dedicated training, adequate time allocation, and investment in supervisory roles [15]. Until these structural challenges are addressed, limiting supervision to qualified professionals with appropriate time and resources is advisable.

Adequate educational supervision and CPS are essential in preparing educators for the evolving challenges of teaching. Combining approaches such as PhBL and CT, supported by AI tools, can empower teachers and students to navigate complex problems innovatively. Additionally, addressing the challenges in educational supervision through training and resource allocation can significantly enhance teaching quality and professional growth, aligning with the broader goals of national education.

By prioritizing these strategies, the Thai education system can ensure that future educators are well-equipped to inspire creativity, critical thinking, and problem-solving in the classroom.

Recognizing the literature gap between creative problem-solving studies in Western developed nations and Southeast Asia; this study investigates how Thai educators perceive factors affecting their creative problem-solving competencies. It explores how educators' characteristics, truth discovery, knowledge creation, idea generation**,** solution discovery, and problem identification affect their CPS skills. The main research objectives of the study are:

(1) To synthesize the principles of CPS from books, texts, and relevant research.

(2) To examine the perceptions of teachers and educational supervisors regarding creative problem-solving.

(3) To analyze the components of creative problem-solving among teachers and educational supervisors.

2. Literature Review

2.1. Creative Problem-Solving (CPS)

Creative Problem-Solving (CPS) is a structured framework that integrates creative and critical thinking to address challenges in diverse contexts. Recent studies emphasize CPS as a dynamic and iterative process, promoting innovative solutions while balancing divergent and convergent thinking. For example, Susilawati, et al. [16] discuss CPS in educational settings, highlighting its effectiveness in fostering critical thinking and collaboration in science learning environments. The researchers found that CPS encourages students to alternate between exploration and evaluation to solve complex, real-

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world problems effectively.

A contemporary perspective provided by Muslim, et al. [17] examines the application of CPS in mathematics education using technology-enhanced methods like GeoGebra. Their findings reveal that CPS promotes conceptual understanding and enhances problem-solving efficiency, especially when tailored to learners' cognitive needs and abilities. Similarly, Hallioui, et al. [18] explore CPS as a pillar of cognitive human-machine collaboration within Industry 5.0, emphasizing its adaptability in integrating technology with human decision-making. These insights underscore CPS's relevance in fostering innovative solutions across educational, technological, and industrial domains.

The stages of CPS—problem identification, idea generation, and solution evaluation—are described as requiring rigorous cognitive and metacognitive efforts. Bhumichai, et al. [19] elaborate on how CPS can be augmented through artificial intelligence and blockchain technologies to improve decision-making processes. Additionally, Nicoara and Stan [20] argue that CPS frameworks, when aligned with collaborative digital tools, enhance team-based problem-solving efficiency by promoting knowledge-sharing and adaptive thinking.

Finally, recent meta-analyses, such as Nicoara and Stan [20] have highlighted the intersection of CPS with productivity and efficiency in organizational settings. Nicoara and Stan [20] findings advocate for integrating CPS into management systems to address the complexities of modern workplace challenges.

2.2. Empirical Evidence on CPS Processes

Empirical research continues to expand our understanding of Creative Problem-Solving (CPS) processes, highlighting their contextual adaptability and practical applications. Adenola [21] investigated CPS behaviors, identifying four core elements: understanding challenges, generating ideas, preparing for action, and planning approaches. Their findings revealed notable variability in these processes among students, emphasizing the importance of adaptable CPS models for individual differences in cognitive styles and problem-solving strategies. Furthermore, the study validated the alignment of observed behavioral patterns with theoretical CPS frameworks, reinforcing the strength of these models across diverse contexts.

Sophonhiranrak, et al. [22] extended this understanding through a meta-analysis of 20 studies focusing on CPS within blended learning environments. They identified nine critical factors influencing CPS success: understanding challenges, generating ideas, preparing for action, planning approaches, learning activities, learning resources, feedback, learning interaction, and evaluation. These findings underscore the importance of structured support systems in fostering CPS. For instance, feedback mechanisms and interactive learning designs significantly enhance the development of creative problem-solving skills by encouraging iterative learning and collaboration.

Other recent studies have further contextualized CPS processes. For example, Muslim, et al. [17] highlighted the application of CPS in mathematics education, demonstrating that integrating CPS with digital tools like GeoGebra enhances problem-solving efficiency. Similarly, Bhumichai, et al. [19] explored the intersection of CPS with advanced technologies such as artificial intelligence, illustrating how these tools can support the stages of idea generation and solution evaluation.

In summary, empirical evidence affirms the effectiveness and adaptability of CPS frameworks. By identifying critical factors, such as feedback and interactive environments, and incorporating technological advancements, these studies provide actionable strategies for designing environments that foster innovative thinking and effective problem-solving.

2.3. Evolution of CPS Theories

The foundations of the Creative Problem Solving (CPS) theory were laid by Torrance [23] who introduced a systematic, five-step process to foster creativity and problem-solving skills. This process included (1) searching for information to clarify the problem, (2) understanding the problem, (3) generating possible solutions, (4) formulating solutions, and (5) accepting and implementing solutions. Torrance's model emphasized the importance of a structured approach to creativity, highlighting both divergent and convergent thinking as integral to problem-solving. This framework became foundational in creative thinking research and was later dubbed the "New Challenge," a term signifying the drive for innovative thought processes in addressing complex problems.

Following Torrance's early work, subsequent researchers such as Anderson [24] and Davis [25] expanded on his ideas, offering refinements to the model. These refinements included incorporating iterative feedback loops, where evaluation and adjustment of solutions occur throughout the process. Additionally, they emphasized the importance of adaptive strategies—methods that enable individuals to adjust their approaches based on evolving insights and external factors during problem-solving.

More recent contributions, such as those by Wadtan, et al. [26] have sought to contextualize CPS within a broader framework, incorporating components like *flexibility, collaboration, and metacognitive awareness* as crucial elements for enhancing CPS abilities. Their research underscores that effective CPS requires individual creativity and the capacity to work collaboratively and reflect on one's thought processes. These modern insights help bridge traditional CPS models with real-world problem-solving demands, emphasizing the importance of adaptability and team-based approaches in contemporary settings.

2.4. Blended Learning and Creative Problem-Solving (CPS)

Blended learning environments play a crucial role in developing CPS skills. Sophonhiranrak, et al. [22] state that interactive learning resources, structured activities, and continuous feedback enhance CPS capabilities. This underscores the need for educators to integrate digital tools and methodologies to foster a CPS-oriented mindset among learners.

The literature highlights that CPS is a multi-faceted process requiring integrating analytical, cognitive, and creative strategies. While theoretical frameworks provide strong foundations, empirical studies emphasize CPS's contextual and adaptable nature. As education shifts towards a skills-based paradigm, incorporating CPS into teaching and supervision practices becomes essential. This review provides a foundation for examining CPS components among Thai teachers and educational supervisors to enhance their capacity for innovation and address 21st-century educational challenges.

3. Methods

This research methodology outlines a systematic approach to examining the components and validation of creative problem-solving (CPS). It consists of two primary phases: a document synthesis to understand CPS components [27] and a CFA to validate the CPS framework.

3.1. Population and Sample

The target population for this study includes teachers and educational supervisors involved in science and technology subjects, such as computational science, design, and technology, or general science, in elementary schools under the jurisdiction of the Office of Basic Education Commission (OBEC), Ministry of Education, in Bangkok and central Thailand during the 2024 academic year. Specifically, this includes teachers from these subjects and educational supervisors overseeing science and technology disciplines.

The sample size was determined following the guidelines by Costello and Osborne [28] which suggest that the sample size should be 10–20 times the number of observable variables. Given that the study framework includes 15 observable indicators, a multiplier of 20 was applied, resulting in a target sample of 300 participants.

Multi-stage random sampling was employed to ensure the sample was representative of the target population. First, schools were stratified by region, specifically by the districts of Bangkok and three central provinces, ensuring proportional representation from each region. Then, within each region, participants were selected using simple random sampling. One teacher was randomly selected from each school, and one educational supervisor was randomly selected from each educational district.

3.2. Data Collection

The sampling process involved two stages. In the first stage, schools were divided into strata based on their regional location, and a proportional number of schools were selected from each region. In the second stage, teachers and supervisors were randomly drawn by lottery. For teachers, one was selected per school, while for educational supervisors, one was selected per district. This process ensured that the sample was representative and random, aligning with the study's objectives (Table 1). The data was collected using Google Forms with teachers and educational supervisors under the Office of Basic Education Commission (OBEC) in October 2024 across three geographic regions (the Bangkok, central, and eastern regions. Participants were part of a program promoting Computational Thinking for developing higher-order thinking skills.

Table 1.
Regional sampling breakdown of Thai educators.

Geographic regions	Teachers			Educational supervisors		
	Population	Sample		Population	Sample	
		Target	Collected		Target	Collected
Metropolitan Bangkok	637	17	9	78	23	12
Central	5.058	137	68	98	29	15
Eastern	1.697	46	23	166	49	25
Total	7.392	200	99	342	100	51

3.3. Instruments

A *Document Synthesis Form*, specifically designed to capture relevant content and insights from the reviewed CPS literature, was used in the initial phase of the study. Subsequently, in the next phase of the study, a questionnaire was created to measure and evaluate five primary components and their 15 indicators on CPS. Section 1 consisted of items related to each educator's characteristics, using a checklist format. Sections 2 – 6 used a 5-level Likert-type opinion scale whose responses ranged from 1-5 with '1' = very low' (1.00-1.49), '2' = 'low' (1.50-2.49), '3' = 'moderate' (2.50-3.49), '4' = 'high' (3.50-4.49), and finally, '5' = 'very high' (4.50-5.00) [29].

3.4. Expert Validation

The instrument underwent evaluation by five experts for content validity. The Index of Item-Objective Congruence (IOC) ranged from 0.60 to 1.00 [30]. Discrimination and reliability coefficient values ranged from 0.68 to 0.88 and 0.77 to 0.92, respectively. These metrics ensure the tool's strength for assessing CPS components.

3.5. Data Analysis

Content Analysis was used to evaluate and synthesize data from the collected documents critically. This process was used to identify recurring themes, concepts, and relationships to define the core components of CPS.

Subsequently, descriptive statistics analysis used SPSS for Windows (V21). The second-order confirmatory factor analysis (CFA) [31] and goodness-of-fit (GoF) of the five components and 15 indicators made use of LISREL 9.10 [32].

3.6. Ethics Statement

The experts and the educators who participated in the study gave their informed consent for inclusion before participating [33]. The study was conducted in accordance with the Declaration of Helsinki, and the authors' university ethics committee approved the protocol. Furthermore, all study participants were notified of the confidentiality of their information.

4. Results

4.1. Resident Characteristics

Table 2 shows that of the 150 sample respondents, 65.33% were female. Almost the same percent (66%) identified themselves as teachers. Interestingly, the educator's experience was nearly equal in their education experience, with 36.67% having 5-10 years of experience, 32.67% having less than five years of experience, and the remaining 30.67% having more than 10 years of experience. As expected, 50.67% had a BA/BS degree, another 45.33% had a Master's degree, with 4% having obtained a Ph.D. Finally, 70.67 noted that their university major had been focused on science and technology.

Table 2.
Educator characteristics (*n*=150).

General information	Educators	%
1. Gender		
- Male	52	34.67
- Female	98	65.33
2. Position		
- Teacher	99	66.00
- Educational supervisor	51	34.00
3. Teaching experience		
- Less than 5 years	49	32.67
- Between 5 - 10 years	55	36.67
- More than 10 years	46	30.67
4. Highest level of education		
- Bachelor's degree	76	50.67
- Master's degree	68	45.33
- Doctorate	6	4.00
5. Field of study		
Science and technology	106	70.67
Other (Art, English, Physical Education, etc.)	44	29.33

4.2. GoF Analysis

Validity assessment of the causal model was undertaken using LISEL 9.1, which suggests values for the CFI ≥ 0.95, GFI ≥ 0.90, and RMSEA ≤ 0.06. Suggested values for Chi-square ($\chi 2$) $p \geq 0.05$ and relative Chi-square ($\chi/2$df) ≤ 2.00 are often suggested [32, 33]. Schumacker and Lomax [34] also suggested that values of AGFI ≥ 0.90, NFI ≥ 0.90, and SRMR ≤ 0.05. For assessing questionnaire validity, Cronbach Alpha (α)values of ≥ 0.70 are suggested. From these criteria and theory, it was established that the model equaled or exceeded all criteria as $\chi 2 = 0.70$, $\chi/2\text{df} = 0.86$, CFI = 1.00, SRMR = 0.031, GFI = 0.99, AGFI = 0.958, NFI = 0.99, RMSEA = 0.00, with α values = 0.77-0.92.

4.3. Descriptive Statistics Analysis

Table 3 shows that educators rated their perceptions of CPS components and indicators at a high level across all dimensions. Among the five components, *Truth Discovery* received the highest mean score (mean = 4.27, SD = .56), reflecting teachers' emphasis on understanding the nature and context of problems.

The second-highest-rated component, *Knowledge Creation* (mean = 4.26, SD = .53), highlights the importance of applying knowledge to real-world challenges. Teachers' strong focus on linking knowledge to practical problem-solving scenarios underscores their commitment to fostering real-world relevance in education.

Idea Generation (mean = 4.21, SD = .59) and *Solution Discovery* (mean = 4.21, SD = .57) received slightly lower scores, though still within the high range. This suggests that while teachers value these components, they may require further development in fostering innovation and evaluating solutions critically.

Key indicators within these components provide additional detail. These include the top indicator (a1), The ability to perceive the problems that need to be solved (mean = 4.31, SD = .59), and the lowest indicator (c3), The ability to solve problems in innovative ways that differ from traditional thinking. (mean = 4.15, SD = .72), indicating an area where additional support and training could be beneficial.

Table 3.
Educator CPS mean and standard deviation (SD) statistics.

Components/Indicators	**Mean**	**SD.**
Component 1: Truth discovery (TD)	4.27	0.56
a1: The ability to perceive the problems that need to be solved.	4.31	0.59
a2: The ability to find relevant information related to the problem and identify the data required by the problem.	4.23	0.63
a3: The ability to link information with the identified problem.	4.28	0.63
Component 2: Problem identification (PI)	4.24	0.59
b1: The ability to identify problems or raise questions from the problem.	4.24	.62
b2: The ability to consider the causes of the problem.	4.20	.63
b3: The ability to prioritize the problems.	4.27	.64
Component 3: Idea generation (IG)	4.21	0.59
c1: The ability to use knowledge to solve problems.	4.27	0.59
c2: The ability to think diversely to solve problems.	4.22	0.64
c3: The ability to solve problems in innovative ways that differ from traditional thinking.	4.15	0.72
Component 4: Solution discovery (SD)	4.21	0.57
d1: The ability to evaluate solutions.	4.20	0.66
d2: The ability to decide on the most appropriate idea or solution.	4.20	0.60
d3: The ability to identify the reasons for choosing the most appropriate idea or solution.	4.22	0.59
Component 5: Knowledge creation (KC)	4.26	0.53
e1: The ability to apply knowledge to solve problems.	4.28	0.54
e2: The ability to link knowledge and solve situations in real-life contexts.	4.25	0.58
e3: The ability to apply problem-solving methods to new problems or create new knowledge.	4.25	0.60

Note: '4' = 'high' (3.50-4.49).

4.4. Evaluating Cognitive Abilities: A Reliability and Validity Analysis

The results presented in Table 4 provide an in-depth analysis of the reliability and validity metrics associated with five cognitive components and their respective indicators. These metrics were derived from a second-order CFA, emphasizing each component's internal consistency, strength of relationships, and explanatory power. This analysis is crucial for evaluating the strength and relevance of the constructs in assessing problem-solving and cognitive skills.

Table 4.
Reliability metrics and explanatory power of cognitive components.

Components/Indicators	(α)	β (SE)	(t)	(R^2)
Component 1: Truth discovery	0.87	0.89(0.05)	19.10**	0.79
a1: The ability to perceive the problems that need to be solved.		0.81	↔	0.65
a2: The ability to find relevant information related to the problem and identify the data required by the problem.		0.90(0.03)	27.00**	0.81
a3: The ability to link information with the identified problem.		0.89(0.04)	22.67**	0.80
Component 2: Problem identification	0.92	0.96(0.04)	24.23**	0.91
b1: The ability to identify problems or raise questions from the problem.		0.89	↔	0.79
b2: The ability to consider the causes of the problem.		0.96(0.03)	36.11**	0.92
b3: The ability to prioritize the problems.		0.88(0.03)	29.99**	0.77
Component 3: Idea generation	0.82	1.00(0.04)	23.38**	1.00
c1: The ability to use knowledge to solve problems.		0.84	↔	0.70
c2: The ability to think diversely to solve problems.		0.82(0.04)	22.97**	0.67
c3: The ability to solve problems in innovative ways that differ from traditional thinking.		0.80(0.04)	22.48	0.65
Component 4: Solution discovery	0.77	0.99(0.04)	23.36**	0.97
d1: The ability to evaluate solutions.		0.85	↔	0.73
d2: The ability to decide on the most appropriate idea or solution.		0.89(0.03)	28.13**	0.79
d3: The ability to identify the reasons for choosing the most appropriate idea or solution.		0.91(0.03)	28.01	0.83
Component 5: Knowledge creation	0.90	0.95(0.04)	23.8**	0.89
e1: The ability to apply knowledge to solve problems.		0.87	↔	0.76
e2: The ability to link knowledge and solve situations in real-life contexts.		0.91(0.03)	35.99**	0.82
e3: The ability to apply problem-solving methods to new problems or create new knowledge.		0.92(0.03)	28.63**	0.84

Note: **Sig.<.01.

To begin with, the internal consistency reliability for each component, as measured by Cronbach's alpha (α), ranged from 0.77 to 0.92. These values indicate strong reliability across all components, adhering to the widely accepted threshold of 0.70 to 0.95. Notably, the component *Problem Identification* achieves the highest α value of 0.92, reflecting exceptional internal consistency, whereas *Solution Discovery* shows the lowest but acceptable α value of 0.77.

The component weights (β) provide further validation, illustrating the strength of the relationships between each indicator and its corresponding component. All components demonstrate strong weights, ranging from 0.81 to 1.00, signifying that the indicators effectively represent their respective constructs. Mainly, *Idea Discovery* achieves a perfect weight of 1.00, underscoring its exemplary alignment with its indicators.

Additionally, the t-values associated with the component weights are all highly significant ($p < 0.01$), exceeding the critical threshold for statistical significance. For example, the indicator *b2* under the component *Problem Identification* achieves a remarkable t-value of 36.11, reinforcing the reliability of its relationship with the component.

The analysis of indicator reliability, represented by R^2 values, reveals that most indicators possess strong explanatory power ($R^2 \geq 0.75$). This suggests that these indicators effectively capture the variance of their associated components. For instance, *Idea Discovery* has an R^2 value of 1.00, highlighting its unparalleled ability to explain variance. A few indicators, such as *c2* under *Idea Discovery*, exhibit moderate explanatory power ($R^2 = 0.67$), which, while slightly lower, still reflects substantial reliability.

Each component encapsulates a distinct aspect of cognitive or problem-solving ability. For instance, *Truth Discovery* focuses on skills such as identifying and linking relevant information, with indicators showing strong reliability and explanatory power (R^2 values ranging from 0.65 to 0.81). Similarly, *Knowledge Creation* emphasizes applying knowledge to new contexts, demonstrating consistently strong R^2 values (0.76–0.84), indicative of its practical relevance.

The reliability and validity metrics presented in this table affirm the model's strength in evaluating cognitive abilities. High α values, significant component weights (β), and substantial R^2 values collectively indicate a well-structured and effective assessment tool. This analysis confirms the utility of these components in measuring problem-solving skills and provides a framework for further research and application in educational and psychological contexts.

4.5. Indicator Correlation Analysis Results

The correlation matrix in Table 5 provides a detailed examination of the interrelationships among the 15 associated indicators. These correlations, derived from LISREL 9.1 analysis, highlight the interconnectedness of the constructs and validate the conceptual framework of cognitive abilities. The matrix also emphasizes statistically significant relationships (Sig. ≤ .01) across components, reflecting the strong internal structure of the model.

The strong correlations between indicators confirm the internal coherence of the framework. High inter-item correlations, particularly among indicators within the same component, signify their consistency in measuring the same underlying construct. Moreover, the moderate-to-high correlations between indicators across different components reveal that these cognitive abilities are not isolated but somewhat interdependent. For instance, *a3* (linking information) from *Truth Discovery* correlates significantly (r = 0.71) with *b1* (problem identification) from *Problem Identification.* This relationship highlights the logical flow between perceiving problems and identifying solutions. Finally, the correlation matrix provides insights into the indicators that serve as critical diagnostic markers for their respective components. Strong correlations such as those between *b2* (considering problem causes) and *b3* (problem prioritization) (r = 0.84) show the importance of these indicators in evaluating the depth of problem analysis.

Table 5.
Indicator correlation matrix.

Item	a1	a2	a3	b1	b2	b3	c1	c2	c3	d1	d2	d3	e1	e2	e3
a1	1.00														
a2	0.80**	1.00													
a3	0.71**	0.70**	1.00												
b1	0.60**	0.63**	0.71**	1.00											
b2	0.70**	0.74**	0.74**	0.85**	1.00										
b3	0.67**	0.68**	0.65**	0.78**	0.84**	1.00									
c1	0.63**	0.67**	0.75**	0.74**	0.72**	0.72**	1.00								
c2	0.60**	0.64**	0.66**	0.71**	0.76**	0.73**	0.70**	1.00							
c3	0.61**	0.67**	0.63**	0.70**	0.78**	0.69**	0.67**	0.84**	1.00						
d1	0.59**	0.67**	0.65**	0.72**	0.73**	0.64**	0.65**	0.72**	0.78**	1.00					
d2	0.62**	0.69**	0.69**	0.68**	0.74**	0.64**	0.72**	0.75**	0.72**	0.78**	1.00				
d3	0.65**	0.73**	0.72**	0.68**	0.76**	0.64**	0.70**	0.76**	0.73**	0.77**	0.84**	1.00			
e1	0.57**	0.65**	0.64**	0.69**	0.73**	0.69**	0.71**	0.70**	0.68**	0.76**	0.75**	0.81**	1.00		
e2	0.58**	0.67**	0.68**	0.73**	0.74**	0.73**	0.67**	0.72**	0.70**	0.77**	0.78**	0.82**	0.87**	1.00	
e3	0.62**	0.70**	0.65**	0.64**	0.72**	0.60**	0.62**	0 .66**	0.73**	0.78**	0.68**	0.78**	0.80**	0.80**	1.00
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.=0.94															
Bartlett's Test of Sphericity =2540.18, df=105, Sig. < 0.01															

Note: **Sig. ≤ .01.

While all indicators contribute meaningfully, some stand out due to their higher correlation values and alignment with key cognitive functions:

- a2 (Identifying relevant information):
- With significant correlations across multiple components (e.g., r = 0.80 with a1), *a2* underscores the importance of accessing and recognizing relevant data, a foundational step for problem-solving.
- b2 (Considering problem causes):
- This indicator highly correlates with its peers in *Problem Identification* (r = 0.84 with b3) and other

components (e.g., $r = 0.74$ with c2, thinking diversely). It is critical for in-depth problem analysis and comprehensive understanding.

- e1 (Applying knowledge):
- *e1* shows strong correlations with all components ($r = 0.81$ with d3, identifying solution reasons), highlighting its role in bridging theoretical knowledge with practical application.

4.6. Testing Importance

Furthermore, the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity provide critical statistical evidence for the appropriateness of the data for factor analysis [35].

KMO Measure of Sampling Adequacy (0.94): The KMO value evaluates whether the sample size and correlation patterns are adequate for factor analysis. Values above 0.80 indicate meritorious adequacy, while values above 0.50 indicate that the analysis can proceed [35]. The value of 0.94 signifies excellent sampling adequacy, confirming that the data is suitable for identifying latent constructs through CFA.

- Bartlett's Test of Sphericity ($\chi^2 = 2540.18$, df = 105, Sig. < 0.01): This test evaluates whether the correlation matrix is significantly different from an identity matrix (i.e., where variables are uncorrelated). The significant result ($p < 0.01$) suggests that the correlation matrix is well-suited for structure detection, confirming the presence of meaningful relationships among variables.

The indicator correlation analysis demonstrates the strength and interrelatedness of the cognitive components and indicators. Key metrics such as KMO and Bartlett's test validate the appropriateness of the data for CFA, while the strong inter-item correlations affirm the framework's reliability and relevance. Indicators like *a2*, *b2*, and *e1* emerge as pivotal elements due to their strong relationships with intra- and inter-component measures, reinforcing their importance in comprehensively assessing cognitive and problem-solving abilities.

The second-order confirmatory factor analysis of the primary school teachers' creative problem-solving principles is shown in Figure 1.

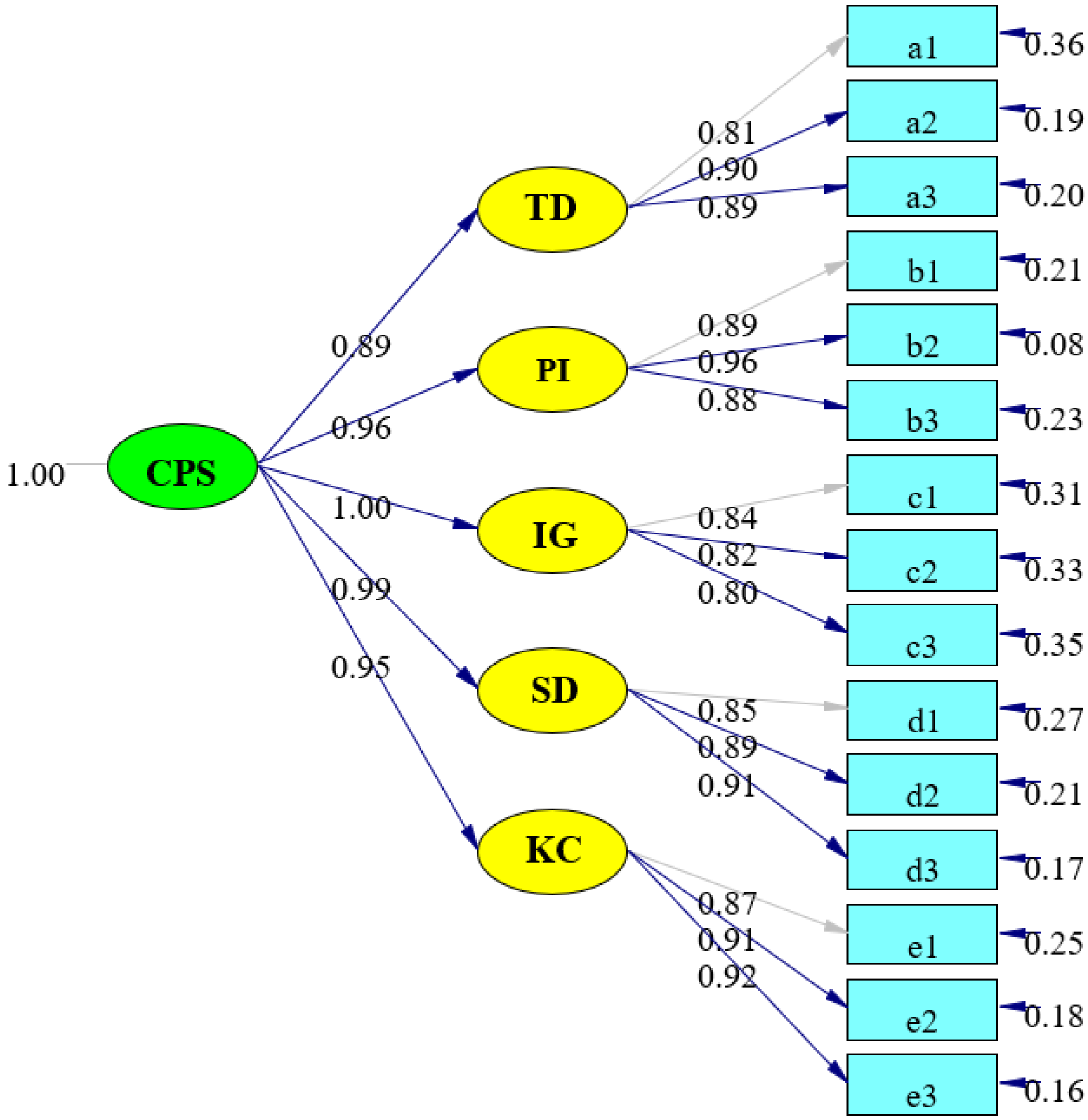

Figure 1.
Results of second-order CFA of teacher CPS.
Note: Chi-Square=29.26, df=34, *p* -value=0.70, RMSEA=0.00, Truth Discovery (TD), Knowledge Creation (KC), Problem Identification (PI), Idea Generation (IG), Solution Discovery (SD), Creative Problem-Solving (CPS).

5. Discussion

The results of the second-order CFA for educator CPS skills determined that the model fits well with the empirical data. This is evidenced by $\chi 2$ not being statistically significant (p = 0.70), $\chi 2$/df = 0.86, RMSEA = 0.00, GFI = 0.99, AGFI = 0.98, NFI = 0.99, CFI = 1.00, RMR = 0.01, and SRMR = 0.01. Moreover, the component weights (b) ranged from 0.80 to 1.00.

5.1. Research Objective 1 (RO1)

RO1 involved the synthesizing of the principles of CPS from books, texts, and relevant research. As such, the study explored the key components of CPS and examined the educators' perceptions of these competencies. The findings provide insights into the structure of CPS, its practical application in education, and areas for potential improvement. The synthesis process identified five core components of CPS, which together formed a comprehensive framework for addressing complex challenges:

1. **Truth Discovery** (TD) - This component emphasizes recognizing problems, identifying relevant information, and linking the information to the problems. It establishes the foundation for understanding and analyzing challenges.
2. **Problem Identification** (PI) - Problem discovery involves framing questions, evaluating root causes, and prioritizing issues. These steps ensure a structured and logical approach to problem-solving.
3. **Idea Generation** (IG) - Generating ideas requires applying knowledge innovatively, thinking in diverse ways, and creating novel solutions. This component reflects the creative aspects of CPS.
4. **Solution Discovery** (SD) - Solution finding includes evaluating potential methods, selecting the most appropriate approach, and justifying the chosen solutions. It integrates analytical and evaluative thinking.
5. **Knowledge Creation** (KC) - This final component highlights applying knowledge in real-life contexts, connecting it to problem-solving processes, and leveraging these insights to generate new knowledge or approaches.

This CPS framework provides a structured yet flexible approach, enabling educators to address problems effectively and innovatively.

5.2. Research Objective 2 (RO2) - Perceptions of CPS Among Teachers and Supervisors

The study explored how educators and supervisors perceive CPS processes, uncovering significant insights into their application and challenges. The findings suggest that while most participants recognize the importance of CPS in addressing complex problems, variations in perceptions emerge based on role, experience, and context. Teachers emphasized the practical aspects of CPS, particularly its ability to foster classroom engagement and facilitate innovative teaching strategies. Supervisors, on the other hand, viewed CPS as a tool for improving institutional processes and decision-making.

Key perceptions include:

1. Value of CPS in Practice: Educators appreciate CPS as a means to enhance teaching effectiveness and student problem-solving skills, aligning with the need for 21st-century competencies [1-3].
2. Barriers to Implementation: Participants highlighted challenges such as limited time, lack of resources, and varying levels of support for creative practices within educational institutions [36, 37].
3. Role-Specific Emphasis: While teachers focused on immediate applications like lesson planning and student engagement, supervisors prioritized strategic elements such as problem identification and solution evaluation [38].

These findings underscore the importance of tailoring CPS training to address these varied perspectives, ensuring educators at all levels can effectively leverage its principles.

5.3. Research Objective 3 (RO3) - Analysis of CPS Components Among Educators and Supervisors

The analysis of CPS components highlights a comprehensive understanding of the framework's five core elements: Truth Discovery, Problem Identification, Idea Generation, Solution Discovery, and Knowledge Creation.

5.3.1. Strengths Across Components

- Teachers demonstrated strong competencies in *Truth Discovery* and *Idea Generation*, reflecting their ability to recognize problems and think creatively to develop innovative teaching methods.
- Supervisors excelled in *Problem Identification* and *Solution Discovery*, showcasing their focus on analytical thinking and decision-making for institutional improvement.

1. Component Weights:
2. The high component weights (b = 0.80–1.00) indicate that educators and supervisors consistently engage with CPS principles, albeit with varying emphases. This variability reflects the adaptive nature of CPS and its ability to cater to diverse educational needs.
3. Areas for Growth:
4. Both groups identified *Knowledge Creation* as an area needing further development. While participants recognize the value of applying CPS principles to real-world challenges, they

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expressed the need for more structured opportunities to connect theoretical knowledge with practical problem-solving.

6. Conclusion

This study identified five core components and 15 indicators of creative problem-solving (CPS) among primary school teachers. The second-order CFA model demonstrated an excellent fit with the empirical data, validating the strength and applicability of the CPS framework. Among the components, *Truth Discovery* (TD) emerged as the most emphasized (mean = 4.27, SD = 0.56), highlighting teachers' prioritization of understanding the nature and context of problems. *Knowledge Creation* (KC) (mean = 4.26, SD = 0.53) ranked closely, reflecting the importance of applying knowledge to real-world challenges.

Problem Identification (PI) (mean = 4.24, SD = 0.59) underscored the necessity of framing and prioritizing issues as a critical step in problem-solving. While *Idea Generation* (IG) (mean = 4.21, SD = 0.59) and *Solution Discovery* (SD) (mean = 4.21, SD = 0.57) scored slightly lower, they remain integral components of CPS. These results suggest that while teachers value fostering innovation and evaluating solutions, additional support and development in these areas may enhance their effectiveness.

Overall, the findings highlight the comprehensive and balanced approach primary school teachers take toward CPS while identifying opportunities for targeted development to strengthen innovation and evaluation capacities further.

7. Future Research Suggestions

To advance the development of creative problem-solving skills among educators and students, the following recommendations are proposed:

1. Policy Advocacy:
2. The Office of the Basic Education Commission, Ministry of Education of Thailand, should prioritize policies that enhance teaching strategies for CPS. These policies are essential for preparing students to navigate and succeed in a rapidly evolving digital society.
3. Targeted Development:
4. Related agencies should integrate the three most crucial CPS components *into educational planning: Idea Generation*, *Problem Identification*, and *Solution Discovery*. Emphasis should be placed on creating a curriculum that encourages innovation, critical thinking, and problem-solving methodologies.
5. Learning Resources and Technology:
6. Schools should develop and implement comprehensive learning support materials, including lesson plans, digital resources, and educational innovations. These tools should facilitate the teaching and application of CPS principles across all subjects.
7. Classroom Integration:
8. Teachers should design and implement activities within their subjects that promote CPS. Practical exercises, project-based learning, and collaborative problem-solving scenarios can ensure that students develop transferable skills applicable to real-world challenges.
9. Focus on Evaluation:
10. Future studies should examine the impact of CPS interventions in classrooms and explore ways to measure the long-term application of these skills in both academic and non-academic settings.

8. Limitations

While the study achieved a substantial portion of its sample size, enhancing participation through targeted outreach, incentives, and logistical support can significantly improve data reliability and representativeness. These steps will ensure strong findings and actionable insights into the components of creative problem-solving among educators.

Moreover, while this study provides valuable insights, future research should address certain limitations. These include:

1. Sample Representativeness:

Although the sample size was substantial, targeted outreach and logistical support could improve participation rates and ensure a more diverse and representative sample of educators.

2. Contextual Specificity:
   The study's focus on Thailand's primary school teachers may limit the findings' generalizability to other educational contexts. Future research should explore CPS across different regions, educational levels, and cultural contexts.
3. Longitudinal Insights:
   The study's cross-sectional design offers a snapshot of CPS skills but does not account for changes over time. Longitudinal studies could provide deeper insights into the development and sustainability of CPS competencies among educators.

By addressing these limitations, future research can build on the current findings to further validate and expand the understanding of CPS in education.

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