Research Article

Cultivating Students' Critical Thinking: A Comprehensive Approach with the Integrative Collaborative Problem-solving (ICoPS) Conceptual Model

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Abstract.
This research aims to develop an innovative learning model to cultivate students' critical thinking skills. The formulated model is anchored in Problem-Based Learning (PBL) principles, a pedagogical approach highly endorsed by experts for its efficacy in enhancing critical thinking abilities. We endeavor to optimize the application of PBL to enhance the overall joyfulness of the learning experience. This research method uses DBR by Reeves, which includes: (1) identifying and analyzing problems by researchers and practitioners in collaboration, (2) development of solutions informed by existing design principles and technology innovation, (3) iterative cycles of testing and refinement of solutions in practice, and (4) reflection to produce "design principles" and enhance solution implementation in practice. Currently, the research is in stage two. In the first stage of DBR, the data were collected using a questionnaire to determine the obstacles to PBL from the teacher's perspective and diagnostics of students' critical thinking using tests. In stage two, we used a literature study to provide theoretical support for learning model developers. The research results are a draft of the Integrative Collaborative Problem Solving (ICoPS) learning model. We developed this model from the PBL and Jigsaw methods involving the TPACK approach. ICoPS syntax is a combination of the three constituent contents. ICoPS syntax includes (1) problem orientation, (2) formation of an expert group, (3) Jigsaw discussion, (4) investigation, (5) presenting of findings, and (6) evaluation. The syntax maximizes students' critical thinking while maintaining ease and practicality when applied in the classroom.

Keywords: problem-based learning, jigsaw discussion, TPACK, critical thinking

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1. INTRODUCTION

The skills of the 21st century play a vital role in enabling continuous learning and adaptation to evolving circumstances. Consequently, these competencies have emerged as the paramount factors contributing to success. As such, mastery of 21st-century skills has become an essential prerogative for citizens in the modern era. These proficiencies constitute the central objectives of technology-enhanced education in today's context [1, 2].

Researchers have chosen to focus on critical thinking skills from the various 21st-century skills, such as critical thinking, creativity, collaboration, and communication [3]. The primary rationale for this is that critical thinking skills are paramount in life. Critical thinking enhances the ability to analyze and synthesize knowledge, form cohesive arguments, foster the emergence of intrinsic motivation, and prepare learners to solve real-world problems. Many experts regard critical thinking as necessary and as the new foundation for 21st-century Learning [4, 5].

The research topic on critical thinking has gained prominence in education over the last decade [2, 6]. Developing critical thinking is essential to instill in students early, as it can become a valuable habit [6, 7]. Cultivating critical thinking in students can be achieved through school lessons. Critical thinking is integral to problem-solving, emphasizing the ability to evaluate information, assumptions, clarification, and possible solutions [8, 9]. The subject of science serves as a domain where students can enhance their critical thinking skills. This is because the study of science requires the application of a variety of these skills.

Research conducted by Abrami, Bernard, Borokhovski, Waddington, Wade, and Persson [10] through a literature review of scientific articles spanning from 1930 to 2009 led to the conclusion that enhancing students' critical thinking through learning can be achieved by optimal dialogue using various methods, employing authentic problems and examples, and providing intensive guidance to students. Furthermore, as suggested by Chou et al. [6], standard strategies to improve critical thinking include engaging students in synchronous and asynchronous online discussions, utilizing various e-learning techniques, active learning, and peer tutoring. Critical thinking in students entails critically analyzing information and data relevant to daily life and is imparted through the process of Learning [11]. Based on these findings, Problem-Based Learning (PBL) is a suitable instructional model for enhancing students' critical thinking skills.

PBL can be highly effective if it meets the requirements. However, based on the literature synthesis, PBL has weaknesses in its implementation, assessment, and pre-requisites. Specifically, PBL can lead to anxiety or discomfort among students [12, 13]. These issues arise when students are not accustomed to the self-directed learning steps required by PBL. This discomfort can affect students' learning outcomes.

We are attempting to develop a new learning model based on PBL. The primary goal is to make PBL easier for teachers to implement and to make students more comfortable. We are combining various theories that support the development of a more practical yet efficient model. The pilot implementation is conducted in science classes, considering the characteristics of secondary school students.

2. METHOD

This research procedure utilizes the Design-Based Research (DBR) model developed by Reeves [14]. DBR is an approach that supports exploring educational issues and refining theory and practice by defining learning outcomes and focusing on creating a learning environment that supports those outcomes [15]. The primary goal of DBR is to establish a stronger connection between educational research and real-world problems [16]. According to Plomp & Nieven [17], design-based research entails repeating the analysis, design, evaluation, and revision processes until it achieves a satisfactory balance between ideas and their realization. In this study, this means that the product created should reliably demonstrate improvements in critical thinking regularly. The DBR model involves a series of approaches allowing for research design flexibility. In this current publication, the research is limited to the second step. The subjects of this study were secondary school students, and science teachers. While the object of research is learning model and critical thinking. The scope of the research is science lessons.

2.1. Identify and Analyze Problems

Researchers use the initial research stage to analyze the existing problems in the field and the underlying factors behind these issues. The main research questions focus on:1) What is the current state of critical thinking skills among secondary school students? 2) What are the challenges in implementing PBL in science education at secondary schools?

We collect data by reviewing previous research from scientific journals to gain an understanding of the general state of critical thinking skills among students in Indonesia. A critical thinking skills test is conducted through sampling in three secondary schools in the Bantul regency, Yogyakarta, Indonesia. The critical thinking test instrument is generic and adapted from questions on the website https://www.123test.com/critical-thinking-test/. The questions are modified to suit the comprehension level of secondary school students.

Science teachers in the Bantul regency are actively conducting an online survey to pinpoint the challenges of implementing PBL in science education. They are disseminating the survey through dedicated WhatsApp groups created for science teachers in the Bantul. Data is collected using the Google Forms application. We invite as many teachers as possible to participate in filling out the questionnaire.

The results of diagnostic CT tests from 180 students in three secondary schools in the Bantul indicate domain scores: interpretation 59.72%, inference 33.89%, deduction 34.17%, assumption 80.56%, and argument analysis 40.83%. The overall mean CT score is 52.1%, with the assumption domain scoring the highest and inference the lowest. In general, students' critical thinking skills need improvement. The survey with 15 science teachers at secondary schools shows that 80% rarely use PBL, while 20% frequently use it. PBL is not a priority for science teachers. All the PBL steps pose difficulties for teachers. The fifth step is identified as the most challenging among the others.

2.2. Development Of Solutions Informed By Existing Design Principals & Technology Innovation

2.2.1. Context analyze

In the context analysis phase, the researcher analyzes various theoretical and practical requirements necessary to achieve the research objectives. Context analysis encompasses domains of critical thinking skills, models, methods, and learning approaches that support critical thinking, characteristics of science education, student characteristics, and the development of a learning model. This context analysis also includes technical aspects such as the resources involved, location, and the timing of the research.

2.2.2. Literature study

Researchers conduct a literature review to provide theoretical support in addressing the formulated research questions. Most of the reference sources come from reputable international journal articles. This stage aims to produce theoretically and logically sound solutions, considering various scholarly aspects. The literature review is conducted through a Systematic Literature Review (SLR) approach, guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines [18]. The objective of the SLR is to identify instructional models that support students' critical thinking development. The databases utilized include Science Direct, Taylor and

Francis, Springer, Wiley Online Library, and the Education Resources Information Center (ERIC).

The outcome of this step is a systematically constructed conceptual model following the guidelines of Joice & Weil [19]. These guidelines include: 1) theoretical rationale, 2) learning syntax, 3) response principles, 4) social system, 5) support system, 6) learning impact, and 7) integration of technology.

3. RESULTS AND DISCUSSIONS

3.1. Literature Study

The researchers have conducted a Systematic Literature Review (SLR), and the results are currently being published. The SLR employed a structured search strategy, including synonyms and alternative terms, in reputable databases, along with inclusion and exclusion criteria, to ensure the accuracy and authenticity of the findings. The articles used in this study are sourced from publications from 2012 to 2022. We did this to support the freshness and relevance of our data.

Based on the SLR, 18 articles were rigorously selected to identify instructional models that support Critical Thinking (CT) and have been proven effective in enhancing CT. The recommended models include Inquiry-Based Learning, PBL, STEM (Science, Technology, Engineering, and Mathematics), cooperative learning, and Predict Observe Explain (POE). Each model possesses unique characteristics, but they share a common feature of activating students in the learning process, fostering collaboration, promoting multidisciplinary learning, encouraging investigation, data analysis, problem-solving, and concluding.

3.2. Hypothetic model of Integrative Collaborative Problem-Solving (ICoPS)

As we know, various innovative learning models have actively engaged students. These models involve processes such as discussion, problem-solving, sharing experiences among group members, and teacher instruction and facilitation. In addition to the five recommended models from the results of the systematic literature review (SLR), project-based learning (PjBL) and discovery learning can also be used [20, 21]. However, we have chosen the PBL model as the solution for enhancing students' critical thinking through learning for several reasons.

The PBL model is widely recognized for its ability to enhance 21st-century skills in students [22–24]. In the PBL model, teachers involve students in solving contextual and real-life problems. PBL can train students to work within groups and develop their full potential to achieve a common goal, which is to solve the given problem. Through the PBL model, students can argue, show mutual respect, think critically, develop creativity, collaborate, practice leadership, and make joint decisions [25]. Students can reap numerous benefits if they become accustomed to the PBL learning model. PBL is also a recommended learning model by the Indonesian Minister of Education for implementation across various educational levels, starting from elementary school.

Our solution is fundamentally centered on the students. We aim to modify PBL to make it more accessible, enjoyable, and foster a joyful group discussion atmosphere. Integrating PBL with other methods can enhance a pleasurable learning environment without diminishing the essence of PBL itself.

Cooperative learning is one of the primary choices to enhance optimal group learning. This perspective aligns with Karacop & Doymus [26], who state that cooperative learning involves students working together in small groups to achieve common goals. Furthermore, students can engage in thinking, learning, and enjoy learning activities with their peers. Cooperative learning is more effective in developing thinking skills than competitive or individual learning. It positively impacts students' motivation and cognitive aspects [27]. In terms of motivation, students strive to achieve personal goals to influence the group's goal achievement. On the cognitive side, it can maximize the degree of change in students to carry out their academic tasks. Cooperative learning comes in various types: NHT, TGT, talking stick, CIRC, Make a match, Snowball throwing, and Jigsaw [28]. The researchers have chosen Jigsaw for integration with PBL based on several considerations.

According to Winschel et al. [29], problem-solving skills can be honed through cooperative learning that provides participants with opportunities to learn from their experiences, knowledge, and mutual understanding with their peers. Hugerat et al. [30] assert that Jigsaw or Jigsaw Discussion (JD) is a cooperative learning method that emphasizes the roles of group members, enabling each participant to take responsibility for mastering the topic, assisting one another in understanding information, and sharing expertise with group members. Jigsaw fosters a cooperative learning environment that encourages students' activities, shared content mastery, and mutual explanation. It necessitates individual responsibility from each member and promotes the group's proficiency in broader topics [26, 29]. Based on this description, the integration of Problem-Based Learning (PBL) with Jigsaw is expected to realize problem-based learning that can optimize group collaboration. The results of the Systematic Literature Review (SLR) further strengthen the use of cooperative learning models.

Researchers have examined student characteristics as an essential aspect, particularly in the context of current middle school students who belong to Generation Z—born between 1995 and 2012. This generation has grown accustomed to the internet and technology since childhood. Hastini et al. [31] noted that Generation Z is accustomed to communicating through smartphones, accessing a wide range of information, and playing games. Internet and technology have become daily necessities for them. They are adept at using social media and prefer online communication. Given these characteristics, educators must be proficient in integrating technology and the internet into their teaching to motivate and engage students. The Technological Pedagogical Content Knowledge (TPACK) approach in education can be an effective solution.

Learning that incorporates technology and the internet is engaging and motivating for students. Integrating technology into learning activities can make students more comfortable and at ease, aligning with their characteristics. Koehler [32] emphasizes that teaching with technology, particularly on complex and multidimensional subjects, requires understanding pedagogical techniques that constructively utilize technology to conduct content. Technology can enhance the understanding of challenging material and how it can be employed to build knowledge. These ideas are at the core of TPACK, and the role of educators is pivotal in the success of this approach, especially when dealing with students from Generation Z who are already familiar with technology.

The researchers have integrated the TPACK model into the PBL framework to reduce student confusion during PBL sessions. Technology implementation in this context primarily focuses on the pedagogical aspect, the scientific content, and the execution of the learning process. We assume that this new model will enhance student motivation, facilitate their comprehension of information, and enable them to explore their skills, including critical thinking. The combination of PBL with Jigsaw promotes more enjoyable and optimized group work. The core idea of this research is the fusion of PBL and Jigsaw within the TPACK environment with a suitable composition. The hypothetical model is called Integrative Collaborative Problem-Solving (ICoPS) with a syntax as illustrated in Figure 1.

The hypothetical ICoPS model comprises six syntaxes that merge the PBL model with the Jigsaw method. At the same time, TPACK is the applied approach for crucial aspects to facilitate implementation and motivate students to learn in groups. In the ICoPS model, social principles focus on how students collectively interact, collaborate, and support each other in solving problems. These principles ensure that every group

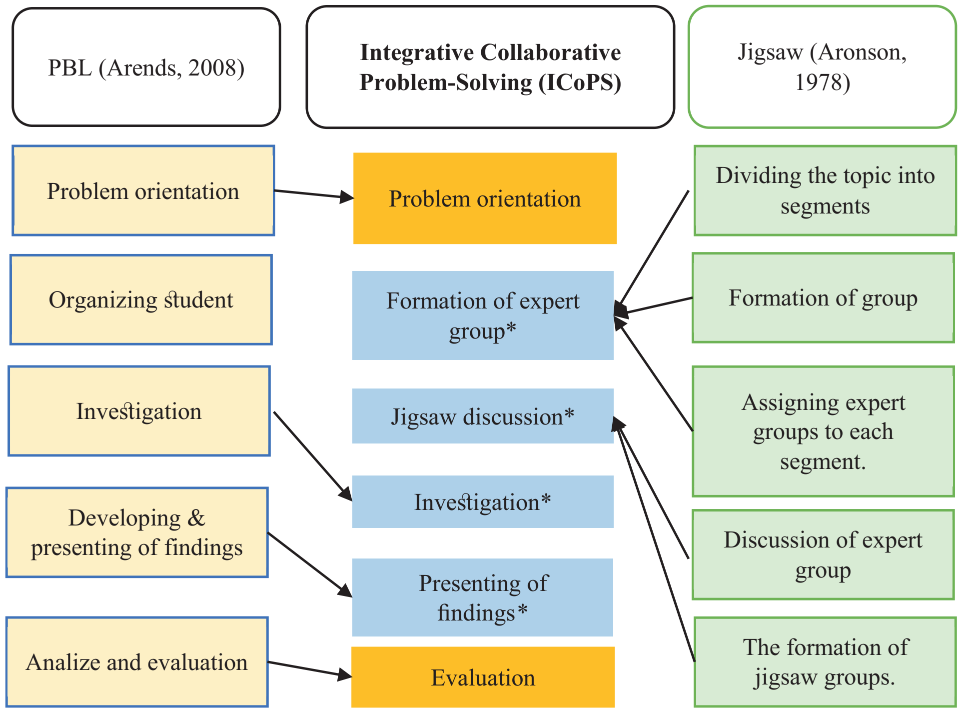

Figure 1: Hipotetic Model of ICoPS.

member has a vital role in group learning, facilitating effective collaboration and creating an inclusive and respectful learning environment.

Reaction principles pertain to how students respond to the discussions, understandings, and solutions generated during group learning. This principle encourages deep reflection, taking responsibility, and critical evaluation of the learning process and outcomes. For example, students contemplate new perspectives on the information they have learned.

Support systems within the ICoPS model refer to various technologies, tools, and resources used to support and facilitate the learning process, collaboration, problem-solving, and evaluation in the group learning environment. These support systems encompass software, online platforms, communication tools, and other resources that assist students and teachers in effectively implementing the ICoPS model.

Instructional impact is the immediate learning outcome achieved by directing students toward the desired objectives. A direct impact of implementing the ICoPS model is the improvement of students' critical thinking. The accompanying impact on students after learning with the ICoPS model can encompass several aspects: (1) in-depth understanding of the subject matter (content knowledge), (2) teamwork and collaboration skills, (3) the development of problem-solving skills, and (4) technology skills and digital literacy. The hypothetical ICoPS model is still in the development stage, and we will conduct validation through expert judgment. In the subsequent phases of the research, it will test its effectiveness and practicality.

4. CONCLUSION

The hypothetical Integrative Collaborative Problem Solving (ICoPS) model has been developed to enhance students' critical thinking (CT) skills. This model represents an integration of Problem-Based Learning (PBL) with Jigsaw in the TPACK environment. PBL is a recommended model by experts for the development of 21st-century skills. At the same time, Jigsaw Discussion serves as a method to encourage student collaboration, and the technological aspect adds an enjoyable and meaningful dimension to the lessons. The ICoPS syntax comprises six steps involving in-depth considerations. It's worth noting that this model remains theoretical and requires validation by experts and field testing.

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