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Design Instructional Collaborative Problem Solving Based on Computational Thinking Skills for Students' Scientific Creativity Skills: A Framework for Effective Teaching

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Abstract

Creative thinking skills are one of the skills that must be applied to higher education. However, this is different from what is currently dreamed of; several studies report that creative thinking skills at the student level still need to be improved. Today, there is a gap between the need for scientific creativity and its application, especially in school education, which is more oriented toward developing intelligence than creativity. Educators must understand scientific creativity and how to set it up in an educational environment. Efforts to build students' scientific creativity require improving the learning environment in a certain way. Therefore, this study aims to create a teaching framework that effectively trains scientific creativity skills for both students and teachers. This study uses literature studies as a form of data collection and analysis. The results of the literature analysis are presented in the form of a learning model design framework called a collaborative problem-solving model based on computational thinking skills. The analysis results have successfully packaged a collaborative problem-solving learning model design based on computational thinking skills based on learning theory and principles, especially scientific creativity. The syntax of the computational thinking skill-based collaborative problem-solving learning model consists of (1) organizing students, (2) investigating problems in study groups, (3) computational-based creative teamwork, and (4) verification.

Keywords: Collaborative problem solving, computational thinking skills, Creativity scientific

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1. Introduction

1.1. Introduce the problem

Collaborative problem-solving, rooted in computational thinking skills, is vital for improving students' scientific creativity abilities, making it a necessary framework for successful instruction. Scientific creativity is an essential quality for pupils to think innovatively and solve intricate challenges in the fast-paced and ever-changing world of today. Through participation in cooperative problem-solving exercises, students cultivate their critical thinking skills and acquire a more profound comprehension of scientific principles. The need to integrate collaborative problem-solving based on computational thinking skills arises from the growing requirement for scientific innovation across many domains. Given the progress in technology and the increasing intricacy of real-world problems, students must cultivate the ability to collaborate in teams and utilize computational thinking to its full potential. This methodology promotes ingenuity by motivating students to investigate alternative resolutions to issues, experiment with theories, and collectively scrutinize evidence.

Additionally, the structure of cooperative problem-solving cantered on computational thinking abilities offers pupils a comprehensive method for acquiring knowledge. The system combines computational thinking principles, including decomposition, pattern recognition, and algorithmic reasoning, with collaborative problem-solving strategies. Collaborating with their classmates allows students to cultivate their scientific ingenuity while also improving their abilities in communication, teamwork, and leadership. The necessity of integrating collaborative problem-solving, rooted in computational thinking skills, into students' scientific creativity capabilities is driven by the imperative to provide them with the fundamental abilities required to excel in contemporary society. This framework enables students to engage in critical thinking, foster collaborative effort, and cultivate new solutions to intricate challenges. By using this methodology, teachers can successfully cultivate students' scientific ingenuity, equipping them to be proactive participants in the scientific field and proficient troubleshooters in their future pursuits.

1.2. Describe relevant scholarship

The collaborative problem-solving (CPS) learning model is often used to support scientific creativity. Collaborative problem-solving is a skill that enables individuals to work together effectively to solve complex and challenging problems. The framework developed by Hesse et al. (2015) focused on teaching CPS skills in educational settings. The framework outlines some of the critical components of a CPS, including understanding the problem, generating and testing solutions, and reflecting on the process. Rummel & Spada (2005) and Germany & Dillenbourg (2008) suggest that this type of learning can produce better results than individual problem-solving and can be taught effectively through specific instructional strategies. The article highlights the importance of creating a supportive learning environment, providing clear assignment instructions, and using appropriate technology to support communication and collaboration. Collaborative problem solving (CPS) is a crucial competency required in the 21st century. There has been an increasing need to understand CPS because it involves both cognitive and social processes, and thus the methods are challenging to examine. Recent research has highlighted that computer-based learning environments allow learners to collaborate with others to solve scientific problems and facilitate their knowledge-building process, which can be tracked dynamically within the system. However, more research has yet to attempt to identify CPS processes (Kang et al., 2019).

Several weaknesses are identified from the journal reference analysis results of the various potentials in the collaborative problem-solving (CPS) model. The lack of scientific integration in the learning process can undermine the usefulness of cognitive constructs at a fundamental level (Neubert et al., 2015). In addition, other challenges arise when students experience confusion in implementing new content and multiple meanings related to scientific practice in creative engineering efforts, especially those related to responsibilities, relationships, and positions when students collaborate on a project (Jordan & Babrow, 2013, 2010; Jordan & McDaniel, 2010). Thus, it is important to consider relational and content uncertainties when understanding how students engage in collaborative problem-solving, especially concerning students' counter-creativity.

Collaborative problem-solving is a complex construct with various definitions; Hesse et al. (2015) refer to it as a joint activity in which small groups interact to take several steps to transform the current state into the desired goal state by involving social interaction and individual performance in the group as success factors. Social skills are related to an individual's ability to manage collaborative processes. They are categorized into three broad sections: (1) perspective-taking (ability to understand and consider the perspectives of others); (2) participation (willingness to engage with tasks and exchange ideas and information); and (3) social regulation (ability to negotiate and resolve conflicts). Cognitive skills concern the problem-solving part of collaborative problem-solving and are divided into two categories: (1) task setting (ability to organize and monitor problem-solving strategies) and (2) learning and knowledge constructing (ability to acquire and build shared knowledge through collaboration) (Boshrabadi & Hosseini, 2020.

However, cognitive challenges can come from difficulties understanding individual thoughts and implementing collaborative problem-solving during the learning process (Häkkinen, 2013; Kirschner et al., 2008; Mäkitalo et al., 2002). The problem of motivation is a triggering factor, for example, related to turns in arguing and the communication process due to differences in goals, priorities, and expectations of group members in developing an idea (Dillenbourg et al., 2009; Järvelä et al., 2015). If collaboration is not supported well enough and students do not have adequate skills, productive learning does not occur, and students may end up with negative learning experiences (Swiecki et al., 2020; Naykki et al., 2017; Rajuan et al., 2007).

In addition, beginners often need more detailed and structured guidance from more knowledgeable peers to develop appropriate knowledge-idea structures about phenomena. When learning through cases and problem-solving, educators invite learners to articulate their existing knowledge structures with their peers, provide normative models or cases, distinguish between normative models and their preexisting knowledge structures, reflect on what has been learned, and move in that direction. There are particular cognitive differences needed to solve unstructured and well-structured problems; for example, focused convergence is needed for well-structured problems, and broadening divergence is needed for unstructured problems (Kim & Tawfik, 2021). Apart from the collaborative problem-solving model, another model currently present is the computational model. Computational models are based on computational thinking skills, which include abstraction phases, algorithm design, and coding verification (Lin et al., 2019). Computational thinking is a 21st-century skill (Wing, 2006). It can be understood as a problem-solving approach applicable to many disciplines. It is a thought process that refers to the basic constructs of computer science, such as decomposition, abstraction, pattern matching, and algorithmic design (including logical thinking) (Kirwan et al., 2022).

Computational thinking skills (CT) refer to representational concepts and practices involved in formulating and solving problems, designing systems, and understanding human behavior by describing basic computational concepts such as problem representation, abstraction, decomposition, recursion, simulation, and verification (Grover & Pea, 2013; Grover & Pea, 2013). CT practice, computational modeling, and programming integrally related to CT have become essential features in the NRC's K–12 science education framework (National Research Council 2011). Several researchers (Blikstein & Wilensky, 2009; Hambrusch et al., 2009; Kynigos, 2007; Sherin, 2013) have demonstrated that computational modelling and programming parallel core practices in science education and can support students' learning about physically challenging science and mathematics concepts (Basu et al., 2016).

Computational thinking skills are designed to develop ideas and for students to work within the scope of science and be able to reason out of the box regarding thought-out ideas, be able to understand computational science, be able to involve themselves in computing in the real world, and be able to involve computing with science across scientific disciplines constructively. It aims to help students harness the true power of computing and become more successful in their fields (Džeroski et al., 2007). Psycharis (2011) reports a significant shift in student's conceptual understanding and consideration of physics coherence, as well as an awareness that physics is closely related to mathematics. In addition, presenting physics in a scientific problem-solving paradigm is a more effective and efficient way to teach physics than traditional approaches. Landau et al. (2008) suggest that computational education integrates tools into education and uses rich experiences to stimulate and activate learners. Further research is needed to develop more robust simulation methods within the framework of computational experiments and with consideration of different knowledge domains and different simulation methods.

However, studies on how computerized environments improve learning performance have yielded mixed results, with some finding that simulation-based learning only significantly improves student test results (Psycharis, 2011). In addition, Araujo et al. (2008) report on modelling physics learning as a creative process, divided into five non-hierarchical stages: selection, construction, validation, analysis, and model expansion," in which the three middle parts overlap, and several steps can often be carried out simultaneously, resulting in an inadequate discussion of understanding. Gupta et al. (2018) argues that there needs to be more research in physics education about the role of influence in modelling learner learning, especially in fine-grain interactions. They stated that most of the research on student-centerer physics learning focused on the content they knew about rather than how students felt about what they were experiencing. To explore what role influence can play in learning, Alsop & Watts (2000a, b) look at how students approach physics topics (radiation and radioactivity) according to their attitudes and perceptions of them. Their study found that it is possible to balance "passionate knowledge and feeling informed" in physics lessons, which keeps students engaged but not off track.

Some influence-based strategies for how to achieve this balance of engagement and learning explored by Häussler & Hoffman (2000) and Erinosho (2013) demonstrate the importance (from a learner's perspective) of connecting physics with non-traditional and out-of-class situations, providing concrete material and relevant examples, and working on physics problems where students can collaborate with peers. Bosse & Gerosa (2016) and Hamerski et al. (2022) build on a compilation of research studies centered around learning difficulties in programming settings. Most of the results from the literature review indicate that students tend to worry about learning syntax, variables, error messages, and understanding code. Students also generally experience nervousness with unknown coding concepts such as functions and parameters, often resulting in students building emotional barriers to these challenges. For example, when learners realize that their code contains semantic errors, they tend to give up and not complete the programming activity because semantic errors take a lot of time and effort to identify and correct. Studies such as those conducted by Kinnunen & Simon (2011, 2012); and the recommendations that emerged from their point to the importance of exploring the influence of learners in certain types of learning environments. Eckerdal et al. (2007)

theorized about why learning computer science evokes affective responses in students. They frame the early experience (where learners form their self-efficacy beliefs for the first time) as consisting of "liminal spaces" (Kinnunen & Simon, 2011, 2012). Meanwhile, collaborative problem solving (CPS) through a series of computational modelling tasks with varying complexities impacts computational modelling challenges and provides opportunities for students to (a) explore resource-intensive processes, such as trial and error, to more systematic processes, such as debugging model errors by leveraging data tools, and (b) learn from each other using shared social regulation and productive collaboration.

2. Method

This research presents a basic framework for collaborative problem-solving learning models based on computational thinking skills. This study also provides an in-depth understanding by comprehensively searching for relevant theories and empirical findings related to the collaborative problem-solving learning model based on computational thinking skills. This study also includes identifying and classifying the design of learning activities appropriate for classroom learning, especially those related to learning in the realm of students' scientific creativity. The research procedure consists of first identifying literature sources that are relevant to the research topic. This can be done by accessing academic databases, scientific journals, articles, books, and other sources related to collaborative problem-solving, computational thinking, scientific creativity skills, and effective teaching methods.

Second, carry out a literature selection process that is in accordance with the research objectives. The selection of relevant literature was carried out, taking into account the previously determined inclusion and exclusion criteria. This ensures that the literature used is of high quality and relevant to the research topic.

Next, analysis and synthesis of the selected literature is carried out. This process involves critical reading, identifying key findings, comparing and combining results from various sources, and constructing comprehensive meaning from related literature.

After that, interpretation and evaluation of the findings from the synthesized literature were carried out. In this stage, researchers can identify patterns, similarities, or differences in the collaborative problem-solving framework based on computational thinking skills for students' scientific creativity skills that have been used in previous research. Apart from that, researchers can also identify the limitations, advantages, and disadvantages of the methods that have been applied.

The final stage is the preparation of conclusions based on the analysis and evaluation of the literature that has been reviewed. This conclusion can include a synopsis of important findings, the success or failure of using collaborative problem-solving based on computational thinking skills in improving students' scientific creativity abilities, as well as recommendations for further research or the development of more effective teaching methods.

3. Results & Discussion

3.1. The rationale for the effective of the Collaborative Problem Solving Based Computational Thinking Skill learning Instructional

In the context of scientific creativity, computational skills are often used to help researchers generate new hypotheses and develop new insights. These models can simulate complex systems and processes, allowing researchers to test various scenarios and explore how various variables interact. One common approach is to use computational models to explore the behavior of complex systems, such as the human brain or the environment. By modelling the system and testing different variables, researchers can gain insight into how the system works and identify new patterns and relationships that might not be apparent through observation alone. Another approach is to use computational models to generate new hypotheses and ideas. For example, researchers can use machine learning algorithms to analyze large data sets and identify patterns that suggest new research avenues. They can also use simulation to explore different scenarios and test the feasibility of different ideas before investing time and resources in further research.

The literature review found several points that should be the focus of the computational model, especially regarding the learning process in schools and its relation to ICT in supporting the learning process. Some things in the spotlight are computational models that prioritize results rather than skills in the process. In addition, students' participation is necessary since the variations in their comprehension of settings, particularly those connected to coding, must be supported by fundamental computer science abilities (Balgiu, 2018; Riese et al., 2021). Therefore, it is essential to involve teamwork or collaboration in applying a computerized system to learning. Several reference sources support these results that teamwork in education can improve student performance and cognitive performance (Chen et al., 2018; Wang & Liao, 2017; Defranco et al., 2011; Wang & Jung, 2011).

An algorithmic solution is a crucial element of computational thinking when it comes to issue-solving. Recognizing and surmounting barriers to accomplishing a goal might be challenging, but utilizing our mental faculties enables us to navigate through any challenges. Studies have demonstrated that both active mental involvement and unconscious thoughts play crucial roles in discovering solutions to an issue (Yadav et al., 2017; Doleck et al., 2017). Computational thinking is a broad methodology for resolving problems that frequently utilizes technology to find solutions within specific limitations.

Hence, it is imperative to include technology education, as computational thinking necessitates the utilization of computer tools for problem-solving. Efficient algorithms play a crucial role in achieving successful problem-solving outcomes and are essential for fostering computational thinking abilities in pupils.

Table 1. Design of a collaborative problem-solving model based on computational skills in indicators of scientific creativity

Indicators of scientific creativity	Collaborative Problem-solving	References	Computational Approach	References
Unusual Use	-	**	√	*
Problem Finding	√	‡	√	‡‡
Product Improvement	-	⁂	√	⁂
Scientific Imagination	-	††††	√	††
Science Problem Solving	√	⸙	√	⸙⸙
Creativity Explain Design	-	ȣ	√	ȣ
Creative Product Design	-	-	√	∆
Source: Griffin & Care, 2015				

Description: ** Kang et al., 2021; Kang et al., 2015., Rizkia et al., 2021; * Taub et al., 2015; ‡ Lavonen et al., 2004; ‡‡ Sengupta & Faris, 2012., Guven & Cakir 2020; ⁂ Ying-Tze Chen et al., 2023; ⁂ Ari et al., 2022; †††† Jordan, 2010; Jordan & McDaniel, 2010; Fredagsvik, 2023, 2022; Daud et al., 2012; †† Psycharis, S. (2011). Ayse & Buyuk, 2021; ⸙ Sun et al., 2020, 2022; ⸙⸙ Israel-Fishelson & Hershkovitz, 2022a-b; Beibit Jakubakynov et al., 2021.; ȣ Astutik & Prahani, 2018, ȣ Guven et al., 2020; ∆ Gök e & Sumeli, 2022; Park & Kwon, 2022a,b

Description: √ (explicit); (-) not explicit

In Table 1, the components of scientific invention often used in collaborative problem-solving models have been dominated mainly by science problem-solving and problem-finding. Meanwhile, the indicators of scientific creativity should be studied more. Meanwhile, the indicator aspect of the scientific invention is very important to train students' ability to identify and plan for problem-solving. This certainly needs to be of particular concern, and the component indicators of scientific creativity must be seen as an essential requirement for innovation. Therefore, this component needs to be considered to meet the needs of scientific ingenuity in collaborative problem-solving models. As an alternative, a computational skill approach is used to meet the needs and complement each other of the collaborative problem-solving based computational skill approach is used to meet the needs and complement each other of the collaborative problem-solving model. The computation skill approach is one of the most popular skills today. This is based on the ability of students to involve computational skills in making a settlement pattern, which consists of the process of computational thinking. Computational skills play an essential role, especially in creating innovation patterns. The analysis of the results found that computational thinking is found in many aspects of creativity. This computational component completes all the needs of scientific creativity, from unusual use to creative product design. This is because computational skills are being developed to train students in creating or innovating, involving scientific creativity, problem-solving, and collaboration.

In the context of computational thinking, Kong et al. (2020) proposed a general competency model for CPS containing three main aspects: building shared knowledge, negotiation and coordination, and maintaining team function. To facilitate collaborative problem-solving in learning, teachers package the learning process into idea-oriented tasks. However, it turns out that there needs to be more efficiency in the learning process (Hmelo-Silver & DeSimone, 2013; Kirschner et al., 2006; Perit et al., 2009). From a research perspective, one of the things that is the object of the findings is that the diverse and complex multidimensional characteristics of the collaborative learning process are something that only needs to be paid attention to (Janssen et al., 2013). A multi-method approach is used to study research gaps that focus on how students work together in groups. This includes looking at cognitive, metacognitive, and behavioral aspects as well as the results of group work (Ouyang et al., 2023).

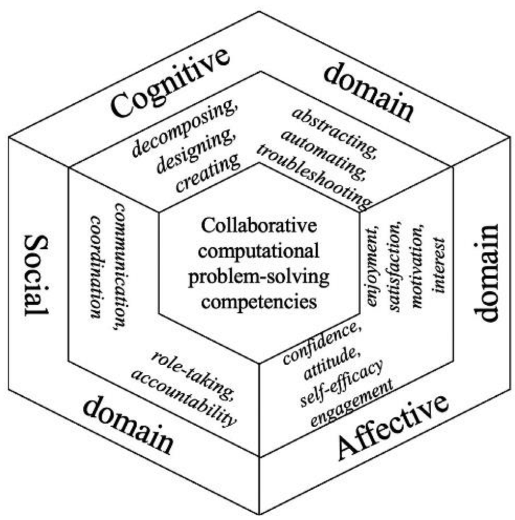

Figure 1. Collaborative computational problem-solving model competency (Lai & Wong, 2020)

Based on Figure 2, collaborative computational problem-solving models consist of four domains consisting of cognitive, affective, and social domains. Each of these domains has components that support the process. The components of computational thinking can be broadly divided into abstraction and automation. Abstraction is a thought process to express real-life problems in a form that can be solved. Collect and analyze the data necessary to solve various problems in everyday life and present it in an easy-to-read manner using the necessary methods of expression, such as diagrams and graphs. After that, the user decomposes the complex elements into small units, extracts the variables required for the solution, and designs the appropriate solution model. In other words, it can be defined as the ability to understand computer problem-solving methods and apply them to problem-solving processes in real life (Nadire & Jeppe, 2020; Kong et al., 2022; Lee & Cho, 2021).

3.2. Framework Collaborative Problem Solving Based on Computational Thinking Skills for Students' Scientific Creativity Skills

The design of collaborative problem-solving based on computational thinking skills is a learning model that focuses on the ability to solve a problem using a computational skill approach that is carried out together (collaboratively). Computational-based collaborative problem-solving models are developed using computational methods to organize and guide the problem-solving process in the learning process involved in the experiment. This model leverages computing and data analytics technologies to facilitate collaboration, automate tasks, and improve decision-making. This consists in breaking complex problems into simpler sub-problems, assigning roles and responsibilities, and facilitating communication and coordination among team members. This model uses algorithms and computational models to simulate various scenarios, predict outcomes, and evaluate potential solutions. The result is a more efficient, effective, and accurate problem-solving process that harnesses the power of collaboration and computing tools to deliver innovative and sustainable solutions. The computational collaborative problem-solving model is designed by considering the need for collaborative problem-solving models and computational skills, especially in scientific creativity. The basis for the development of a computationally based computational collaborative problem-solving model is presented in Table 2.

Table 2. The basis to the development of a collaborative problem-solving framework based on computational skills

Design Collaborative Problem Solving (Chen et al., 2018; Fiore et al., 2017; Cukurova et al., 2016; Graesser et al., 2017)	Computational skill (Lin et al., 2019)	*Modification Collaborative Problem Solving Based Computational*	Indicator of scientific creativity
-	-	Organizing students	-
Exploring & understanding	Abstraction	Investigating problems in study groups	Unusual Use; Science Imagination; Sensitivity of Science Problem
Representation & Formulating	Algorithm Design	Computational-based creative teamwork	Science Problem Solving; Creative Experimental
Planning & executing	Coding		
Monitoring & reflecting	Verification	Verification	Improve Technical Product; Creative Science product Design

Based on Table 2, the first stage of the computation-based collaborative problem-solving model is organizing students. This aims to build the motivation and readiness of students and their involvement at the beginning of the learning process. This is to focus students' attention before the core learning begins. Dolph et al. (2016); Fredricks et al. (2011) suggested that engagement, motivation, and learning readiness contained cognitive, behavior, and emotional criteria. An interesting course is considered important because it helps students develop an interest in a subject and provides positive experiences (Carini et al., 2006; Hidi & Renninger, 2006). Learning Motivation Theory (ARCS) emphasizes the aspects of attention relevance, confidence, and satisfaction. The purpose of the ARCS model is to provide instructions to students so that they are interested in the learning process. Giving pointers is expected to be able to have a positive influence on the achievement of the expected learning objectives.

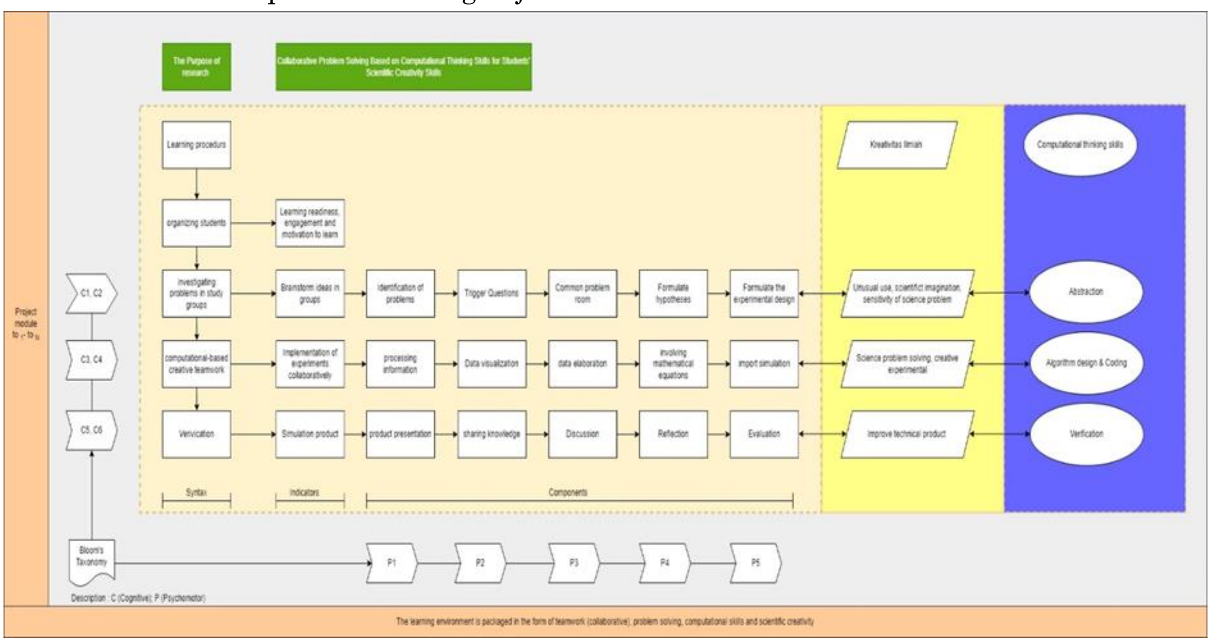

Figure 2. Framework for the effectiveness of collaborative design problem solving based on computational thinking skills

In managing students in the design of collaborative problem-solving based on computational skills, participants are directed to listen to directions from lecturers, and lecturers provide several initial simultaneous actions to build motivation and students' readiness and involvement in the learning process. The lecturer directs students to sit in the group and listen to the instructions given by the lecturer. This ARCS guides the learning process and allows lecturers to explore learning by integrating motivation into the developed institutional designs (Keller, 1999). In addition, motivation, readiness, and the involvement of students in the learning process are also the focus of attention.

Student readiness and involvement can be determined by a readiness to participate in the learning process by being present on time, listening to instructions given by the teacher, respecting each other among group mates, and having responsibility in the group. This aims to provide a sense of cooperation and mutual support for one another during the learning process. This aligns with the main principles of engagement theory developed by Kearsley & Schneiderman (1998) concerning the core principles of engagement theory, talking about students being meaningfully involved in learning activities through interactions with others and valuable assignments. In addition, lecturers provide conditional classrooms so students can work calmly and comfortably and not create stress or tension during the learning process. Vero & Puka (2017) report that constructing student motivation is essential for quality education. Vu et al. (2022) said that the influence of motivation on achievement is well documented. The general view is that there is a relationship between "motivation → achievement" and "attainment → motivation" and that motivation and achievement influence each other over time.

The next stage is the investigation of problems in the study group. This stage is modified from the exploratory and understanding model to the collaborative problem-solving model and computational skills in the abstraction component. In general, the problem investigation model in study groups accommodates the needs of the phase one model of collaborative problem-solving and abstraction. At this stage, the investigation of problems in study groups is presented through brainstorming ideas, which involves identifying problems in questions, sharing problem spaces, formulating hypotheses, and designing experimental designs. It is similar to the exploring and understanding components of the collaborative problem-solving model, which involves developing team perspectives and abilities and problem-solving collaboratively to achieve goals (Fiore et al., 2017).

Meanwhile, compound abstraction involves filtering out irrelevant details and focusing on the most important aspects of a problem to create simple models that can be used to identify patterns, develop algorithms, and make predictions. Abstraction is breaking down complex problems into simpler, more manageable components, making it easier to understand and solve problems (Mirolo et al., 2021; Çakiroğlu & Cevic, 2022). The hallmark of the second stage of collaborative problem-solving based computational skill is that students emphasize their sensitivity to their problems; students' express ideas in groups, identifying the issues they face by brainstorming and generating ideas involving creative thinking processes. Students in groups are directed to compile and convey as many ideas related to the problems faced as possible so that they can make formulations that will later be able to formulate hypotheses and design experiments with scientific imagination, sensitivity to science problems that have been improving on the consensus at the beginning.

At this stage, students are presented with ideas packaged in the form of creative idea exploration. In this stage, the lecturer gives trigger questions in the form of problem identification, which aims to build students' conceptions of prior knowledge. The initial knowledge can be from previous learning experiences or from generating a pre-existing understanding system into a thread of information packaged as a new knowledge package. Then, each member of a study group team records their understanding of the teacher's questions in a joint problem-solving session in the group room, where they present this new knowledge. Additionally, Vygotsky's theory of constructivism suggests that being given a thinking tool in the form of a question will result in cognitive development in a person. In view, using thinking tools cannot be separated from the influence of the sociocultural environment surrounding them. The emergence of various questions given by the social environment in a learning group will be increasingly complex. In this stage, students actively construct knowledge through their learning activities. The teacher acts as a mediator or facilitator in the learning process. After students as a group build the understanding provided through problem identification and joint problem solving, the next stage is for students to formulate a problem in the form of a hypothesis and an experimental design. Students synthesize the information obtained at the problem identification stage, then, in groups, present the packages of knowledge possessed by students in a group and try to formulate hopes or make an initial design of the experiment to be carried out. The teacher acts as a supervisor and facilitator during the ongoing activity process.

This aims to construct students' understanding through an information processing system by prioritizing the principles of assimilation and accommodation in the learning process. In the theory of information processing related to assimilation and accommodation, Piaget suggests that the assimilation stage is associated with the adaptation process of students to a new group environment where they develop their potential. Meanwhile, capacity refers to changes in schema according to the situation or system of new knowledge acquired. In this case, the formulation of the hypothesis and the initial design of the experiment were obtained through the stimulus in the shared space. At this stage, scientific creativity involves indicators of unusual use, scientific imagination, and sensitivity to scientific problems. Vygotsky believes that creativity emerges from every human activity that produces something new. Creative acts can make anything from physical objects to musical scores and new mental constructs. Therefore, the invention present when the main artistic, scientific, and technical discoveries Mercier & Higgens (2014) reported in their study involving 96 students that (1) one of the most important elements in creating an investigative process is creating a shared problem space associated with the use of external representations in collaborative problem-solving processes; (2) it is very important to accommodate technological needs that will be implemented in learning so that students can carry out learning effectively. Pekmez et al. (2010) reported that presenting a problem or concept through an event can help students identify a problem related to the question, provide varied responses, and lead to potential scientific creativity. During a pilot implementation of computational essays in an introductory electricity and magnetism course, students reported facilitating creative inquiry at various levels in the physics course (Oddeen & Caballero, 2019).

The results of AlMutairi's (2015) study explain that activities that begin with the brainstorming stage can help students package an appropriate, varied, and creative idea or ideas based on an atmosphere that is spontaneously open and free and does not limit freedom in submitting the ideas produced. Paulus et al. (2007) and Sophonhiranraka et al. (2015) show that the brainstorming process in problem identification can encourage students to develop the ideas presented based on the concepts obtained. Santrock (2007) and Arends (2012) write that students can construct understanding independently if it is increased through social interaction between students and lecturers, where students are asked questions to explore their prior knowledge. Contextual presentation of problems related to daily activities can help improve students' scientific creativity (Siew et al., 2015).

The next stage is computation-based creative teamwork. At this stage, students will do experiments that involve computing. The stages are modified from the settings of the collaborative problem-solving model and the computational approach with the processes of exploring, understanding, planning, and executing. At this stage, the two steps in collaborative problem-solving are simplified into computation-based creative teamwork focused on carrying out collaborative experiments consisting of components of information processing, data visualization, elaboration, and manipulation up to the final stage of the resulting simulation. At this stage, it generally has a description similar to collaborative problem-solving, namely building and sharing representations, building negotiations, building communication in solving problems, identifying and compiling assigned tasks, organizing teams in the involvement process, and implementing plans (Fiore et al., 2017). At this stage, computational-based creative teamwork involves solving problems built through negotiation, communication, and problem-solving skills involving mathematical equations to achieve consensus on the expected simulation product. This aligns with the computational model process's coding design algorithm component. The algorithm design stage involves creating instructions that a computer or machine can follow to solve a particular problem. At this stage, the problem is broken down into smaller and more manageable components to make it easier to solve (Lee et al., 2022). The hallmark of this stage is that activities involve information processes carried out collaboratively in problem-solving. At this stage, the involvement of scientific problem-solving and creative experimentation is a complete concern in the implementation process.

Dual Coding Theory is one of the theories that underlie this stage. According to this theory, we use two types of mental codes to represent information: verbal and nonverbal.

Verbal codes are based on language and describe data in a linguistic form. On the other hand, nonverbal codes are images, sounds, or different sensory experiences used to convey information in a visual or auditory form. The theory states that multiple coding methods are more effective than using only one type of code. When data is processed in both verbal and nonverbal codes, it leads to better understanding and retention. Furthermore, another supporting theory is the Positive Dependence Principle: Positive Addiction Theory has important implications for how we interact with others personally and professionally. Recognizing the importance of interdependence and cooperation can build stronger relationships and foster a more positive and supportive environment. Chen & Lo (2019) and Mumford (2012) state that learning in the form of collaborative creativity has a positive impact on students' scientific and creative abilities. Computational experiments provide an important tool for students to implement inquiry-based scenarios (Psycharis, 2013). The affordability of the agent-based computer model and visualization used in this study in conjunction with a series of LH structure learning activities was found to help students build an understanding of the physics of electricity concepts compared to students who used the same model and completed the problem using the order of the HH structure (Jacobson et al., 2015). In a study, Huang et al. (2012) reported that collaborative creativity learning can help students practice scientific and creative abilities. Cocu et al. (2015) and Ersoy (2014) said in their study that scientific creativity with collaborative use in the learning process could increase student activity in recreation and improve work results, especially concerning creative product design, science imagination, and engineering products.

Lecturers can adapt the findings of this research to consciously train teams in collaborative learning processes and guide them to reach a consensus to achieve the goal of fostering creative thinking in digital technology-enabled courses. In particular, teachers should help students participate in collaborative group learning in an accessible way. Collaborative learning environments can improve students' collaboration skills in group problem-solving to grow student flexibility (Hu et al., 2022). The team-group environment can improve students' collaboration skills in solving problems in groups (Burns et al., 2014; Rogat et al., 2011); group learning is proven to be able to increase student creativity (Bettoni et al., 2015; Cocu et al., 2015; Laisema & Wannapiroon, 2014). All sessions are designed according to the principles of constructivism to concretely bridge abstraction and reality, making students use problem-solving strategies and creativity to achieve learning outcomes. To reinforce theoretical explanations of algorithm design, problem-solving, coding, and robotics concepts and to boost student engagement, practical assignments follow the theoretical explanations. Some studies are carried out individually throughout the training, but in most studies, we encourage student collaboration to ensure ongoing engagement (Ozmutlu et al., 2021). Keith et al. (2019) report that the emergence of different roles correlates with periods of collaboration impacting students' engagement in computational thinking, including solution planning, algorithmic operations, debugging, and robotic design. Scientific creativity concerns interaction in understanding a problem, formulating and testing hypotheses, making an experimental design, finding solutions, simplifying a problem, and evaluating and developing a conclusion (Lin, 2011; Usta & Akanat, 2015).

The next stage is verification. At this stage, it is simplified from the reflecting and monitoring stage. At the verification stage, it is packaged in the form of knowledge sharing through discussions and presentations related to the resulting simulation products. Similar to verification at the computational skills stage, this stage deals with analysis regarding the suitability of the stages prepared with the expected results. Confirmation at this stage is packaged in the form of product appearance, which has been designed by each group based on the student worksheet that has been given. Each group describes the achievements and obstacles that arise during the process, and at the end of this stage, the lecturer will provide feedback in the form of a brief explanation of the principles and methods. At this stage, the lecturer will provide input related to the simulation products provided and improvements. At this stage, the main characteristics are improved technical products and creative science product design. The final stage of this series of products is the evaluation stage, which relates to the assessment of each product produced. The cognitive-social theory is one of the reinforcing theories at this stage. It refers to the dynamic and reciprocal interactions between people (individuals with a set of learned experiences), the environment (external social context), and behaviour (responses to stimuli to achieve goals)—behavioural Ability: A person's ability to perform behaviour through essential knowledge and skills. Moreover, "self-efficacy refers to the degree of belief a person has in his ability to carry out a behaviour successfully.

In addition to these two fundamental theories, situated learning theory is one of the points of consideration in this design. This theory emphasizes the importance of learning in a specific context, such as a collaborative problem-solving environment. Assessment can provide feedback on the collaborative process's effectiveness, helping participants reflect on their learning and refine their problem-solving strategies (Lave & Wenger, 1991). Hesse et al. (2015) reported that joint problem-solving activities would be successful if group members could share solutions presented in various representations in other groups. Osborne & Dillon (2008) and Ulfa et al. (2021) reported that competitive theory could build students' understanding by discussing two or more alternative ideas about data phenomena. Scientific creativity is related to individual and social insights in solving a scientific and technical problem innovatively and productively. Dillenbourg & Traum (2006) reported that sharing solution activities in the form of elaborating scientific ideas was used to improve the quality of projects. Li et al. (2022) said that further exploration of concepts related to scientific ideas effectively provides adequate quality. Kan & Gero (2008) state that our intelligence and creativity result from the interspace.

4. Conclusions

Collaborative problem-solving-based computational thinking skills can change the learning paradigm to focus on students' scientific creativity. In the learning model, collaborative problem-solving-based computational thinking skills have great potential in terms of learning effectiveness; this is based on simplified learning design patterns with various potential aspects, in particular: (1) Group Structure: Collaborative problem-solving-based computation requires a clear group structure consisting of individuals who have different skills and knowledge. This group structure should support the formation of practical cooperation and collaboration. (2) Individual Involvement: Each individual in the group must be actively involved in the problem-solving process. Establishing meeting schedules, identifying each group member's responsibilities, and ensuring that each member has the chance to speak and contribute will help achieve this. (3) Communication and Collaboration: Interpersonal communication and collaboration are important for collaborative problem-solving-based computational thinking skills. In the learning process, Groups have effective means of communication, such as video conferencing or online collaboration platforms, to facilitate discussion, the exchange of ideas, and information sharing. (4) Joint Learning: Collaborative problem-solving-based computational learning also emphasizes the importance of group-shared learning. Individuals in groups can learn from each other's experience and knowledge to improve their ability to generate and brainstorm ideas. (5) Lecturers or teaching staff act as facilitators and mediators in the implementation process and the learning process in the form of student center learning.

Several things need to be considered when implementing a design of collaborative problem-solving-based computational thinking skills in the learning process: (1) Active Individual Involvement: Collaborative problem-solving based on computation requires the active involvement of each individual in the group. This includes participation in discussions, problem-solving, and decision-making. (2) Clear Division of Tasks: Each individual in the group has clear responsibilities and tasks in solving problems. A clear division of tasks can help avoid overlapping and optimize time use. (3) Collaboration and Knowledge Sharing: Computational collaborative problem solving based on promoting collaboration and sharing of knowledge between individuals in groups-this can help increase understanding of the problem at hand and broaden individual perspectives within the group

In terms of practical implications, the current framework provides specific guidance on how teachers and instructional designers can apply collaborative problem-solving-based computational thinking skills using scientific creativity approaches. This framework also serves as a design for how teachers can produce well-designed collaborative problem-solving learning designs based on computational thinking skills because the framework is simple, usable, and flexible in the context of higher education.

Overall, the conceptual framework proposed in this study is considered preliminary. Therefore, it is highly recommended that future researchers conduct further research to investigate its effectiveness

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