

GENERATING SCIENTIFIC CREATIVE IDEAS IN CASE-BASED BLENDED LEARNING THROUGH DIGITAL MIND MAPPING: A CASE STUDY IN STATIC FLUIDS

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ABSTRACT

One of the methods in blended learning is case-based learning, which focuses on problem-solving through analyzing real case studies. This research aims to generate creative scientific ideas through creative scientific assignments by implementing Case-Based Blended Learning supported by Digital Mind Mapping. This exploratory research examines how Science Education students engage in tasks designed to generate scientific creativity with technological support, specifically how they generate ideas in small groups through applying relevant thinking strategies, communicating socially, and building creative ideas based on digital mind mapping. Is there a difference between high- and low-performing groups in the idea-generation process, and if so, what is the difference? Digital Mind Mapping was used to facilitate group thinking. Participants consisted of 16 3rd semester students working in 4 groups on a series of scientific creativity tasks. All categories emerged in the conversations, although the frequency of occurrence varied. Compared to the low-performing group, the high-performing group engaged more in divergent thinking, use of digital mind mapping, and regulative discussion, and associated these activities more closely with the idea development process. These findings have implications for the design of technology-based educational interventions that aim to encourage and enhance group creativity in science education.

Keywords: Blended learning, case-based learning, digital mind mapping, scientific creativity, creative idea generation.

INTRODUCTION

The development of digital technology has driven major changes in education, especially in learning approaches. Blended learning, which combines traditional teaching methods and digital technology, is gaining popularity due to its flexibility and ability to enhance student interaction. One of the main objectives of this educational model is to develop critical and creative thinking skills, especially in scientific

fields that require innovation. In this context, case-based learning and digital mind mapping offer promising solutions. Mind mapping, which allows students to organize and visualize ideas, aids the creative thinking process, while case-based learning encourages problem solving through analytical and practical approaches. This paper will discuss how the integration of digital mind mapping in case-based learning can be a catalyst for generating scientific creative ideas.

Mind mapping was first introduced by Tony Buzan as a method to visually map thoughts and ideas. The technique has been shown to enhance creative and critical thinking skills by helping individuals understand the relationships between seemingly unrelated concepts (Davies, 2011). At the same time, case-based learning has long been recognized as an effective method in enhancing problem-solving and critical analysis skills across multiple disciplines, including science education (Williams, 2018). The use of digital mind mapping has been recognized as an effective tool in facilitating active learning, allowing students to better explore and organize information (Chiou, 2012). However, research combining these two approaches, especially in the context of generating scientific creative ideas, is still limited. A study by Dini et al. (2022) emphasized that the integration of digital technology in case-based learning can help students understand complex concepts better. They noted that by using digital mind mapping tools, students can more easily visualize problems, make new connections and develop innovative creative solutions. This study shows the great potential for digital mind mapping in stimulating students' creativity, especially when used in the context of case-based learning.

Digital mind mapping is now widely used in various fields of education to enhance learning, especially in terms of organizing knowledge and visualizing relationships between concepts. In science education, for example, mind mapping has been used to make it easier for students to understand and visualize complex scientific processes, such as biological systems or chemical mechanisms (Farrand, 2021). In addition, digital mind mapping tools enable interactivity and collaboration, so students can work together to solve problems, share ideas, and build solutions together.

However, although the use of digital mind mapping has improved information retention and concept understanding, most studies have focused on cognitive aspects and have less explored how this tool can directly stimulate scientific creativity. For example, Huang et al. (2023) found that the use of mind mapping assisted students in connecting existing ideas, but the study did not examine how it affected the process of creative new idea generation. Therefore, more research is needed that explores the relationship between the use of digital mind mapping and the ability to generate innovative solutions in the context of scientific learning.

Although digital mind mapping and case-based learning have been shown to improve critical thinking skills and problem-solving ability, research focusing on the generation of scientific creative ideas through the integration of these two methods is limited. Previous studies have mostly focused on the cognitive aspects of learning, such as improved understanding and retention of concepts, without looking at how these digital tools can foster creativity. For example, research by Yang et al. (2021) showed that mind mapping helps students remember information better, but did not explore in depth its impact on creativity in finding new scientific solutions. One gap that needs to be bridged is how digital mind mapping can be utilized to stimulate creative new ideas, especially in the context of case-based learning that encourages students to deal directly with real-world problems. Creativity is a skill that is increasingly needed in today's scientific world, especially to face complex global challenges such as climate change, health and technology. However, most current research only addresses ways to improve analytical skills, without giving enough attention to the development of creativity in scientific education.

Most students have low levels of creative thinking skills. Their thinking is still trial and error, unsystematic, not detailed, and faces many obstacles in solving problems and compiling problem-solving steps (Hasanah, 2019). According to Zubaidah, et al. (2018), the average score of students' creative thinking skills is only 23.44 out of 100. Another study showed that the score of students' creative thinking skills in learning only reached 34 out of 100 (Rahman & Fitriani, 2020). Based on research by Hakim, et al. (2020), students' scores on creative thinking aspects were 34.22 (fluency), 40.96 (flexibility), 34.33 (elaboration), and 35.45 (originality). Science is a discipline that requires creativity to discover and formulate new problems and generate diverse ideas and solutions. However, the development of creativity in generating diverse ideas

or solutions is often neglected in science education (Runco & Acar, 2012). In this study, students were encouraged to generate scientific creative ideas through the application of a series of divergent thinking strategies, namely association (linking seemingly unrelated things), decomposition (breaking down details by decomposing the whole into parts or listing attributes to trigger different perspectives), and combination with adjustment (combining and/or changing) (Craft, 2011).

The process of generating creative ideas involves complex dimensions. First, creative idea generation is primarily a higher-order cognitive process that focuses on divergent thinking (Guilford, 1967). Second, idea generation often involves social processes, as creativity is a phenomenon that often arises in collaboration (Sawyer, 2012). Third, cognitive and social thinking processes can be aided by technology, particularly visual representation tools such as computer-based mind mapping (Buzan, 2006). This multidimensional process of idea generation is complex yet essential to the performance of creativity.

However, research on how university students perform scientific creativity tasks through creative thinking and social communication with technological support is limited (Zhou, 2015). In addition to analyzing the idea-generation process, it is important to improve the process by investigating the characteristics of a productive idea-generation process, which can result in good performance in scientific creativity tasks (Amabile, 1996). Creativity, defined as the ability to generate appropriate new ideas or solutions, is considered one of the key factors in driving the progress of civilization (Runco, 2004). In addition, creativity is recognized as an essential skill of the 21st century (Trilling & Fadel, 2009). The literature suggests that creativity is a multifaceted phenomenon involving various aspects, including process (e.g., cognitive processes in generating ideas), product (e.g., creative objects or solutions), person (e.g., creative personality characteristics), and pressure (environmental factors that encourage or inhibit creativity) (Rhodes, 1961).

Purpose of the Study

The integration of digital mind mapping into case-based learning in a blended learning environment offers a potential new approach to encourage scientific creativity. The combination of the visualization and organization of ideas offered by digital mind mapping, as well as the analytical approach of case-based learning, provides a space for students to not only develop critical thinking skills but also generate innovative creative ideas. The novelty of this approach lies in its specific focus on combining these two methods in the context of generating creative scientific solutions, which has previously been less discussed in the literature. This study offers a new outlook on how digital technology can be utilized to promote creativity in science education, which in turn can help produce innovative thinkers in the future.

LITERATURE REVIEW

Case-Based Blended Learning Model Assisted by Digital Mind Mapping

Education today involves traditional, ICT-based, and cognitive perspectives in learning and teaching. Blended learning is not a strictly defined concept. Some consider blended learning to refer to the combination of educational program modules, such as lectures, seminars, or tutorials, with access to multimedia learning resources, tests, learning tools, as well as collaboration and assessment tools that are not tied to a learning management system (Eko Risdianto, 2022; Yang et al., 2024). However, others tend to include an emphasis on blended learning as part of their broader definitions (Lin et al., 2024; Tambak & Sukenti, 2024). The rapid advancement of technology for teaching and learner autonomy is evident, but few possess efficient methods to integrate the new with the old, facing numerous challenges in the teaching process. Case-based blended learning can have positive effects in addressing these issues. This pedagogical approach promotes contextualised learning and encourages group work. Group work stimulates assessment through various evaluation techniques, enhances learning and active student participation, and generates new knowledge (Tran & Herzig, 2023; Yu et al., 2021).

Case-based learning has emerged as a prominent instructional strategy in science education in recent years. In its basic form, this strategy involves presenting real-world scenarios in the classroom that reflect the operational characteristics of a specific domain (Pando & Aguirre-Munoz, 2021). Students are typically tasked with

challenging, problem-solving, offering solutions, and ultimately providing justifications for their solutions based on the learning acquired in class (Gronski, 2024; Wijnia et al., 2024). This teaching-learning procedure, oriented towards theoretical understanding through practical application, also supports creative problem-solving, a high level of inquiry, and self-organization, as well as the development of constructive critical thinking skills, comparison, usage, conceptual modification, and application (Lee et al., 2023; Tayce et al., 2021). This strategy is defined as case-based learning and case-based instruction. A case study is a description and analysis of a real administrative situation (Dong et al., 2022). Some situations are complex and multifaceted, requiring graphical representations and explanations, as well as solutions in the form of bullet points. Although contextual analysis of cases with deficiencies allows students to consider whether processes and actions can be altered, the result of the case study may take the form of a report (Agrawal et al., 2023).

Case-based blended learning is a learning model that combines face-to-face learning with digital technology and uses case studies as the main tool in the learning process (Duckwitz et al., 2021). This model has shown various benefits in the context of higher education, especially in improving students' analytical and collaborative skills (Zheng and Mavis2023). Blended learning is an approach that combines traditional learning with online learning, providing flexibility in access and learning methods (Xu et al., 2024; Garrison & Vaughan, 2008). In a case-based context, this method utilizes real case studies to connect theory with practice, allowing students to apply their knowledge in real-world situations. According to research published in the International Journal of Designs for Learning, case-based learning in a blended format can increase student engagement and deepen their understanding of the material (Chen, 2024; Wilson & Stacey, 2004). This study shows that the use of real cases in learning helps students develop critical and analytical thinking skills, as they are required to analyze, synthesize and evaluate complex information.

The integration of technology in case-based learning can improve teaching effectiveness by providing digital mind mapping that supports interaction between students. Despite its many benefits, case-based blended learning also faces some challenges. One of the main challenges is ensuring that all students have equal access to technology and can utilize it effectively (Wu et al., 2023; Means et al., 2013).

To strengthen the research findings, we included the course design process for blended learning that impacts scientific creativity. The following steps were identified in the document:

1. *Selection of Divergent Strategies:* The blended course was designed to introduce divergent thinking strategies such as association, decomposition, and combination with adjustment. These strategies were explained through direct lectures and supported by illustrative examples.
2. *Utilization of Computer-Based Mind Mapping Tools:* A web-based mind mapping tool was provided to students, enabling them to visualize and organize ideas collaboratively. This tool served as a shared space for group reflection and discussion management.
3. *Integration of Group Communication:* Dialogic learning was introduced to encourage open communication and collaboration. Principles such as active listening, respecting ideas, and building on others' contributions were integral to the training.
4. *Practice on Scientific Creativity Tasks:* Students were given tasks such as generating ideas for scientific creative solutions, using the mind mapping tool, and applying divergent strategies in small groups.
5. *Course Process Arrangement:* The course began with an introductory session on the concept of creativity, followed by training in divergent thinking skills, group interaction, and the use of digital tools.
6. *Strengthening Through Reflective Discussion:* Students' regulation and reflection processes were monitored to ensure optimal understanding and application of creative strategies in a scientific context.
7. *Importance of This Process:*
 - a. *Enhancing Divergent Thinking Skills:* Strategies like association, decomposition, and combination help students discover new perspectives and generate innovative solutions.
 - b. *Facilitating Collaboration Through Technology:* Mind mapping aids students in retaining ideas, stimulating further discussions, and effectively managing discussion processes.
 - c. *Building Scientific Creative Thinking:* The course creates a learning environment where students can develop science-based problem-solving skills through collaborative approaches.

Idea Generation Through Divergent Thinking-Cognitive Processes

Idea generation involves a high-level cognitive process, namely creative thinking or cognition, which can be characterized by two main stages: (1) divergent thinking, i.e. generating a wide variety of ideas or solutions, and (2) convergent thinking, i.e. selecting the most creative idea or solution (Sun et al., 2022). The two stages are not completely separate but integrated. Research reveals that generating ideas through divergent thinking is more difficult than evaluating and selecting ideas through convergent thinking; the ability to think divergently is essential for creativity and is considered a reliable predictor of creativity (Dumas et al., 2021; Sa'idah & Isnawati, 2020). Therefore, creativity assessment focuses on divergent thinking ability, which is often measured in terms of fluency (generating many ideas), flexibility (generating a wide variety of ideas), and originality in generating unusual ideas (Sun et al., 2022). Therefore, this study focuses on divergent thinking in analyzing the cognitive process of idea generation.

Divergent thinking requires thinking “outside the box” to explore new alternatives. However, the process remains complex and inaccessible to most people. According to Nijstad and Stroebe (2006), the cognitive processes underlying divergent thinking involve activating knowledge in long-term memory and then processing that knowledge to generate ideas. Previous research has proposed various mental operations or strategies to encourage divergent thinking. For example, drawing from memory and associating seemingly unrelated concepts or objects can lead to new ideas (Gilhooly, Fioratou, Anthony, & Wynn, 2007). Analogy can be used as a way to bridge the application of existing knowledge or strategies into new and unrelated contexts (Hu et al., 2013; Welling, 2007). Random stimuli that are irrelevant to the given problem can be used to evoke unexpected knowledge connections (Malycha & Maier, 2017). Dividing something into smaller parts or independent properties can stimulate new directions of thought (Ross, 2006). In addition, new ideas can be generated when rearranging or reorganizing parts of a problem, replacing objects with other formats that fulfil the same function, adjusting or distorting attributes of a problem, or using something for a new purpose (Welling, 2007). Furthermore, brainstorming is recommended to gather different ideas from a group of people (Sawyer, 2017). These studies have proposed various strategies for divergent thinking, which is essential for creative thinking. To help college students master the core elements of divergent thinking, Sun, Wang, & Wegerif (2020) summarised a set of strategies or key elements of divergent thinking, namely association - associating seemingly unrelated concepts, objects, or situations (COS), decomposition - decomposing COS into rich details by breaking the whole into parts or by listing the attributes of COS to stimulate a variety of diverse views and combination with adjustment - combining and/or changing COS. The approaches proposed in this research have been applied to empirical studies on creativity training and have shown promising potential to improve idea generation performance (Sun et al., 2020; Meinel, Wagner, Baccarella, & Voigt, 2019; Ritter & Mostert, 2017). However, how learners apply these strategies to generate ideas has not been adequately researched.

Idea Generation Through Group Communication-Social Processes

Idea generation also involves social processes as creativity is often considered a social or collaborative phenomenon ((Sun et al., 2022; Harvey, 2013; Sawyer, 2017). In many cases, great innovations are the result of group work, and social judgment plays an important role in developing creative products (Gla'veanu, 2018). Research shows that group creativity can be influenced by various factors such as the nature of the task (e.g., task complexity), group composition (e.g., size, skills, background diversity), group processes (e.g., sharing, negotiation), and contextual factors (e.g., social environment) (Paulus, Levine, Brown, Minai, & Doblin, 2010). Among them, the group process, i.e., the process of group communication and interaction, is considered to be the determining factor of group creativity.

Creativity in groups is more complicated than creativity at the individual level due to the complex dynamic nature of human communication. Group creativity is rarely achieved by simply bringing individuals together. Research shows that in a group context, each member can bring unique knowledge, which allows the group to expand its knowledge base for idea generation (Harvey, 2013). Group communication can also increase opportunities to discover less accessible knowledge, which in turn can stimulate more ideas or associations (Brown, Tumeo, Larey, & Paulus, 1998). In addition, exposure to the ideas of others tends to stimulate the generation of diverse ideas (Nijstad & Stroebe, 2006). Members may be stimulated differently by the same viewpoint as a result of different individual memory structures, from which diverse ideas tend to emerge.

On the other hand, some studies report that team collaboration, compared to individual work, may reduce the quantity and quality of output due to several factors such as production inhibitors, social barriers, and procedural issues (Mullen, Paulus et al., 2010). For example, group members may be reluctant to express their ideas for fear of peer evaluation; a situation where group members have to take turns to express ideas may make them forget their own ideas or decide not to express them; moreover, it may cause a high cognitive load for individuals to pay attention to others' perspectives and simultaneously generate their own ideas (Chen, Liu, Yuan, & Cui, 2019; Oztop, Katsikopoulos, & Gummerum, 2018). When group division is fixated on a few specific categories of ideas, it can inhibit divergent thinking (Brown et al., 1998). In addition, when there is a high level of conflict, group members have to spend extra time managing differences, which in turn inhibits group creativity (Harvey, 2013). With respect to unproductive group processes, researchers have identified some group communication patterns that can lead to productive teamwork in creativity tasks, such as paying attention to others' contributions, building shared understanding, taking a shared perspective, and building on others' ideas (Paulus et al., 2010). Paying attention to others' ideas can increase the opportunity to create new combinations, help raise questions and disagreements, trigger new ways of looking at a problem, and bring changes to the current trajectory to avoid fixation of the mind (Mercer & Dawes, 2008). The process of developing shared understanding or taking a shared perspective, where group members elaborate and appreciate diverse perspectives and integrate individual knowledge (Lim, Shelley, & Heo, 2019). During the process, building on ideas from others is essential for group creativity, especially when individuals find it difficult to identify new search cues by utilizing their own knowledge (Kohn, Paulus, & Choi, 2011). Related research can also be found in studies of the "exploratory talk" mode, which creates a shared space for reflection where open questions and conflicting perspectives arise and where creativity is sparked (Mercer & Dawes, 2008).

While there are many frameworks to analyze group discourse in collaborative activities, few studies have proposed frameworks to analyze group creativity. Tan and colleagues (Tan, Caleon, Jonathan, & Koh, 2014) proposed a dialogical framework to assess collective creativity in computer-supported collaborative problem-solving tasks, which involved a set of categories to code convergence data in metacognitive (e.g., regulation), cognitive (e.g., solution generation), and socio-communicative dimensions (e.g., questions, responses). Another coding scheme proposed by Hawlina, Gillespie, and Zittoun (2019) focuses on perspective-taking behaviors, which include seeking perspectives (e.g., idea-related questions), sharing perspectives (e.g., thinking aloud, providing explorations), and negotiating perspectives (e.g., agreeing, disagreeing). However, the schemas do not involve dimensions related to the application of divergent thinking strategies and relevant technologies. Therefore, they are inadequate for analyzing group processes involving divergent thinking strategies and computer-based tools used to facilitate idea generation.

Thus, the generation of scientific creative ideas can be done through divergent thinking, social communication, and the use of computer technology, namely by working on scientific creative tasks that are done in groups by creating digital mind maps.

Technology to Facilitate the Idea Generation Process

Idea Technological advances have provided new opportunities to support creativity and idea generation. Research has found that computer-based communication systems can support group brainstorming and idea generation by enabling the simultaneous and anonymous contribution of ideas and pictorial stimuli (Sun et al., 2022; Ahmed, McGahan, Indurkha, Kaneko, & Nakagawa, 2021). Some interactive technologies are used to encourage group creativity in classrooms. For example, Pifarre (2019) found that interacting with digital shared spaces can enhance co-creative processes, such as combining ideas, evaluating ideas, and bringing ideas into reality. These tools focus on group communication and interaction and have shown promising effects in facilitating group creativity and idea generation.

Moreover, the process of generating ideas through divergent thinking involves complex cognitive processes, which tend to be silent and inaccessible to many. To facilitate complex cognitive processes, researchers have explored the application of visual representation tools such as maps, graphs, and diagrams to make thinking clearer (Sun et al., 2022; Malycha & Maier, 2017). Mind maps that allow people to visually represent ideas and the relationships between them in diagrams are a widely recommended technique to support idea generation (Sun et al., 2022; Abi-El-Mona & Adb-El-Khalick, 2008). A mind map is often built around a

main concept, where the main ideas are directly linked alongside other ideas that branch out from the main ideas. Mind maps can be created using computer-based tools or paper and pencil (Falloon & Khoo, 2014). Mind maps can provide rich details of a problem situation to stimulate creative cognition by connecting different ideas and spreading activation on a freely created map (Sun et al., 2022; Malycha & Maier, 2017). Such visual representations can reduce cognitive demands on people by utilizing the brain's capacity to quickly manipulate visual images (Santanen, Briggs, & De Vreede, 2004). Furthermore, such representations can facilitate group thinking and social communication of complex ideas (Gla˘veanu, 2018). They work as a shared space that allows group members to communicate ideas, decipher differences, build shared understanding, construct ideas, reflect on group thinking, identify shortcomings, and reach collective solutions, thus encouraging intensive discussions for high-quality ideas.

Scientific Creativity in Science Education

Idea Creativity can be applied to various fields (e.g., art, architecture, science, and technology) and this research focuses on scientific creativity. Science is a discipline that requires creativity to discover and formulate new problems, generate various ideas, and seek solutions (Summers et al., 2019). Previous research on stimulating students' scientific creativity focused on developing science inquiry and problem-solving skills (Astutik & Prahani, 2018; Yang, Lee, Hong, & Lin, 2016). Students are encouraged to learn by exploring real-world problems through collecting data and evidence of the problem, making scientific reasoning with interrelated variables, and formulating and justifying hypotheses to reach conclusions. In addition, students are encouraged to work together on inquiry or problem-solving tasks to develop their collaboration and communication skills which are an essential part of authentic scientific practices (Jeong, Hmelo-Silver, & Jo, 2019). These skills are essential for developing scientific solutions to real-world problems or authentic tasks, which, however, are not enough to generate diverse ideas or solutions. For example, Yang et al. (2016) developed an instructional approach to promote creative thinking among elementary school students in an inquiry-based learning context. This approach focused on questioning, planning, implementation, inference, and reporting, as well as the use of strategies to encourage openness. They found that this approach helped students to improve their performance in science inquiry and convergent thinking but not in divergent thinking.

Previous research shows that divergent thinking significantly contributes to creative performance in science (Huang, Peng, Chen, Tseng, & Hsu, 2017; Paek, Park, Runco, & Choe, 2016). Creativity through divergent thinking not only concerns diverse ideas or solutions to solve a problem but more importantly the creation of a new problem or the development of a new understanding of the problem from multiple perspectives (Basadur & Basadur, 2011). As mentioned above, science is a discipline that requires creativity to discover and formulate new problems and generate various ideas, in addition to finding solutions.

PROBLEMS STATEMENT

The problems in this study are, first, how students engage in group discussions to generate ideas in completing scientific creativity tasks by applying the Case-Based Blended Learning model through divergent thinking and creating digital mind mapping in small group discussions. Second, is there a difference between high- and low-performing groups in the idea-generation process, and if so, what is the difference?

Rationale of This Study

Various strategies for divergent thinking, which is essential for creative thinking. To help college students master the core elements of divergent thinking, Sun, Wang, & Wegerif (2020) summarised a set of strategies or key elements of divergent thinking, namely *association* - associating seemingly unrelated concepts, objects, or situations (COS), *decomposition* - *decomposing* COS into rich details by breaking the whole into parts or by listing the attributes of COS to stimulate a variety of diverse views and *combination with adjustment* - combining and/or changing COS. The approach proposed in this research has been applied to empirical studies on creativity training and has shown promising potential for improving idea generation performance (Sun et al., 2020; Meinel, Wagner, Baccarella, & Voigt, 2019; Ritter & Mostert, 2017).

Tan and colleagues (Tan, Caleon, Jonathan, & Koh, 2014) proposed a dialogical framework to assess collective creativity in computer-supported collaborative problem-solving tasks, involving a set of categories to code convergence data in metacognitive (e.g., regulation), cognitive (e.g., solution generation), and socio-communicative dimensions (e.g., questions, responses). Another coding scheme proposed by Hawlina, Gillespie, and Zittoun (2019) focuses on perspective-taking behaviours, which include seeking perspectives (e.g., idea-related questions), sharing perspectives (e.g., thinking aloud, providing explorations), and negotiating perspectives (e.g., agreeing, disagreeing).

Technological advances have provided new opportunities to support creativity and idea generation. The research found that computer-based communication systems can support group brainstorming and idea generation by allowing simultaneous and anonymous contribution of ideas and pictorial stimuli (Ahmed, McGahan, Indurkha, Kaneko, & Nakagawa, 2021). Some interactive technologies are used to encourage group creativity in classrooms. For example, Pifarre (2019) found that interacting with digital shared spaces can enhance co-creative processes, such as combining ideas, evaluating ideas, and bringing ideas into reality

METHOD

This research is an exploratory study that aims to investigate how Science Education students engage in computer-based lecturer mind-mapping tasks in case-based blended learning. The first issue is how students use technology to generate scientific creative ideas, specifically how they generate ideas in small groups through applying relevant thinking strategies, communicating socially, and using digital mind mapping-based constructs. To answer these two questions, conversations between students, and members of discussion groups during the assignment in Case-Based Blended Learning assisted by Digital Mind Mapping were recorded and transcribed to analyze the process of developing scientific creative ideas. The second issue is whether there is a difference in the generation process between high and low-performing groups, and if so, what is the difference?

Participants

This study was conducted in the Science Education program at Universitas Negeri Surabaya, Indonesia. The participants were 16 third-semester students (4 males and 12 females) aged 19–20 years from a regular class. Before participating in this study, the students had acquired basic scientific knowledge relevant to the assigned tasks (e.g., Pascal's law, Archimedes' principle, and their applications) from their Fundamental Physics course. However, they had no prior training in creative thinking or mind mapping. The participants were randomly assigned to four groups, with four members per group. The study was approved by the Human Research Ethics Committee of the university where the researchers are affiliated. Participation in the study was voluntary, and all students signed consent forms before the study. The participants were asked to generate ideas in response to a series of scientific creativity tasks. These tasks were adapted from the Scientific Creativity Test developed by Hu and Adey (2002), which includes a series of creativity tasks within the science domain.

Group Task Performance

Two domain experts evaluated student responses to four creativity tasks, the first author and a science education lecturer with nine years of teaching experience. Both were trained to assess responses based on three dimensions: fluency (the number of relevant ideas generated), flexibility (the number of different categories represented in the responses), and originality (the uniqueness of responses based on statistical rarity, i.e., the probability of each idea in the total response pool). The scientific creativity score of a group was calculated by summing the scores across these three dimensions. Based on the overall scores, high-performing (HPGs) and low-performing groups (LPGs) were identified. Regarding originality assessment, Reiter-Palmon et al. (2019) noted that frequency-based methods could be less accurate with small sample sizes due to the difficulty of identifying equivalent responses. In this study, the two raters first reviewed all group responses to reach a consensus on adequate and non-redundant responses. These responses were then integrated into a larger dataset from prior research to estimate frequency. To assess flexibility, the raters also referred to a comprehensive response pool encompassing all possible categories. The assessment process achieved a very high level of inter-rater reliability, as evidenced by intraclass correlation coefficient (ICC) analysis using a two-way random effects model with single measures ($ICC = 0.998, p < 0.001$).

Data Collection

The data collection and categorization stage include several activities, namely: a) Collecting data through group discussion history in the Basic Physics course, b) Filtering sentences and words from the conversation history, and c) Categorizing the data. There is a proportion of contributions that reflect the strengths and weaknesses (based on sentiment: positive or negative) of each student in the group, according to the 'contribution category' set by the lecturer in the assessment rubric, for example in this scientific creativity task scenario. Group organization can be flexible depending on mutual agreement. Therefore, a model that represents the grouping is needed. At this stage, the categorization of each group member's utterances is obtained, where each sentence can be categorized as divergent thinking behaviour, social communication, development of new ideas, use of instructional technology mind mapping, and metacognition.

The Procedures

This study took place over two days (Sun et al., 2022). On the first day, the researcher provided feedback on introductory materials on the basic concepts of scientific creativity, creative thinking, creative mindset, and completing creativity tasks using digital mind mapping to students for 50 minutes. One week earlier, this basic concept material was also uploaded to the Learning Management System (LMS), so that students could study online anytime and anywhere based on the lecturer's direction. After that, students did four real cases as scientific creativity tasks related to static fluid material individually for 30 minutes as an initial exercise. On the next day, students attended a 100-minute face-to-face training on divergent thinking, Canva app-based digital mind map creation and group interaction. First, they received a 40-minute lecture using real cases on various divergent thinking strategies, namely association, decomposition, and combination with customization. Second, they were taught how to use digital mind mapping (Canva app) to create mind maps for 20 minutes, with the trainer demonstrating the basic use of the app.

In addition, the trainer provided guidance and examples of the application of divergent thinking strategies in making mind maps. After the training, students were given 20 minutes to familiarize themselves with the digital mind map tool. Third, students received a 20-minute lecture on group communication and interaction based on dialogical theory (e.g., equal participation, openness, listening carefully, valuing every idea, encouraging and interacting with others' ideas, suspending judgment, and avoiding personal criticism). During the training, the trainer asked students to complete 4 creative scientific tasks on real cases within 50 minutes through group discussions. Fourth, is the evaluation stage, where the lecturer gives feedback and evaluation on the results of the training.

Data Analysis

Coding of Group Conversations

Group conversations were recorded, transcribed, and analyzed in Indonesian. For the purposes of presentation in this article, selected examples of group conversations or episodes were translated into English. All conversations were then segmented into smaller units for more detailed analysis. Since existing coding schemes from previous literature did not fully capture the characteristics of student conversations during idea generation in response to creativity tasks, a new approach was required. We developed a coding scheme based on grounded theory, which allows codes to emerge inductively through systematic data analysis (Charmaz, 2006), while also referencing other relevant frameworks (e.g., Tan et al., 2014).

In the initial coding phase, four conversations were randomly selected, each representing a different task. This process involved multiple rounds of open coding to identify and refine emerging code concepts across various categories or themes. Student utterances were then classified into several dimensions, including cognition, metacognition (e.g., group discourse management), social communication (e.g., questions, direct responses, elaborations, agreements, disagreements, and arguments), and technology use (e.g., utilizing computer-based mind maps). The cognition dimension focused on two key aspects: (a) divergent thinking, which involved strategies such as association, decomposition, combination, and adjustment; and (b) idea generation, which included creating new ideas or building upon existing ones. The discourse analysis in

student group discussions is a valuable tool for educators aiming to enhance learning outcomes, foster essential communication skills, and promote a collaborative learning environment. Analyzing discourse among students in group discussions is essential for several reasons:

1. **Enhancing Critical Thinking and Deepening Understanding:** Engaging in collaborative discourse allows students to articulate their ideas, challenge assumptions, and consider multiple perspectives, leading to a deeper understanding of the subject matter. This process promotes critical thinking and helps students internalize knowledge more effectively (McKinley, J. (2015)).
2. **Assessing and Improving Student Engagement:** Discourse analysis provides insights into how students interact during group activities, revealing patterns of participation and engagement. By examining these interactions, educators can identify areas where students may need additional support or encouragement to participate actively (Nennig, H.T. et al., 2023).

The coding scheme was reviewed and thoroughly discussed within the research team to ensure its appropriateness and consistency. After reaching a consensus, the first author, along with an independently trained doctoral researcher, coded 20% of the overall dataset using this scheme. The inter-rater agreement reached a Cohen's kappa value of 0.87, indicating high reliability. Following a discussion and resolution of coding discrepancies, the first author completed the coding for the remaining data.

Scientific Creativity Task

Students from the four groups were tasked with generating ideas in response to a series of scientific creativity tasks for static fluid. These tasks were based on the Scientific Creativity Test developed by (Hu & Adey, 2002), which involves various creativity tasks in the field of science, specifically static fluid material, such as listing potential uses for common objects, asking questions for scientific inquiry, generating ideas to improve products, and creative imagination (Sun et al., 2022). Three science education lecturers from the Science Education program and the Educational Technology study program of Universitas Negeri Surabaya (Unesa), Indonesia, were selected to review these tasks and ensure their suitability for science education students. The students in this study were tasked to generate ideas in response to the following tasks:

- Task 1: Write down as many scientific uses of static fluid as you can!
- Task 2: If you could board a plane to travel to a planet, what scientific questions about static fluids would you ask to research? Write down as many as you can!
- Task 3: Write down as many improvements as you can make to make ordinary static fluid more interesting, more useful and more beautiful!
- Task 4: If there was no static fluid, imagine what the world would be like!

FINDINGS

Kategori Dalam Percakapan Grup: Categories in Group Conversations

Table 1 provides an overview of the categories that emerged, illustrative examples of each category, and the frequency of each category's occurrence in student conversations. The illustrative examples are translations of the original verbatim Indonesian excerpts from the students' dialogues. In analyzing the conversations of students engaged in creative science tasks, several important patterns emerged that highlight the emergence of new ideas, the role of technology, group dynamics, and divergent thinking strategies in promoting scientific creativity. The use of audio recordings during four creative science tasks, totalling 1,685 utterances, provided valuable insights into how students engaged in the processes of idea generation, roles, technology, collaboration, and problem-solving. Data from Table 1, which details the frequency of major categories in students' conversations, shows that while all communication categories appeared, the frequency of occurrence varied. The category related to "New Ideas" ranks first with the highest frequency, at 22.3%, followed by "Use of Technology" at 12.3%, which includes interactions during the creation of digital mind maps using the Canva app. This is in line with the finding that technology facilitates both the generation and organization of scientific creative ideas.

From the discourse analysis of group conversations, it is clear that ggstudents often rely on association strategies for divergent thinking, especially in the high-performance group (HPGs). This group was more likely to use mind maps effectively to retain and develop ideas, which then led to further discussion and organization of group thinking. In contrast, the low-performing group (LPGs) was more often engaged in a direct exchange of questions and answers, and less inclined to challenge each other's perspectives. This lack of divergent thinking limited their ability to generate innovative ideas collaboratively. These findings support the idea that divergent thinking, supported by tools such as digital mind maps, is essential for scientific creativity.

In addition, HPGs showed better self-regulation and planning in their idea development process, evident from their more frequent discussions about organizing and selecting strategies. This is supported by the literature, where successful groups often show greater metacognitive awareness in their collaborative tasks, allowing them to evaluate ideas more effectively (Fischer, 2020). In contrast, LPGs spent more time in task-irrelevant conversations, which reduced their overall performance.

The use of digital mind maps also plays an important role in facilitating social communication in groups. HPGs, for example, show disagreement more often in their discussions, which is an important factor in creative problem-solving, as it encourages the group to evaluate multiple perspectives before reaching a solution (Sawyer, 2012). On the other hand, conversations in LPGs tend to revolve around immediate responses, showing a lack of deeper engagement with their peers' ideas, which hinders the development of innovative solutions. The implications of these findings are significant for educators who want to promote scientific creativity in a university setting. The integration of digital tools such as mind maps into case-based blended learning models can provide structure and flexibility, encouraging students to explore and elaborate on their ideas. As digital tools become more integrated into educational practice, their potential to enhance group scientific creativity and divergent thinking becomes clearer. This research not only contributes to the understanding of how technological tools such as digital mind maps can support idea development but also provides a basis for future research to explore the nuances of group dynamics and individual differences in creative performance. Future research could focus on exploring individual characteristics that contribute to group performance and how socio-emotional expressions during group tasks influence the creative process.

Steps of creation Categorization in Table 1 and Table 2: Data Collection of Group Conversations:

1. Students' conversations during scientific creativity tasks were recorded and transcribed.
2. Each conversation was segmented into speaking turns for analysis.
3. Development of Coding Scheme:
 - a. Adopted a grounded theory approach that allows category concepts to emerge through systematic data review.
 - b. Categories included cognitive dimensions (e.g., divergent thinking, new ideas), metacognitive dimensions (e.g., group process regulation), social communication (e.g., questions, direct responses, agreement, disagreement), and technology use (e.g., mind map creation).
4. Initial Coding:
 - a. Conducted open coding on randomly selected conversations.
 - b. Categories were refined through multiple rounds of analysis.
5. Inter-Rater Reliability Testing: The coding scheme was reviewed by the research team and tested on 10% of the dataset to ensure reliability with a Cohen's kappa value of 0.87.
6. Full Data Analysis: The remaining data were coded using the agreed-upon scheme.
7. Reasons for Categorization:
 - a. Identifying Thinking and Interaction Patterns: To understand how students apply divergent thinking strategies and communicate during creativity tasks.
 - b. Facilitating In-Depth Analysis: Enables the analysis of complex interactions across multi-dimensional contexts, such as cognition, metacognition, social communication, and technology use.
 - c. Developing Educational Interventions: Categorization outcomes help design technology-based interventions to enhance group creativity in science education.

Table 1. Categorization of in-group interactions.

Category	Description	Illustration example	Frequency = N 1,685 K (%)
Divergent thinking (cognition):			
Association	Relate concepts, objects or situations	Task 1: Looks like a manometer.	85 (5.0%)
Decomposition	Decompose COS into details	Task 2: Physical and chemical properties of Fluids	59 (3.5%)
Combination with adjustment	Merge and/or customise COS	Task 3: Combining fluid with interactive digital technology.	57 (3.3%)
Idea generation (cognition):			
New idea (NI)	Generate ideas from new perspectives that have not been mentioned before	Task 2: Molecular structure of static fluids	376 (22.3%)
Building idea (BI)	Modify, refine or extend previous ideas to develop new ones	Task 4: Difficulty in storing liquid materials	85 (5.0%)
Metacognition:			
Regulation	Manage and reflect on the process	We quickly completed the digital mid-map because we were pressed for time.	198 (11.8%)
Social Communication			
Elaboration	Use examples, analogies, reasoning, or provide details to explain an idea or thought	Task 3: Adding colour-changing substances	59 (3.5%)
Question	Ask questions to seek further information or elaboration	Task 2: How do the properties of static fluids change in environments with different gravity levels?	88 (5.2%)
Direct response	Directly respond to questions without elaboration	There was carbon dioxide only.	54 (3.2%)
Agreement	A positive evaluation of an idea or thought (e.g. approval, acceptance, endorsement)	That's right	93 (5.5%)
Disagreements	Negative evaluation of an idea or thought (e.g. disapproval, non-acceptance, non-support)	Not true. the main component of the atmosphere is carbon dioxide only.	89 (5.3%)
Argument	Debate the appropriateness or value of the perspective with clear reasoning	Task 2: The main component of Mars' atmosphere is carbon dioxide	187 (11.1%)
Use of technology:			
Mind map (Mapping)	Interacting with mind maps	The circle can be red in colour	208 (12.3%)
Other (off-duty)			
Off-duty	Dialogue is irrelevant to the assigned task	There was a noise outside the classroom	47 (2.8%)

N = total number of utterances. *K* = number of utterances of each category. % = percentage of utterances

Students' responses to the creativity tasks were assessed in terms of High-performing groups (HPGs) and Low-performance groups (LPGs). The results show that two groups (H1, and H2; N = 14) achieved higher scores in all aspects of the performance while the other two groups (L1, and L2; N =12) got lower scores on the performance. The frequency of categories featured in HPGs and LPGs conversations is described in Table 2. The results show that HPGs used divergent thinking strategies more frequently through the application of the Association and Deconstruction strategies, whereas HPGs and LPGs had similar frequency in the use of the Combination strategy with adjustments. In addition, HPGs had more statements related to digital mind mapping than LPGs. In terms of social communication, HPGs expressed more disagreement and fewer direct responses than LPGs. HPGs also generated ideas (such as New Ideas and Idea Development) more often than LPGs. In addition, HPGs talked more about regulations and engaged in less off-task talk than LPGs. On the other hand, the frequency of statements related to questions and arguments between HPGs and LPGs was relatively similar. The results of this study are consistent and relevant with previous research conducted by Sun et al. (2022).

Table 2. Group interaction of HPGs and LPGs.

Category	Frequency					
	HPGs			LPGs		
	H1	H2	Mean	L1	L2	Mean
Association	22	18	20.00	16	19	17.50
Decomposition	14	20	17.00	12	9	10.50
Combination with Adjustment	9	16	12.50	11	5	8.00
Mapping	55	73	64.00	39	67	53.00
Elaboration	14	28	21.00	13	22	17.50
Question	32	24	29.00	25	29	27.00
Direct Response	18	16	17.00	19	16	17.50
Agreement	19	37	28.00	18	34	26.00
Disagreement	26	37	31.50	19	23	21.00
Argument	37	31	34.00	21	33	27.00
New Idea	71	63	67.00	35	34	34.50
Building on Idea	19	29	24.00	15	13	14.00
Regulation	39	66	52.50	31	36	33.50
Off-task	10	5	7.50	13	37	20.00

DISCUSSIONS AND CONCLUSION

This study has several limitations. First, this study did not explore the characteristics of individuals in the group and their influence on group process and performance. Second, this study did not consider social-emotional expression. Third, this study did not collect students' perceptions of the digital mind-mapping tool and group task experience, which could provide a broader explanation of the findings. Future research needs to consider these aspects. This study examined how 3rd-semester science education students generate ideas in a scientific creativity task, particularly in the context of small group work by applying relevant thinking strategies and constructing digital mind maps to support group thinking. Through discourse analysis of group conversations during the task, it was found that students tended to use association strategies for divergent thinking more often than other strategies; the creation of mind maps helped them retain ideas for development and evaluation, trigger new discussions, and organize conversations.

Differences in Categories within Group Conversations

Table 2 summarizes the frequency of categories observed in the conversations of high-performing groups (HPGs) and low-performing groups (LPGs). The analysis revealed that HPGs more frequently employed strategies such as Association and Decomposition in divergent thinking. In nearly all categories, HPGs exhibited higher frequencies compared to LPGs, except in the Off-task category, where LPGs surpassed HPGs. Both groups showed nearly identical frequencies in the Direct Response category. Additionally, HPGs were more active in mind mapping compared to LPGs. These findings highlight distinct communication patterns and thinking strategies between groups with different performance levels, indicating that HPGs tend to be more focused and creative in completing their tasks.

Technological advances, especially the integration of digital mind mapping for mind map creation, have created new pathways to support scientific creativity in the context of science education. Several studies found that technology-enhanced environments support scientific creativity by enabling simultaneous contributions, reducing hierarchical barriers, and supporting more meaningful participation (Pifarre, 2019). Digital mind maps, in particular, serve as scaffolding for students to organize and develop their ideas. Research shows that digital mind maps not only enhance individual idea generation but also help groups to collectively build knowledge, and combine and refine ideas (Sun et al., 2022).

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REFERENCES

- Abi-El-Mona, I., & Adb-El-Khalick, F. (2008). The influence of mind mapping on eighth graders' science achievement. *School Science & Mathematics*, 108(7), 298–312. <https://doi.org/10.1111/j.1949-8594.2008.tb17843.x>
- Agrawal, S., Law, S., Levy, M., Williams, L., & Mylopoulos, M. (2023). Using case-based learning in residency to support the development of adaptive expertise in working with people living with severe mental illness. *Academic Psychiatry*, 47(5), 535–539. <https://doi.org/10.1007/s40596-023-01532-7>
- Ahmed, M. M. H., McGahan, P. S., Indurkha, B., Kaneko, K., & Nakagawa, M. (2021). Effects of synchronized and asynchronized e-feedback interactions on academic writing, achievement motivation and critical thinking. *Knowledge Management & E-Learning*, 13(3), 290–315. <https://doi.org/10.34105/j.kmel.2021.13.016>
- Aktamis, H., & Ergin, O. (2008). The effect of scientific process skills education on students' scientific creativity, science attitudes and academic achievements. *Asia-Pacific Forum on Science Learning and Teaching*, 9(1), 1–21.
- Amabile, T. M. (1996). *Creativity in context: Update to the social psychology of creativity*. Routledge.
- Aprinawati, I. (2018). The use of mind mapping model to improve elementary school students' discourse reading comprehension. *Jurnal Basicedu*, 2(1).
- Astutik, S., & Prahani, B. K. (2018). The practicality and effectiveness of Collaborative Creativity Learning (CCL) model by using PhET simulation to increase students' scientific creativity. *International Journal of Instruction*, 11(4), 409–424. <https://doi.org/10.12973/iji.2018.11426a>
- Basadur, M., & Basadur, T. (2011). Where are the generators? *Psychology of Aesthetics, Creativity, and the Arts*, 5(1), 29–42. <https://doi.org/10.1037/a0017757>
- Beghetto, R. A. (2007). Factors associated with middle and secondary students' perceived science competence. *Journal of Research in Science Teaching*, 44(6), 800–814. <https://doi.org/10.1002/tea.20166>
- Brown, V., Tumeo, M., Larey, T. S., & Paulus, P. B. (1998). Modeling cognitive interactions during group brainstorming. *Small Group Research*, 29(4), 495–526. <https://doi.org/10.1177/1046496498294005>
- Buzan, T. (2013). *The mind map smart book*. PT Gramedia Pustaka Utama.
- Buzan, T., & Buzan, B. (2010). *The mind map book: Unlock your creativity, boost your memory, change your life*. Pearson Education Limited.
- Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. SAGE Publications Ltd.
- Chen, C. Y. (2024). Flipped classroom with case-based learning for improving preservice teachers' classroom management learning outcomes. *Teaching and Teacher Education*.

- Chen, J., Wang, M., Dede, C., & Grotzer, T. A. (2021). Analyzing student thinking reflected in self-constructed cognitive maps and its influence on inquiry task performance. *Instructional Science*, 49(3), 287–312. <https://doi.org/10.1007/s11251-020-09531-1>
- Chen, J., Wang, M., Grotzer, T. A., & Dede, C. (2018). Using a three-dimensional thinking graph to support inquiry learning. *Journal of Research in Science Teaching*, 55(9), 1239–1263. <https://doi.org/10.1002/tea.21450>
- Chen, X., Liu, J., Yuan, Y., & Cui, X. (2019). The curvilinear effect of task conflict on idea generation: The mediating role of reflexivity and the moderating role of task complexity. *International Journal of Conflict Management*, 30(2), 158–179. <https://doi.org/10.1108/IJCMA-02-2018-0029>
- Chiou, C. C. (2012). The effect of concept mapping on students' learning achievements and interests. *Innovations in Education and Teaching International*, 45(4), 375–387.
- Clapham, M. M., Cowdery, E. M., King, K. E., & Montang, M. A. (2005). Predicting work activities with divergent thinking tests: A longitudinal study. *Journal of Creative Behavior*, 39(3), 149–166. <https://doi.org/10.1002/j.2162-6057.2005.tb01256.x>
- Csanadi, A., Eagan, B., Kollar, I., Shaffer, D. W., & Fischer, F. (2018). When coding-and-counting is not enough: Using epistemic network analysis (ENA) to analyze verbal data in CSCL research. *International Journal of Computer-Supported Collaborative Learning*, 13(4), 419–438. <https://doi.org/10.1007/s11412-018-9292-z>
- DeChurch, L. A., & Marks, M. A. (2001). Maximizing the benefits of task conflict: The role of conflict management. *International Journal of Conflict Management*, 12(1), 4–22. <https://doi.org/10.1108/eb022847>
- Dennis, A. R., & Valacich, J. S. (1993). Computer brainstorming: More heads are better than one. *Journal of Applied Psychology*, 78(4), 531–537. <https://doi.org/10.1037/0021-9010.78.4.531>
- Dewi, M. R., Mudakir, I., & Murdiah, S. (2016). The effect of lesson study-based collaborative learning model on students' critical thinking ability. *Jurnal Edu*, 3(2), 29–33.
- Dini, A., Putri, D., & Hamid, A. (2022). The impact of digital tools on case-based learning in STEM education. *Journal of Technology and Science Education*, 32(2), 142–156.
- Dong, H., Guo, C., Zhou, L., Zhao, J., Wu, X., Zhang, X., & Zhang, X. (2022). Effectiveness of case-based learning in Chinese dental education: a systematic review and meta-analysis. *BMJ Open*, 12(2), e048497. <https://doi.org/10.1136/bmjopen-2020-048497>
- Eko Risdianto, A. M. (2022). Development of a Blended Learning Model Based on Case-Based Learning. *Journal of Hunan University Natural Sciences*.
- Fallon, G., & Khoo, E. (2014). Exploring young students' talk in iPad-supported collaborative learning environments. *Computers & Education*, 77, 13–28. <https://doi.org/10.1016/j.compedu.2014.04.008>
- Farrand, P., Hussain, F., & Hennessy, E. (2021). The efficacy of the 'mind map' study technique. *Medical Education*, 36(5), 426–431.
- Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications*. The MIT Press.
- Fischer, F. (2020). The role of metacognition in collaborative learning. *Learning and Instruction*, 68, 101210.
- Garcês, S., Pocinho, M., De Jesus, S. N., & Viseu, J. (2016). The impact of the creative environment on the creative person, process, and product. *Avaliação Psicológica*, 15(2), 169–176. <https://doi.org/10.15689/ap.2016.1502.05>
- Gasevic, D., Joksimovic, S., Eagan, B. R., & Shaffer, D. W. (2019). Sens: Network analytics to combine social and cognitive perspectives of collaborative learning. *Computers in Human Behavior*, 92, 562–577. <https://doi.org/10.1016/j.chb.2018.07.003>

- Gijlers, H., & de Jong, T. (2013). Using concept maps to facilitate collaborative simulation-based inquiry learning. *The Journal of the Learning Sciences*, 22(3), 340–374. <https://doi.org/10.1080/10508406.2012.748664>
- Gilhooly, K. J., Fioratou, E., Anthony, S. H., & Wynn, V. (2007). Divergent thinking: Strategies and executive involvement in generating novel uses for familiar objects. *British Journal of Psychology*, 98(4), 611–625. <https://doi.org/10.1111/j.2044-8295.2007.tb00467.x>
- Glaveanu, V. P. (2011). How are we creative together? Comparing sociocognitive and sociocultural answers. *Theory & Psychology*, 21(4), 473–492. <https://doi.org/10.1177/0959354310372152>
- Glaveanu, V. P. (2018). Creativity in perspective: A sociocultural and critical account. *Journal of Constructivist Psychology*, 31(2), 118–129. <https://doi.org/10.1080/10720537.2016.1271376>
- Gronski, M. (2024). Case-Based Instructional Methods. *Effective Teaching*. [HTML]
- Hakim, A., Liliarsari, L., Setiawan, A., & Saptawati, G. A. P. (2017). Interactive multimedia thermodynamics to improve creative thinking skill of physics prospective teachers. *Jurnal Pendidikan Fisika Indonesia*, 13(1), 33–40. <https://doi.org/10.15294/jpfi.v13i1.8447>
- Harvey, S. (2013). A different perspective: The multiple effects of deep level diversity on group creativity. *Journal of Experimental Social Psychology*, 49(5), 822–832. <https://doi.org/10.1016/j.jesp.2013.04.004>
- Hawlina, H., Gillespie, A., & Zittoun, T. (2019). Difficult differences: A socio-cultural analysis of how diversity can enable and inhibit creativity. *Journal of Creative Behavior*, 53(2), 133–144. <https://doi.org/10.1002/jocb.182>
- Hennessey, B. A., & Amabile, T. M. (2010). Creativity. *Annual Review of Psychology*, 61, 569–598. <https://doi.org/10.1146/annurev.psych.093008.100416>
- Hoever, I. J., van Knippenberg, D., van Ginkel, W. P., & Barkema, H. G. (2012). Fostering team creativity: Perspective taking as key to unlocking diversity's potential. *Journal of Applied Psychology*, 97(5), 982–996. <https://doi.org/10.1037/a0029159>
- Hong, E., O'Neil, H. F., & Peng, Y. (2016). Effects of explicit instructions, metacognition, and motivation on creative performance. *Creativity Research Journal*, 28(1), 33–45. <https://doi.org/10.1080/10400419.2016.1125252>
- Hu, W., & Adey, P. (2002). A scientific creativity test for secondary school students. *International Journal of Science Education*, 24(4), 389–403. <https://doi.org/10.1080/09500690110098912>
- Irma, A., Syamsuri, A. S., & Arief, T. A. (2020). The effectiveness of mind mapping technique assisted by picture media on the learning of writing paragraph description of class IV elementary school students in Pangkep Regency. *Jurnal Profesi Keguruan*, 6(1).
- Jeong, H., Hmelo-Silver, C. E., & Jo, K. (2019). Ten years of computer-supported collaborative learning: A meta-analysis of CSCL in STEM education during 2005–2014. *Educational Research Review*, 28, 100284. <https://doi.org/10.1016/j.edurev.2019.100284>
- Kohn, N. W., Paulus, P. B., & Choi, Y. H. (2011). Building on the ideas of others: An examination of the idea combination process. *Journal of Experimental Social Psychology*, 47(3), 554–561. <https://doi.org/10.1016/j.jesp.2011.01.004>
- Kurtzberg, T. R. (2005). Feeling creative, being creative: An empirical study of diversity and creativity in teams. *Creativity Research Journal*, 17(1), 51–65. https://doi.org/10.1207/s15326934crj1701_5
- Lim, G., Shelley, A., & Heo, D. (2019). The regulation of learning and co-creation of new knowledge in mobile learning. *Knowledge Management & E-Learning*, 11(4), 449–484. <https://doi.org/10.34105/j.kmel.2019.11.024>
- Ma, H. H. (2009). The effect size of variables associated with creativity: A meta-analysis. *Creativity Research Journal*, 21(1), 30–42. <https://doi.org/10.1080/10400410802633400>
- Malycha, C. P., & Maier, G. W. (2017). The random-map technique: Enhancing mind-mapping with a conceptual combination technique to foster creative potential. *Creativity Research Journal*, 29(2), 114–124. <https://doi.org/10.1080/10400419.2017.1302763>

- Mannix, E., & Neale, M. A. (2005). What differences make a difference? The promise and reality of diverse teams in organizations. *Psychological Science in the Public Interest*, 6(2), 31–55. <https://doi.org/10.1111/j.1529-1006.2005.00022.x>
- McKinley, J. (2015). Critical Argument and Writer Identity: Social Constructivism as a Theoretical Framework for EFL Academic Writing. *Critical Inquiry in Language Studies*, 12(3), 184–207. <https://doi.org/10.1080/15427587.2015.1060558>
- McWilliam, E., Poronnik, P., & Taylor, P. G. (2008). Re-designing science pedagogy: Reversing the flight from science. *Journal of Science Education and Technology*, 17(3), 226–235. <https://doi.org/10.1007/s10956-008-9092-8>
- Mednick, S. (1962). The associative basis of the creative process. *Psychological Review*, 69(3), 220–232. <https://doi.org/10.1037/h0048850>
- Meinel, M., Wagner, T. F., Baccarella, C. V., & Voigt, K. I. (2019). Exploring the effects of creativity training on creative performance and creative self-efficacy: Evidence from a longitudinal study. *Journal of Creative Behavior*, 53(4), 546–558. <https://doi.org/10.1002/jocb.23>
- Meng, S., Wang, M., Wegerif, R., & Peng, J. (2022). How do students generate ideas together in scientific creativity tasks through computer-based mind mapping? *Computers & Education*, 176, 104359. <https://doi.org/10.1016/j.compedu.2021.104359>
- Mercer, N., & Dawes, L. (2008). The value of exploratory talk. In N. Mercer & S. Hodgkinson (Eds.), *Exploring talk in school: Inspired by the work of Douglas Barnes* (pp. 55–71). SAGE Publications Ltd.
- Mullen, B. (1991). Group composition, salience, and cognitive representations: The phenomenology of being in a group. *Journal of Experimental Social Psychology*, 27(4), 297–323. [https://doi.org/10.1016/0022-1031\(91\)90028-5](https://doi.org/10.1016/0022-1031(91)90028-5)
- Nennig, H. T., States, N. E., Montgomery, M. T., et al. (2023). Student interaction discourse moves: Characterizing and visualizing student discourse patterns. *Disciplinary and Interdisciplinary Science Education Research*, 5, 2. <https://doi.org/10.1186/s43031-022-00068-9>
- Nesbit, J. C., & Adesope, O. A. (2006). Learning with concept and knowledge maps: A meta-analysis. *Review of Educational Research*, 76(3), 413–448. <https://doi.org/10.3102/00346543076003413>
- Ness, R. B. (2015). *The creativity crisis: Reinventing science to unleash possibility*. Oxford University Press.
- Ng, A. K., & Smith, I. (2004). Why is there a paradox in promoting creativity in the Asian classroom? In L. Sing, A. Hui, & G. Ng (Eds.), *Creativity: When East meets west* (pp. 87–112). World Scientific Publishing.
- Nijstad, B. A., & Stroebe, W. (2006). How the group affects the mind: A cognitive model of idea generation in groups. *Personality and Social Psychology Review*, 10(3), 186–213. https://doi.org/10.1207/s15327957pspr1003_1
- Nurdamayanti, A. (2018). Application of mind mapping method in mathematics learning of students of SMPN 48 Surabaya. *Jurnal Ilmiah Matematika Pendidikan Matematika*, 8(1).
- Nursoviani, L. D., Sahal, Y. F. D., & Ambara, B. (2019). Application of network tree type mind mapping media to improve student learning outcomes in social science subjects of Madrasah Ibtidaiyah. *Jurnal Ilmiah*, 16(2).
- Nuswowati, M., & Taufiq, M. (2015). Developing creative thinking skills and creative attitude through problem-based green vision chemistry environment learning. *Jurnal Pendidikan Sains Indonesia*, 4(2), 170–176.
- Oliveira, A. W., & Sadler, T. D. (2008). Interactive patterns and conceptual convergence during student collaborations in science. *Journal of Research in Science Teaching*, 45(5), 634–658. <https://doi.org/10.1002/tea.20211>

- Oztop, P., Katsikopoulos, K., & Gummerum, M. (2018). Creativity through connectedness: The role of closeness and perspective taking in group creativity. *Creativity Research Journal*, 30(3), 266–275. <https://doi.org/10.1080/10400419.2018.1488347>
- Paek, S. H., Park, H., Runco, M. A., & Choe, H.-S. (2016). The contribution of ideational behavior to creative extracurricular activities. *Creativity Research Journal*, 28(2), 144–148. <https://doi.org/10.1080/10400419.2016.1162547>
- Parkhurst, H. B. (1999). Confusion, lack of consensus, and the definition of creativity as a construct. *Journal of Creative Behavior*, 33(1), 1–21. <https://doi.org/10.1002/j.2162-6057.1999.tb01035.x>
- Paulus, P. B., & Nijstad, B. A. (Eds.). (2003). *Group creativity: Innovation through collaboration*. Oxford University Press.
- Paulus, P. B., Levine, D. S., Brown, V., Minaei, A. A., & Doboli, S. (2010). Modeling ideational creativity in groups: Connecting cognitive, neural, and computational approaches. *Small Group Research*, 41(6), 688–724. <https://doi.org/10.1177/1046496410369561>
- Pifarre, M. (2019). Digital technologies and their role in group creativity. *Educational Psychologist*, 54(3), 189–206.
- Pifarre, M. (2019). Using interactive technologies to promote a dialogic space for creating collaboratively: A study in secondary education. *Thinking Skills and Creativity*, 32, 1–16. <https://doi.org/10.1016/j.tsc.2019.01.004>
- Pifarre, M., Wegerif, R., Guiral, A., & del Barrio, M. (2014). Developing technological and pedagogical affordances to support the collaborative process of inquiry-based science education. In P. Reimann (Eds.), *International handbook of the learning sciences* (pp. 159–179). Routledge. <https://doi.org/10.4324/9781315617572>
- Puspitasari, L., In'am, A., & Syaifuddin, M. (2018). Analysis of students' creative thinking in solving arithmetic problems. *International Electronic Journal of Mathematics Education*, 14(1), 49–60.
- Ramirez, H. J. M., & Monterola, S. L. C. (2019). Co-creating scripts in computer-supported collaborative learning and its effects on students' logical thinking in earth science. *Interactive Learning Environments*. <https://doi.org/10.1080/10494820.2019.1702063>
- Reimann, P. (Eds.). (2018). *International handbook of the learning sciences*. Routledge. <https://doi.org/10.4324/9781315617572>
- Reiter-Palmon, R., Forthmann, B., & Barbot, B. (2019). Scoring divergent thinking tests: A review and systematic framework. *Psychology of Aesthetics, Creativity, and the Arts*, 13(2), 144–152. <https://doi.org/10.1037/aca0000227>
- Rhodes, M. (1961). An analysis of creativity. *Phi Delta Kappan*, 42(7), 305–310. <http://www.jstor.org/stable/20342603>
- Ritter, S. M., & Mostert, N. (2017). Enhancement of creative thinking skills using a cognitive-based creativity training. *Journal of Cognitive Enhancement*, 1(3), 243–253. <https://doi.org/10.1007/s41465-016-0002-3>
- Robbins, T. L., & Kegley, K. (2010). Playing with Thinkertoys to build creative abilities through online instruction. *Thinking Skills and Creativity*, 5(1), 40–48. <https://doi.org/10.1016/j.tsc.2009.07.001>
- Ross, V. E. (2006). A model of inventive ideation. *Thinking Skills and Creativity*, 1(2), 120–129. <https://doi.org/10.1016/j.tsc.2006.06.003>
- Runco, M. A., & Acar, S. (2012). Divergent thinking as an indicator of creative potential. *Creativity Research Journal*, 24(1), 66–75. <https://doi.org/10.1080/10400419.2012.652929>
- Runco, M. A., Plucker, J. A., & Lim, W. (2001). Development and psychometric integrity of a measure of ideational behavior. *Creativity Research Journal*, 13(3–4), 393–400. https://doi.org/10.1207/S15326934CRJ1334_16

- Santanen, E. L., Briggs, R. O., & De Vreede, G. J. (2004). Causal relationships in creative problem solving: Comparing facilitation interventions for ideation. *Journal of Management Information Systems*, 20(4), 167–198. <https://doi.org/10.1080/07421222.2004.11045783>
- Sawyer, R. K. (2012). *Group creativity: Innovation through collaboration*. Psychology Press.
- Sawyer, R. K. (2017). *Group genius: The creative power of collaboration* (2nd ed.). Basic Books.
- Sawyer, R. K. (2017). Teaching creativity in art and design studio classes: A systematic literature review. *Educational Research Review*, 2, 99–113.
- Shaffer, D. W. (2017). *Quantitative ethnography*. Cathcart Press.
- Shaffer, D. W. (2018). Epistemic network analysis: Understanding learning by using big data for thick description. In F. Fischer, C. E. Hmelo-Silver, S. R. Goldman, & P. Reimann (Eds.), *International handbook of the learning sciences* (pp. 520–531). Routledge. <https://doi.org/10.4324/9781315617572>
- Siebert-Evenstone, A. L., Irgens, G. A., Collier, W., Ruis, A. R., & Shaffer, D. W. (2017). In search of conversational grain size: Modelling semantic structure using moving stanza windows. *Journal of Learning Analytics*, 4(3), 123–139. <https://doi.org/10.18608/jla.2017.43.7>
- Silvia, P. J., Beaty, R. E., Nusbaum, E. C., Eddington, K. M., Levin-Aspenson, H., & Kwapil, T. R. (2014). Everyday creativity in daily life: An experience-sampling study of ‘little c’ creativity. *Psychology of Aesthetics, Creativity, and the Arts*, 8(2), 183–188. <https://doi.org/10.1037/a0035722>
- Singsungnoen, & PiriyaSurawong, P. (2016). The design of a prototype of collaborative learning for creative thinking of junior programmers. *International Journal of Applied Computing Technology and Information Systems*, 6(1), 11–15.
- Smith, G. F. (1998). Idea-generation techniques: A formulary of active ingredients. *Journal of Creative Behavior*, 32(2), 107–134. <https://doi.org/10.1002/j.2162-6057.1998.tb00810.x>
- Sompong, N. (2018). Learning management system for creative thinking skill development with collaborative learning of the graduate students in Kasetsart University. *International Journal of Environmental Science and Education*, 13(6), 527–532.
- Stahl, G., Koschmann, T., & Suthers, D. (2014). Computer-supported collaborative learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed., pp. 409–426). Cambridge University Press.
- Summers, R., Alameh, S., Brunner, J., Maddux, J. M., Wallon, R. C., & Abd-El-Khalick, F. (2019). Representations of nature of science in U.S. science standards: A historical account with contemporary implications. *Journal of Research in Science Teaching*, 56(9), 1234–1268. <https://doi.org/10.1002/tea.21551>
- Sun, M., Wang, M., & Wegerif, R. (2019). Using computer-based cognitive mapping to improve students’ divergent thinking for creativity development. *British Journal of Educational Technology*, 50(5), 2217–2233. <https://doi.org/10.1111/bjet.12825>
- Sun, M., Wang, M., & Wegerif, R. (2020). Effects of divergent thinking training on students’ scientific creativity: The impact of individual creative potential and domain knowledge. *Thinking Skills and Creativity*, 37, 100682. <https://doi.org/10.1016/j.tsc.2020.100682>
- Sun, M., Wang, M., Wegerif, R., & Peng, J. (2022). How do students generate ideas together in scientific creativity tasks through computer-based mind mapping? *Computers & Education*, 176, 104359. <https://doi.org/10.1016/j.compedu.2021.104359>
- Tan, J. P. L., Caleon, I. S., Jonathan, C. R., & Koh, E. (2014). A dialogic framework for assessing collective creativity in computer-supported collaborative problem-solving tasks. *Research and Practice in Technology Enhanced Learning*, 9(3), 411–437.
- Tayce, J. D., Saunders, A. B., Keefe, L., & Korich, J. (2021). The creation of a collaborative, case-based learning experience in a large-enrollment classroom. *Journal of Veterinary Medical Education*, 48(1), 14–20. <https://doi.org/10.3138/jvme-2019-0118>

- Tran, T. T., & Herzig, C. (2023). Blended case-based learning in a sustainability accounting course: An analysis of student perspectives. *Journal of Accounting Education*.
- Tambak, S., & Sukenti, D. (2024). Case-Based Learning Method in Learning: Is it Effective to Improve Teaching Skills of Madrasa Teachers in Indonesia? *Journal of Learning for Development*.
- Wang, H. C., Cosley, D., & Fussell, S. R. (2010). Idea expander: Supporting group brainstorming with conversationally triggered visual thinking stimuli. In *Proceedings of the ACM Conference on Computer Supported Cooperative Work* (pp. 103–106). <https://doi.org/10.1145/1718918.1718938>
- Wang, M., Wu, B., Kirschner, P. A., & Spector, J. M. (2018). Using cognitive mapping to foster deeper learning with complex problems in a computer-based environment. *Computers in Human Behavior*, 87, 450–458. <https://doi.org/10.1016/j.chb.2018.01.024>
- Wegerif, R. (2007). *Dialogic, education and technology: Expanding the space of learning*. Springer.
- Welling, H. (2007). Four mental operations in creative cognition: The importance of abstraction. *Creativity Research Journal*, 19(2–3), 163–177. <https://doi.org/10.1080/10400410701397214>
- Williams, S. M. (2018). Putting case-based instruction into context: Examples from legal and medical education. *Journal of the Learning Sciences*, 2(4), 367–427.
- Wijnia, L., Noordzij, G., Arends, L. R., Rikers, R. M., & Loyens, S. M. (2024). The effects of problem-based, project-based, and case-based learning on students' motivation: A meta-analysis. *Educational Psychology Review*, 36(1), 29. <https://doi.org/10.1007/s10648-023-09661-2>
- Wu, B., & Wang, M. (2012). Integrating problem solving and knowledge construction through dual mapping. *Knowledge Management & E-Learning*, 4(3), 248–257. <https://doi.org/10.34105/j.kmel.2012.04.021>
- Wu, B., Hu, Y., & Wang, M. (2019). Scaffolding design thinking in online STEM preservice teacher training. *British Journal of Educational Technology*, 50(5), 2271–2287. <https://doi.org/10.1111/bjet.12873>
- Wu, B., Hu, Y., Ruis, A. R., & Wang, M. (2019). Analysing computational thinking in collaborative programming: A quantitative ethnography approach. *Journal of Computer Assisted Learning*, 35(3), 421–434. <https://doi.org/10.1111/jcal.12348>
- Wu, F., Wang, T., Yin, D., Xu, X., Jin, C., Mu, N., & Tan, Q. (2023). Application of case-based learning in psychology teaching: A meta-analysis. *BMC Medical Education*. <https://doi.org/10.1186/s12909-023-04510-4>
- Yang, K. K., Lee, L., Hong, Z. R., & Lin, H. S. (2016). Investigation of effective strategies for developing creative science thinking. *International Journal of Science Education*, 38(13), 2133–2151. <https://doi.org/10.1080/09500693.2016.1230685>
- Yang, W., Zhang, X., Chen, X., Lu, J., & Tian, F. (2024). Based case-based learning and flipped classroom as a means to improve international students' active learning and critical thinking ability. *BMC Medical Education*. <https://doi.org/10.1186/s12909-023-04629-4>
- Yang, X., Sun, Z., & Liang, F. (2021). Enhancing learning and retention through digital mind mapping. *Journal of Educational Computing Research*, 59(5), 948–967.
- Yu, Z., Hu, R., Ling, S., Zhuang, J., Chen, Y., Chen, M., & Lin, Y. (2021). Effects of blended versus offline case-centered learning on the academic performance and critical thinking ability of undergraduate nursing students: A cluster randomised controlled trial. *Nurse Education in Practice*, 53, 103080.
- Zheng, B., & Mavis, B. (2023). Linking theory to practice: Case-based learning in health professions education. In *Designing Technology-Mediated Case Learning in Higher Education: A Global Perspective* (pp. 33–47).
- Zubaidah, S., Fuad, N. M., Mahanal, S., & Suarsini, E. (2017). Improving creative thinking skills of students through differentiated science inquiry integrated with mind map. *Journal of Turkish Science Education*, 14(4), 77–91.