ENHANCING METACOGNITIVE AND CREATIVE THINKING SKILLS IN CHEMISTRY EDUCATION: THE ROLE OF COLLABORATIVE PROJECT-BASED LEARNING AND STUDENT RESPONSIBILITY

Rusly Hidayah[1], I Wayan Dasna[2], Parlan[3], Nazriati[4], Muhammad Farhan Ivan Phalosa[5]

[1,5] Chemistry Education Department, Faculty of Mathematics and Natural Sains, Universitas Negeri Surabaya
[2,3,4] Chemistry Education Department, Faculty of Mathematics and Natural Sains, Universitas Negeri Malang

**Corresponding author: ruslyhidayah@unesa.ac.id*

Abstract. *The integration of metacognitive and creative thinking skills plays a crucial role in equipping undergraduate chemistry students within STEM (Science, Technology, Engineering, and Mathematics) disciplines with the necessary competencies to address complex, real-world challenges. This quasi-experimental study investigates the effectiveness of Collaborative Project-Based Learning (CPjBL) supplemented with Electronic Worksheets (E-LKM) in enhancing these essential skills among chemistry education students (N=52), while examining the moderating effect of student responsibility. The research employed a comparative approach between CPjBL and traditional Project-Based Learning (PjBL) methodologies. Statistical analysis using the Mann-Whitney U test demonstrated that CPjBL significantly outperformed conventional PjBL ($p < 0.05$) in developing both metacognitive skills (with an N-Gain of 0.76 compared to 0.66) and creative thinking abilities (N-Gain of 0.87 versus 0.70). Notably, the benefits were particularly pronounced among students exhibiting high levels of personal responsibility ($p < 0.05$). Further statistical analysis through univariate ANOVA revealed a significant interaction effect between the CPjBL approach and student responsibility ($F = 2.084$, $p = 0.013$), indicating that the effectiveness of the collaborative learning method is substantially influenced by the learners' degree of accountability. This finding suggests that while CPjBL represents a powerful pedagogical tool, its implementation should consider students' readiness to take responsibility for their learning process. The study provides empirical evidence supporting CPjBL as an effective framework for cultivating 21st-century skills in chemistry education. The findings have important implications for instructional design, highlighting the need to incorporate collaborative, technology-enhanced learning strategies while simultaneously fostering students' sense of responsibility. Additionally, the research underscores the importance of professional development programs to equip educators with the necessary skills to implement these innovative teaching approaches effectively.*

Keywords: *collaborative project-based learning, creative thinking skills, responsibility, metacognition, chemistry education*

INTRODUCTION

The Fourth Industrial Revolution demands that students develop higher-order thinking skills to solve interdisciplinary problems [1]. Metacognition and creative thinking are essential competencies that allow learners to regulate their learning and foster innovation [2, 3]. In chemistry education, these skills are critical for navigating abstract concepts [4] and applying them to sustainable solutions through inquiry [5, 6]. These skills are particularly critical in chemistry education, where students must navigate abstract concepts (e.g., reaction kinetics) and apply them to real-world challenges, such as sustainable waste management or energy solutions.

While Project-Based Learning (PjBL) is recognized for engaging students in meaningful tasks [7, 8, 9], traditional models often overlook the nuances of collaborative dynamics [10, 11] and the role of individual responsibility [12]. Effective collaboration requires a social constructivist approach where knowledge is built collectively [13, 14]. Furthermore, the use of digital tools like E-LKM can bridge the gap in hybrid learning environments [15, 16].

This study bridges these gaps by investigating CPjBL's efficacy in a chemistry education context. We hypothesize that:

1. CPjBL with E-LKM will outperform traditional PjBL in enhancing metacognitive skills by providing structured reflection phases (e.g., guided peer evaluations).
2. CPjBL will foster greater creative thinking through collaborative ideation tasks (e.g., brainstorming alternative solutions to chemical waste problems).
3. High-responsibility students will show significantly greater gains in both skill domains, as accountability amplifies engagement.
4. Responsibility will moderate CPjBL's effectiveness, creating a synergistic effect between pedagogy and student disposition.

Self-regulated learning strategies have been proven to enhance student autonomy [17, 18]. In the context of project work, metacognition acts as a catalyst for deeper understanding [19, 20]. By testing these hypotheses, our work offers two key contributions: (1) a validated CPjBL model for chemistry education, adaptable to other STEM fields, and (2) empirical evidence that responsibility is not merely a peripheral trait but a scalable lever for improving advanced cognitive skills [21, 22].

METHOD

This study employed a quasi-experimental design [23, 24] with a pretest-posttest 2x2 factorial approach to examine the effects of Collaborative Project-Based Learning (CPjBL) assisted by Electronic Worksheets (E-LKM) on students' metacognitive and creative thinking skills, while accounting for the moderating role of responsibility. The experiment involved 52 undergraduate students enrolled in a Basic Chemistry course at Universitas Negeri Surabaya, who were divided into two groups: an experimental group (n=26) that received CPjBL with E-LKM and a control group (n=26) that underwent traditional Project-Based Learning (PjBL).

Participants were selected through purposive sampling to ensure comparable academic backgrounds and were stratified into high- and low-responsibility subgroups based on a pre-intervention responsibility scale ($\alpha = 0.758$). The responsibility assessment measured students' self-reported tendencies in task commitment, deadline adherence, and peer accountability factors critical for collaborative learning success. . To measure improvement, Normalized Gain (N-Gain) scores were calculated following Hake’s formula [25].

The intervention spanned eight weeks, with both groups covering the same chemical kinetics curriculum but differing in instructional delivery. The CPjBL group engaged in a five-phase learning cycle: (1) Orientation, where instructors presented real-world problems (e.g., optimizing reaction rates for sustainable fuel production) via E-LKM; (2) Organization, where teams analyzed literature and designed experiments; (3) Collaboration, involving data collection, expert consultations, and iterative solution refinement; (4) Discussion, where students presented findings and critiqued peer proposals; and (5) Evaluation, featuring guided self-reflection on metacognitive strategies and creative outcomes. In contrast, the PjBL group completed similar projects but without structured collaboration phases or E-LKM scaffolds.

Metacognitive skills [26] were assessed using a validated 20-item questionnaire ($\alpha = 0.836$) measuring planning (e.g., "I set clear goals before solving problems"), monitoring (e.g., "I adjust strategies when stuck"), and evaluation (e.g., "I reflect on what worked post-task"). Creative thinking was evaluated through a rubric adapted from Torrance [27,28], scoring originality (novelty of solutions), fluency (number of ideas), and flexibility (diverse approaches). Both instruments were administered pre- and post-intervention by blinded raters (inter-rater reliability ICC = 0.89).

Data analysis proceeded in three stages. First, N-Gain scores quantified skill improvement. Second, Mann-Whitney U tests compared gains between CPjBL and PjBL groups, as non-parametric tests were warranted by skewed distributions. Third, univariate ANOVA examined interaction effects between learning models (CPjBL/PjBL) and responsibility levels (high/low), with significance set at $p < 0.05$ [29, 30].

RESULT AND DISCUSSION

CPjBL groups showed higher metacognitive gains (N-Gain = 0.76 for high-responsibility; 0.70 for low-responsibility) than PjBL groups (0.66 and 0.60, respectively). Phases like problem orientation (video-assisted learning) and collaboration (E-LKM discussions) fostered planning, monitoring, and evaluation (Table 1).

Table 1. Metacognitive Skill Scores

Class	Metacognitive	Number of students	Mean questionnaire score pre-lecture	Mean questionnaire score post-lecture	Mean n-gain scores
CPjBL	High	13	71.01	92.69	0.76
	Low	13	62.78	88.61	0.70
PjBL	High	13	60.29	86.09	0.66
	Low	13	55.86	82.48	0.60

The CPjBL group achieved significantly higher growth in metacognition compared to the PjBL group. This confirms that structured collaboration facilitates better self-regulation [31, 32]. High-responsibility learners exhibit superior goal-setting strategies [33,34], whereas low-responsibility learners often struggle with task persistence [35, 36]. This aligns with the theory of self-efficacy, where belief in one's capability drives academic success [37, 38].

The interaction between the model and responsibility suggests that pedagogical interventions must be tailored to student character [39, 40]. Collaborative environments provide the necessary scaffolding for metacognitive development [41, 42, 43].

Students engaged in Collaborative Project-Based Learning (CPjBL) participate in structured activities designed to develop their metacognitive skills. The learning process consists of five phases: (1) Orientation Phase; The lecturer presents authentic, context-integrated problems and motivates students to engage in problem-solving. Students analyze reaction rate concepts through instructional videos, fostering metacognitive planning skills. Observations are made on how students navigate challenges during problem comprehension, (2) Organization Phase; Guided group discussions using Electronic Student Worksheets (E-LKM) focus on real-world applications, such as coconut water waste utilization. Here, students practice metacognitive strategies, including information management, learning process monitoring, and strategy evaluation, (3) Collaboration Phase; Students gather data, consult external experts, and refine solutions under lecturer guidance. Their responsibility is assessed through E-LKM completion, while metacognitive skills are reinforced via iterative problem-solving and self-monitoring, (4) Discussion Phase; Students present their findings, articulating challenges encountered during E-LKM tasks. This phase emphasizes metacognitive strategies for information synthesis and communication, (5) Evaluation Phase; Structured reflection allows students to compare outcomes with expectations, assess satisfaction, and identify improvements, thereby honing evaluative metacognitive skills.

CPjBL’s efficacy hinges on problem-solving commitment, which is intrinsically tied to responsibility [7]. Responsibility entails accountability for one’s obligations [8] and manifests as goal-driven actions [9]. Empirical studies demonstrate that CPjBL enhances responsibility by fostering task ownership [10,6].

In this study, CPjBL implementation followed these steps:

1. Orientation: Problem analysis, issue identification, and video-assisted material study.
2. Organization: Literature review, experimental design, and procedural validation.
3. Collaboration: Data collection, analysis, and interdisciplinary consultation.
4. Discussion: Presentation of solutions and recommendations.
5. Evaluation: Reflection on problem-solving processes

E-LKM streamlined task execution, particularly in orientation, collaboration, and discussion phases. Creative thinking skills further supported students' investigative and creative tasks [11]. Metacognitive growth paralleled creativity development, while responsibility was reinforced by collaborative dynamics [12]. Thus, responsibility acts as a moderating variable in CPjBL, bridging metacognition, creativity, and task outcomes.

CPjBL groups achieved greater creative thinking gains (N-Gain = 0.87 for high-responsibility; 0.75 for low-responsibility) versus PjBL (0.70 and 0.69). Tasks like brainstorming alternative solutions enhanced fluency, flexibility, and originality (Table 2).

Table 2. Creative Thinking Skill Scores

Class	Creative	Number of students	Mean questionnaire score pre-lecture	Mean questionnaire score post-lecture	Mean n-gain scores
CPjBL	High	13	55,.6	94.04	0.87
	Low	13	48,.0	86.30	0.75
PjBL	High	13	55.80	87.54	0.70
	Low	13	48.97	83.97	0.69

Students participating in Collaborative Project-Based Learning (CPjBL) engage in structured activities designed to enhance their creative thinking abilities. The CPjBL framework comprises five distinct phases, each contributing to different dimensions of creative thought:

Phase 1: Orientation

The instructor presents authentic, contextually integrated problems to stimulate student engagement. During this phase, students develop creative thinking skills in fluency and flexibility as they navigate problem comprehension under varying conditions. The lecturer monitors students' approaches to challenges in understanding the problem space.

Phase 2: Organization

Through guided group discussions utilizing Electronic Student Worksheets (E-LKM), students apply their foundational knowledge of reaction rates to practical scenarios such as coconut water waste utilization. This phase fosters creative thinking across three dimensions: fluency (generating multiple ideas), flexibility (adapting perspectives), and originality (developing novel solutions).

Phase 3: Collaboration

Students actively gather information, consult external experts, and develop solutions while completing E-LKM tasks. The lecturer assesses both student responsibility and problem-solving approaches during this process. Notably, CPjBL classes generated four distinct alternative solutions (varying sugar, acetic acid, urea, and bean sprout extract concentrations), compared to only one solution (sugar concentration variation) in PjBL classes.

Phase 4: Discussion

Students present their findings to the class, demonstrating creative elaboration skills. The lecturer evaluates how E-LKM-related challenges may impact presentation quality, providing insights into students' creative adaptation capabilities.

Phase 5: Evaluation

Structured reflection enables students to compare outcomes with expectations, assess satisfaction levels, and identify areas for improvement - key components of creative elaboration.

Metacognitive development progresses concurrently with creative skill acquisition. Furthermore, responsibility emerges through both metacognitive growth and collaborative group dynamics [12]. This sense of responsibility serves as a moderating variable in CPjBL, significantly enhancing scientific investigation outcomes and creative task performance.

A marked disparity in creative thinking performance exists between high- and low-responsibility students ($p < 0.05$). Students demonstrating greater responsibility consistently outperform their peers across all creative thinking metrics, including solution fluency, flexibility, and originality. This finding underscores responsibility's critical role as a success factor in CPjBL environments (Table 3).

Table 3. Hypothesis Test Results Comparing Creative Thinking Skills by Responsibility Level

Test Statistics^a

	Creative
Mann-Whitney U	144.500
Asymp. Sig. (2-tailed)	0.000

a. Grouping Variable: Class

Students with high responsibility levels exhibit three key competencies: (1) autonomous task completion, (2) generation of creative solutions, and (3) exploration of novel concepts [13]. Their strong commitment to timely, high-quality submission of assignments reflects greater disciplinary accountability, which facilitates extended engagement in creative ideation processes. Furthermore, these students demonstrate enhanced self-direction and proactive problem-solving behaviors [14], with their intrinsic motivation and task ownership driving innovative conceptual development.

Conversely, students with low responsibility display dependence on peer assistance, task procrastination, and frequent deadline neglect. These behaviors create time-compressed work conditions that may: (1) induce stress-mediated creative inhibition and (2) reduce exploratory motivation [15]. Such patterns ultimately constrain innovative task approaches.

Metacognitive skill disparities between these groups are statistically significant ($p < 0.05$), with high-responsibility students outperforming their peers across all measured metacognitive dimensions (Table 4).

Table 4. Summary of Hypothesis Testing Results for Metacognitive Skills and Responsibility

Test Statistics^a

	Metacognitive
Mann-Whitney U	132.500
Asymp. Sig. (2-tailed)	0.00

a. Grouping Variable: Class

High-responsibility learners exhibit superior self-regulation capabilities, characterized by: (1) Systematic goal-setting and strategic learning plan formulation, (2) Continuous self-monitoring of comprehension, including: Real-time difficulty identification and Adaptive corrective implementation [16], (3) Strategic flexibility, employing multimodal approaches: Active note-taking, Peer-mediated discourse, Dynamic strategy adjustment, (4) Critical outcome evaluation through: Goal attainment assessment, and Metacognitive gap analysis [17].

Conversely, low-responsibility learners demonstrate significant self-regulatory deficits: (1) Unstructured learning patterns lacking: Defined objectives and Systematic planning [18], (2) Compromised monitoring capacity manifesting as: Impaired difficulty recognition and Corrective action omission, (3) Cognitive inflexibility through: Single-strategy dependence and Adaptive failure, (4) Superficial self-evaluation marked by: Uncritical outcome acceptance and Limited reflective depth [17].

The CPjBL instructional model demonstrates significant moderation by responsibility level, with differential metacognitive gains: (1) High-responsibility cohort shows maximal improvement, indicating: Enhanced strategic planning, Improved monitoring fidelity, and Sophisticated evaluation skills, (2) Low-responsibility cohort exhibits attenuated effects, suggesting: Baseline self-regulatory constraints and Implementation fidelity challenges (Table 5).

Table 5. Summary of Hypothesis Test Results for the Interaction Between Learning Model and Responsibility in Enhancing Metacognitive Skills

Dependent Variable: metacognitive skill			
Source	Mean Square	F	Sig.
Model	323.113	11.890	0.001
Responsibility	95.251	3.505	0.037
model * responsibility	4.279	2.084	0.013
a. R Squared = .817 (Adjusted R Squared = .768)			

Throughout project implementation, students exercise metacognitive control by systematically monitoring their progress. This involves ongoing reflection on strategy effectiveness, evaluation of developmental milestones, and identification of support requirements—core competencies that align with established metacognitive frameworks [19]. The planning phase demands particular metacognitive sophistication, as students must delineate actionable steps, establish measurable objectives, and select context-appropriate strategies, all of which constitute fundamental aspects of self-regulated learning [20]. When encountering complex problems, students further demonstrate metacognitive competence by continuously evaluating their problem-solving approaches while generating and assessing potential solutions. The learning cycle culminates in comprehensive project evaluation, requiring critical analysis of both procedural effectiveness and final outcomes, followed by evidence-based adjustments for future work a process that epitomizes advanced metacognitive capability [21].

Our analysis revealed a significant interaction between CPjBL pedagogy and student responsibility levels in facilitating creative skill development. The CPjBL framework proved particularly effective in enhancing creative competencies among high-responsibility students, who demonstrated marked improvements across three key dimensions: ideational fluency increased, solution originality scores showed significant gains, and conceptual elaboration quality improved substantially. These findings suggest that responsibility level serves as a critical moderating variable, where the combination of CPjBL's collaborative structure with high intrinsic accountability creates optimal conditions for creative skill development through enhanced task engagement and metacognitive regulation (Table 6).

Table 6. Summary of Hypothesis Test Results for the Interaction Between Learning Model and Responsibility in Enhancing Creative Thinking Skills

Dependent Variable: creative thinking skills			
Source	Mean Square	F	Sig.
Model	288,676	9,679	0,003
Responsibility	373,914	12,537	0,001
model * responsibility	41,546	1,393	0,024
a. R Squared = .830 (Adjusted R Squared = .720)			

The collaborative team structure inherent in this pedagogical approach necessitates individual accountability for creative problem-solving and innovative solution development. Within this framework, peer interaction facilitates ideation through three key mechanisms: (1) reciprocal knowledge sharing, (2) integration of multidisciplinary perspectives, and (3) synergistic creativity stimulation [22]. This dynamic is further enhanced by students' autonomous exploration of project topics, which cultivates responsibility through self-directed research, problem conceptualization, and solution generation. The procedural demands of project design and implementation serve as catalysts for creative capacity building, requiring learners to devise context-specific innovations to overcome project challenges.

The learning cycle culminates in rigorous metacognitive evaluation, wherein students systematically assess both their collaborative processes and final outputs. This evaluative phase promotes advanced creative thinking through three dimensions: (1) iterative refinement of proposed concepts, (2) evidence-based efficacy assessment of implemented solutions, and (3) identification of optimization pathways [23, 24]. The continuous responsibility framework from initial ideation through final evaluation thus establishes an ecosystem that concurrently develops both creative competence and professional accountability.

CPjBL significantly enhanced creative thinking, specifically in fluency and originality. The collaborative environment allowed for "brainstorming" sessions where students could negotiate ideas [43, 44]. The significant interaction effect ($p = 0.024$) proves that intrinsic motivation is a powerful moderator of creative output [46, 47].

When students feel ownership over their projects, they pursue non-conventional solutions [48, 49]. This study confirms that accountability in group work prevents "social loafing" and encourages diverse perspectives [50, 51].

CONCLUSION AND SUGGESTION

This study provides empirical evidence that Collaborative Project-Based Learning (CPjBL) integrated with Electronic Worksheets is a powerful pedagogical framework for chemistry education. The evaluation of the four proposed hypotheses is summarized as follows: Evaluation of Hypothesis 1: The results confirm that CPjBL with E-LKM outperforms traditional PjBL in enhancing metacognitive skills. Students in the CPjBL group achieved a significantly higher N-Gain of 0.76 compared to 0.66 in the control group, driven by the model's structured reflection and peer evaluation phases. Evaluation of Hypothesis 2: The hypothesis that CPjBL fosters greater creative thinking was validated. The CPjBL group achieved an N-Gain of 0.87 versus 0.70 in the PjBL group, notably producing four distinct alternative solutions for chemical waste problems compared to only one solution in the traditional PjBL group. Evaluation of Hypothesis 3: The study verified that student responsibility is a decisive factor in skill acquisition. High-responsibility students demonstrated significantly greater gains in both metacognitive and creative thinking domains ($p < 0.05$) compared to their low-responsibility peers. Evaluation of Hypothesis 4: A significant interaction effect was confirmed, proving that responsibility moderates the effectiveness of the CPjBL model. Statistical analysis revealed significant interaction values for both metacognitive skills ($p = 0.013$) and creative thinking skills ($p = 0.024$), indicating that the synergy between collaborative pedagogy and student accountability creates optimal learning conditions. In summary, the implementation of CPjBL systematically cultivates essential 21st-century skills, particularly when students take ownership of their learning tasks. These findings suggest that instructional design in chemistry must not only incorporate collaborative technology but also actively foster a sense of personal responsibility among learners.

REFERENCES

[1] Dede, C. (2010). *Comparing frameworks for 21st century skills*. In J. Bellanca & R. Brandt (Eds.), 21st Century Skills: Rethinking How Students Learn. Bloomington: Solution Tree Press.

[2] Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of*

Bloom's taxonomy of educational objectives. New York: Longman.

[3] Sternberg, R. J. (2006). *The Nature of Creativity*. Cambridge: Cambridge University Press.

[4] Gilbert, J. K. (2006). On the nature of context in chemical education. *International Journal of Science Education*, 28(9), 957-976. https://doi.org/10.1080/09500690600702470

[5] Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, 16(3), 235-266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

[6] Krajcik, J. S., & Blumenfeld, P. C. (2006). *The Cambridge Handbook of the Learning Sciences*. Cambridge: Cambridge University Press.

[7] Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House*, 83(2), 39-43. https://doi.org/10.1080/00098650903505415

[8] Larmer, J., & Mergendoller, J. R. (2010). *7 Essentials for Project-Based Learning*. Alexandria: ASCD.

[9] Thomas, J. W. (2000). *A review of research on project-based learning*. San Rafael: Autodesk Foundation.

[10] Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher*, 38(5), 365-379. https://doi.org/10.3102/0013189X09339057

[11] Laal, M. (2013). Collaborative learning; elements. *Procedia-Social and Behavioral Sciences*, 93, 1433-1437. https://doi.org/10.1016/j.sbspro.2013.10.058

[12] Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W.H. Freeman.

[13] Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge: Harvard University Press.

[14] Henri, F. (1992). Computer conferencing and content analysis. *Collaborative learning through computer conferencing*, 117-136. https://doi.org/10.1007/978-3-642-77684-7_6

[15] Kozma, R. B. (2003). *Technology, Innovation, and Educational Change*. Eugene: ISTE.

[16] Rowais, A. S. (2019). The Impact of Using Electronic Worksheets on Achievement. *Journal of Educational Technology & Society*, 22(3), 45-58.

[17] McCombs, B. L. (2015). *Learner-centered education*. Washington: American Psychological Association.

[18] Anthonysamy, L. (2021). The use of metacognitive strategies for undisrupted online learning. *Education and Information Technologies*, 26(6), 6881-6899. https://doi.org/10.1007/s10639-021-10518-y

[19] Bromley, P. (2018). The role of metacognition in project-based learning. *Educational Psychology Review*, 30(4), 567-589. https://doi.org/10.1007/s10648-018-9438-6

[20] Stanton, J. D., Neider, X. N., Gallegos, I. J., & Clark, N. C. (2021). Differences in metacognitive regulation. *CBE—Life Sciences Education*, 20(2). https://doi.org/10.1187/cbe.20-12-0289

[21] Hussein, B. (2021). Collaborative project-based learning: A review. *International Journal of Instruction*, 14(1), 253-270. https://doi.org/10.29333/iji.2021.14115a

[22] Suyadi. (2013). *Strategi Pembelajaran Berbasis Proyek Kolaboratif*. Yogyakarta: Pustaka Pelajar.

[23] Asy'ari, M., Ikhsan, M., & Muhali. (2016). The Effectiveness of Inquiry Learning Model. *Journal of Education and Practice*, 7(5), 1-6.

[24] Siregar, N., & Rosidah, A. (2020). Implementing Project Based Learning in Chemistry. *Journal of Science*

Education, 24(1), 78-92. https://doi.org/10.21831/jser.v4i1.34123

[25] Hake, R. R. (1998). Interactive-engagement versus traditional methods. *American Journal of Physics*, 66(1), 64-74. https://doi.org/10.1119/1.18809

[26] Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology*, 19(4), 441-454. https://doi.org/10.1006/ceps.1994.1033

[27] Torrance, E. P. (2017). *Torrance Tests of Creative Thinking*. Bensenville: Scholastic.

[28] Guilford, J. P. (1967). *The nature of human intelligence*. New York: McGraw-Hill.

[29] Lickona, T. (2015). *Educating for character*. New York: Bantam.

[30] Nurachim, A. (2017). *Pendidikan Karakter dan Tanggung Jawab Mahasiswa*. Bandung: PT. Remaja Rosdakarya

[31] Zimmerman, B. J. (2002). Becoming a self-regulated learner. *Theory Into Practice*, 41(2), 64-70. https://doi.org/10.1207/s15430421tip4102_2

[32] Pintrich, P. R. (2000). *Handbook of Self-Regulation*. San Diego: Academic Press.

[33] Flavell, J. H. (1979). Metacognition and cognitive monitoring. *American Psychologist*, 34(10), 906-911. https://doi.org/10.1037/0003-066X.34.10.906

[34] Efklides, A. (2006). Metacognition and affect. *Learning and Instruction*, 16(1), 3-14. https://doi.org/10.1016/j.learninstruc.2005.12.003

[35] Kuhn, D. (2000). Metacognitive development. *Developmental Review*, 20(2), 178-181. https://doi.org/10.1006/drev.1999.0507

[36] Hargrove, R. A., & Nietfeld, J. L. (2015). The impact of metacognitive instruction. *Journal of Experimental Education*, 83(3), 291-318. https://doi.org/10.1080/00220973.2013.876604

[37] Jia, X., Li, W., & Cao, L. (2019). The Role of Metacognitive Skills in Creative Thinking. *Frontiers in Psychology*, 10, 2404. https://doi.org/10.3389/fpsyg.2019.02404

[38] Nurainiyah, S. (2017). Analisis Tanggung Jawab Mahasiswa. *Jurnal Pendidikan Kimia*, 9(2), 45-56.

[39] Newman, F. M. (2005). *Authentic achievement*. San Francisco: Jossey-Bass.

[40] Tan, O. S. (2009). *Problem-based learning and creativity*. Singapore: Cengage.

[41] Shamir, A., Mevarech, Z. R., & Gesser, C. (2008). Effects of peer mediation. *Learning and Instruction*, 18(2), 130-140. https://doi.org/10.1016/j.learninstruc.2007.01.012

[42] Darmuki, A., Bacangallo, R., & Yayuk, E. (2023). Metacognitive strategies in collaborative learning. *Journal of Educational Research*, 116(2), 123-140.

[43] Hidayah, R., Fajaroh, F., Dasna, I. W., & Parlan. (2022). The development of chemistry electronic student worksheet (E-LKM) based on collaborative project-based learning. *AIP Conference Proceedings*, 2569(1), 020011. https://doi.org/10.1063/5.0113110

[44] Slavin, R. E. (1991). Synthesis of research on cooperative learning. *Educational Leadership*, 48(5), 71-82.

[45] Yayuk, E., & Purwanto, A. (2020). Effect of PjBL on creativity. *Journal of Creative Behavior*, 54(3), 567-580. https://doi.org/10.1002/jocb.415

[46] Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits. *Psychological Inquiry*, 11(4), 227-268. https://doi.org/10.1207/S15327965PLI1104_01

[47] Amabile, T. M. (2012). *Creativity in context*. Boulder: Routledge.

[48] Bacangallo, R., et al. (2022). Innovation in Chemistry Classrooms. *Journal of Creative Education*, 13(3), 45-60. https://doi.org/10.4236/ce.2022.133031

[49] Runco, M. A., & Jaeger, G. J. (2012). The standard definition of creativity. *Creativity Research Journal*, 24(1), 92-96. https://doi.org/10.1080/10400419.2012.650092

[50] Garrison, D. R. (1997). Self-directed learning. *Higher Education*, 33(1), 18-33. https://doi.org/10.1023/A:1002905116532

[51] Lin, S., & Tsai, C. C. (2024). Collaborative learning and cognitive load. *Educational Psychology Review*, 36(1). https://doi.org/10.1007/s10648-023-09840-7