JPIS JURNAL PENDIDIKAN ILMU SOSIAL
p-ISSN: 1412-3835
e-ISSN: 2541-4569
VOL 33, NO. 2, DES 2023

ENHANCING ENVIRONMENTAL DECISION-MAKING: THE ROLE OF DOUBLE-LOOP SPATIAL LEARNING AND GAMIFICATION

Frida Vania Alfizahr[1], Alfyananda Kurnia Putra[2], Syazwani Binti Sazali[3]
[1,2] Faculty of Social Sciences, Universitas Negeri Malang, Indonesia
[3] Universitas Kuala Lumpur, Malaysia
email: frida.vania.2007216@students.um.ac.id

ABSTRACT

The Double-Loop Spatial Learning model presents a form of integration with various educational materials, particularly in the context of inland waters within the dynamics of the hydrosphere. This research aims to ascertain the impact of the gamification-assisted double-loop spatial learning model on the critical thinking abilities and environmental decision-making in the study of inland water dynamics pertaining to hydrospheric material, employing a quasi-experimental research type with a non-equivalent control group design for the research design. The sampling technique used was purposive sampling, resulting in the selection of students from the 10th grade Social Science 1 class as the experimental group and the 10th grade Social Science 2 class as the control group. Based on the results of the independent sample t-test, it is indicated that there is a significant effect of the gamification-assisted Double-Loop Spatial Learning model on the critical thinking abilities and environmental decision-making in the experimental group's study of inland waters, with the t-test values obtained being 10.938 for critical thinking ability and 3.522 for environmental decision making.

Keywords: *Double-loop spatial learning, gamification, critical thinking, environmental decision making*

Received: *09 November 2023*
Accepted: *07 Desember 2023*
Published: *23 Desember 2023*

INTRODUCTION

The landscape of geography education has undergone significant transformations over time. This encompasses the methodologies through which students engage with specific subjects for educational purposes, as well as the developmental advantages accruing to students. Geographic education extends beyond the exploration of Earth's physical representation to also facilitate cognitive development. The capacity to comprehend and analyze phenomena from a spatial perspective is central (Lü et al., 2019). The relationship between objects and places within a spatial framework—a critical skill with practical applications in decision-making and problem-solving (Delgado et al., 2019; Zhong et al., 2018). Despite its affirmed importance in the literature, there is a shortfall in the implementation of effective approaches to integrate spatial thinking into the geography curriculum effectively (Lowrie et al., 2019).

Critical thinking is the deliberate process through which individuals assess the merit of their ideas using a rational, reflective, independent, and clear approach. Recent research indicates that critical thinking, particularly within the context of geography, is essential for enabling students to logically excavate and evaluate information, forming deeper understandings (Herawati, 2022), of environmental phenomena (Shaw et al., 2020; Turohmah et al., 2021). However, data from the Programme for International Student Assessment (PISA) in 2018 reveals that the critical thinking abilities of Indonesian students—specifically in science—are far from satisfactory, with 35% of students falling below the threshold of basic competence (PISA, 2018). This limitation indicates an urgent need to develop educational strategies that bolster these capabilities.

Furthermore, the Environmental Performance Index report of 2022 underscores a significant shortfall in environmental concern within Indonesia, where the nation scored a mere 28.2 out of 100, positioning it at an alarmingly low rank globally (Environmental Performance Index, 2022). This indicates the imperative need to incorporate environmental ethical values into geographic education, an aspect that has not been comprehensively integrated into the geography education curriculum (Alabas, 2021).

In light of this gap, the present study proposes the Double-Loop Spatial Learning model as an innovation in geographic education. This model is designed not only to develop students' critical thinking in the context of geography but also to facilitate informed environmental decision-making (Muhammad & Purwanto, 2020). The Double-Loop concept, which encourages students to engage in continuous reflection and evaluation processes, has not been widely adopted or tested in the Indonesian context, particularly in challenging topics such as inland waters (Putra, Sumarmi, Fajrilia, et al., 2021). This study aims to bridge this gap by investigating how this innovative learning model can influence students' understanding of geography and enhance their ability to apply this knowledge in real-world contexts, especially when facing the increasingly complex environmental challenges (Vauras et al., 2019).

Double-Loop Spatial Learning is a specialized learning model designed to cultivate cognitive skills, enabling individuals to effectively navigate challenges and make informed decisions. In the endeavor to integrate theory and practice, the Double-Loop Spatial Learning model strives to bolster a holistic approach to geographic education by training students to connect theoretical understanding with actual spatial phenomena through practical application and visual representation (Matthies & Coners, 2018). The implementation of this model prioritizes the habituation of profound critical thinking, focusing on cognitive aspects that are identifiable and observable, introducing a new paradigm in geographic education (Kuhn, 2019).

However, existing literature has not fully elucidated how this learning model impacts students' critical thinking abilities within the context of the hydrosphere—an area that urgently necessitates further research, considering the urgency of increasingly complex environmental issues (Markus et al., 2018). Within this context, the model promises the development of robust skills for addressing issues of inland waters, prioritizing strategic thinking and effective solutions (Burzynski et al., 2020).

Implementing the DLSL model, students are prompted to cultivate critical thinking skills, nurture a visionary mindset, and foster logical and coherent reasoning. Furthermore, this model endeavors to foster a deeper understanding of Environmental Decision-Making, preparing students to address realistic spatial issues (Elsawah et al., 2020). This requires sustained interaction between students and the environment, promoting creative behavior in decision-making (Efendi et al., 2020)— a critical aspect that has not been thoroughly explored within the context of Indonesian geographic education (Davies et al., 2021).

In this research, the selection of materials is anchored in the pivotal role of the hydrosphere in sustaining life, particularly its significance as a focal point in geography education. The hydrosphere material, which relates to the spatial and ecological aspects of social life (Syaibana et al., 2022), provides students with opportunities to address significant questions about the world around them (Santoso, 2022). However, there is a gap in the literature regarding how the Double-Loop Spatial Learning approach, with a focus on hydrosphere material, can facilitate analytical critical thinking in a broader context of spatial decision-making (Rizqiyah et al., 2023; Tsutsui et al., 2022).

This study also investigates the potential of gamification as a strategy to enhance student engagement in the learning process. Although gamification has been recognized as a tool to increase motivation and engagement within the context of digital learning, its application in the context of geographic education, especially pertaining to hydrospheric content, has not been extensively explored (Kalogiannakis et al., 2021; Putra, Sumarmi, et al., 2022). Gamification can provide an interactive and engaging environment, potentially transforming students' perceptions of analytical learning into a more enjoyable experience (Mattawang & Syarif, 2023). This approach can facilitate cognitive, behavioral, and affective engagement of students in learning, which is crucial for deep understanding and application of geographic concepts in real life (Kim & Castelli, 2021; Luo, 2022).

Gamification elements such as leaderboards, quests, points, progress bars, and rewards, when well-designed, can enhance critical thinking abilities and environmental decision-making by creating a more dynamic and contextual learning environment (Oliveira et al., 2021; Schlömmer et al., 2021). By identifying and addressing this gap, the present study aims to test the influence of the Double-Loop Spatial Learning model integrated with gamification elements on students' critical thinking abilities and Environmental Decision-Making in hydrosphere content. This is a significant step towards understanding how geographic education can be more effective in developing the competencies needed to face environmental challenges in the modern era.

However, current discourse in geographic education research reveals a gap in understanding the long-term impact of iterative learning models such as DLSL on students' attitudes and actions towards the environment. There is a deficiency in longitudinal studies that track the evolution of students' environmental attitudes and actions following interventions with models like DLSL. In response to this gap, this study aims to longitudinally assess the impact of DLSL on students' environmental attitudes and behaviors, providing empirical evidence for the sustainability and scalability of such pedagogical interventions within geographic education.

RESEARCH METHOD

The Double-Loop Spatial Learning Model provides an integrative framework that enriches pedagogical content, especially in the context of studying inland waters as part of the hydrological cycle. Learning geography as an empirical science can utilize this model aided by the use of GimKit to enhance applicability and illustrate its impact on the quality of student learning. Therefore, this study aims to elucidate the following research questions (RQs):

RQ 1: How does Gamification-Supported Double-Loop Spatial Learning affect Critical Thinking Abilities in the study of Inland Waters within the Hydrological Cycle?
RQ 2: How does Double-Loop Spatial Learning influence Environmental Decision-Making in the study of Inland Waters within the Hydrological Cycle?

This research adopts a quasi-experimental design with a non-equivalent control group to assess the efficacy of Gamification-Supported Double-Loop Spatial Learning in fostering students' capacities for critical thinking and environmental decision-making. This design was chosen to facilitate controlled comparisons between the experimental and control groups, considering the limitations present in authentic educational settings. Table 1 outlines the research design scheme in detail.

Table 1.
Research Design

Experiment Group	X	O
Control Group	-	O

Source: Sugiyono (2017)

Explanation:
X : Treatment with Gamification-Assisted Double-Loop Spatial Learning Model
- : Treatment with Instructional Learning Model
O : Posttest for Critical Thinking and Environmental Decision Making

The subjects of this study comprised first-level students (grade X) in the Social Sciences program at SMA Islam Almaarif Singosari for the Even Semester of the Academic Year 2022/2023. The research was conducted from February 27 to April 20, 2023.

The determination of subjects was done by purposive sampling based on: (1) students' availability to actively participate during the research period; (2) the diversity of students' understanding of geography concepts; and (3) having been involved in learning by using learning techniques that utilize information technology, which is relevant to the research focus.

Social Science group X-1 (Female: 17, Male: 13) was the experimental group was treated with the gamification-assisted Double-Loop Spatial Learning model, and Social Science group X-2 (Female: 15, Male: 15) was the control group received instructional learning and conventional media.

Students' critical thinking abilities were measured using an objective test instrument in a multiple-choice format. This instrument comprised 10 questions based on six predetermined indicators of critical thinking ability, the details of which are illustrated in Table 2. These questions were designed to comprehensively measure the cognitive aspects of students and are in accordance with the prevailing principles of learning evaluation.

Instead, an open-ended questionnaire with six questions was used to measure environmental decision-making ability. As shown in Table 3, indicators by Mincemoyer & Perkins were used as the basis for the construction of these questions.

The validation and reliability testing were conducted using statistical methods appropriate for ensuring that the instruments employed possess dependable validity (Pearson or Spearman) and reliability (Cronbach's Alpha). This statistical analysis declared that the instrument for critical thinking ability had a validity value of 0.361 and a reliability of 0.705, both falling within the high category. As for the environmental decision-making instrument, the validity value was 0.254 and the reliability was 0.703, which are also considered high.

A threshold value of 0.70 or higher typically denotes a commendable instrument; however, it is contingent upon the subject of research, and in some cases, lower values may be deemed acceptable.

Table 2.
Critical Thinking Indicators According to Facione

No.	Indicator	Sub-Indicator
1.	Interpretation	The ability to understand a problem
2.	Analysis	The ability to identify and draw conclusions on the relationships among questions, statements, concepts, descriptions, or other forms
3.	Evaluation	The ability to assess the credibility of statements and logically appraise the relationships among statements, descriptions, questions, or concepts
4.	Inference	The ability to identify elements used to draw conclusions

No.	Indicator	Sub-Indicator
5.	Explanation	The ability to assert confidently and reason logically based on obtained results
6.	Self Regulation	The ability to resolve problems and to apply analytical and evaluative skills

Source: Facione in Faiziyah, 2022

Table 3.
Environmental Decision Making Indicator According to Mincemoyer &Perkins

No.	Indicator	Sub-Indicator
1.	Define Problem	Capable of identifying, detailing, and clearly understanding a problem
2.	Generate Alternatives	Able to consider formulations of various problem-solving alternatives in order to select the most effective and efficient
3.	Check Risk and Consequences	Competent in analyzing risks and consequences based on the formulated alternatives
4.	Select Alternatives	Capable of choosing the most suitable solution or alternative from the various options available
5.	Evaluation	Able to determine the extent to which a solution or action succeeds in achieving the desired goal

Source: Mincemoyer & Perkins (in Fahrudin, 2019)

To meet the requirements of rigorous statistical analysis, this study analyzed the data through two important stages. First, a normality test using Shapiro-Wilk, which was chosen due to the small sample size. The normality test results indicated a Sig. value of 0.077 for the experimental group in critical thinking ability, 0.094 for the control group in the same variable, 0.112 for the experimental group in environmental decision making, and 0.118 for the control group in the same variable, confirming the normal distribution of data.

Subsequently, the homogeneity of variance was tested using Levene's Test for its capacity to effectively test for variance homogeneity without considering the normal distribution of data. The specific Sig. value for the homogeneity of the experimental group in critical thinking ability was 0.082, while for the environmental decision making variable it was 0.297, as detailed in Table 4.

Table 4.
Levene's test for Equality of Variance Data Results

		Levene Statistic	df1	df2	Sig.
Posttest Berpikir Kritis	Based on Mean	3.135	1	58	.082
	Based on Median	3.147	1	58	.081
	Based on Median and with adjusted df	3.147	1	57.372	.081
	Based on trimmed mean	3.157	1	58	.081
Posttest Environmental	Based on Mean	1.109	1	58	.297
	Based on Median	1.106	1	58	.297

Decision Making	Based on Median and with adjusted df	1.106	1	57.999	.297
	Based on trimmed mean	1.072	1	58	.297

Source: Data Analysis Results by the Researcher (2023)

Assuming the fulfillment of criteria for normal distribution and homogeneity of variance, the subsequent procedure was the testing of comparative hypotheses. An Independent Sample t-Test was applied to assess the impact of the Double-Loop Spatial Learning model integrated with gamification on critical thinking abilities and environmental decision making. This test compared the mean posttest scores between the experimental and control groups to identify any statistically significant differences, indicative of the intervention's effectiveness.

RESULTS AND DISCUSSION

Research Finding on Problem Question I

In answering the question posed by the first research question (RQ 1), hypothesis testing is required to determine the acceptance or rejection of the null hypothesis (H_0). The difference in mean scores between the experimental and control groups at the time of the post-test was examined using an independent samples t-test. The results are depicted in Tables 4 and 5 below.

Table 5.
Critical Thinking Posttest Result

Group	N	Mean	Std. Deviation
Experiment	30	90	4,275
Control	30	80	8,155

Source: Data Analysis Results by the Researcher (2023)

Based on Table 5, students taught with the Double-Loop Spatial Learning model exhibited higher mean scores in the experimental group for critical thinking ability posttests compared to the control group.

Table 6.
Critical Thinking Independent Sample t-test Results

		Levene's test for equality of variances		t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Critical Thinking Posttest	Equal variances assumed	3.135	.082	10.938	58	.000	8.866
	Equal variances not assumed			10.938	53.935	.000	8.866

Source: Data Analysis Results by the Researcher (2023)

Referencing Table 6, the results of the independent t-test reveal that the hypothesis test is significant with 0.000<0.05, indicating a significant difference. This data suggests that the Double-Loop Spatial Learning model, assisted by gamification, has an impact on critical thinking abilities. Therefore, the null hypothesis H_0 is rejected.

Research Finding on Problem Question II

Regarding the second research question (RQ 2), which inquires about the impact of the Double-Loop Spatial Learning model on environmental decision-making in geography education, the details can be observed in Table 7.

Table 7.
Scoring Results of Environmental Decision Making Questionnaire

Class	**N**	**Mean**	**Std. Deviation**
Eksperimen	30	89	6,123
Kontrol	30	84	5,318

Source: Data Analysis Results by the Researcher (2023)

Based on Table 7, an average difference of approximately 5 between the experimental and control groups signifies a higher mean score for the experimental class, indicating that the Double-Loop Spatial Learning model effectively enhances environmental decision-making skills within the context of hydrosphere studies.

Table 8.
Environmental Decision Making Independet Sample t-test Results

		Levene's test for equality of variances		**t-test for Equality of Means**		
		F	Sig	T	Sig. (2-*tailed)*	Mean Difference
Posttest Environmental Decision Making	Equal variances assumed	1.109	.297	3.522	.001	5.20000
	Equal variances not assumed			3.522	.001	5.20000

Source: Data Analysis Results by the Researcher (2023)

Referencing Table 7, the results of the independent t-test reveal that the hypothesis test yielded a p-value of 0.001, which is less than the significance threshold of 0.05, thereby indicating a statistically significant difference. This data suggests that the Double-Loop Spatial Learning model exerts an influence on environmental decision-making. Consequently, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted, confirming that the experimental intervention has a positive effect.

DISCUSSION

Geographic education is not merely a subject taught in schools but also serves as a vital conduit for environmental learning, acting as a catalyst in the development of attitudes, values, and environmental consciousness. This form of education equips students with the necessary knowledge and skills to engage in environmentally responsible actions (Ardoin et al., 2020). In this context, innovative pedagogical models such as Double-Loop Spatial Learning (DLSL) are beginning to gain traction. The DLSL model, as conceptualized by Lockwood & De Chenne (2020), involves an iterative cycle in which students are actively engaged in discovering and analyzing spatial representations of environmental issues.

The DLSL model transcends traditional learning paradigms by fostering a profound and reflective process in which students not only absorb information about environmental phenomena but also critically evaluate and redesign solutions within realistic contexts (Castro, 2023). This pedagogical approach is in line with the principles of experiential learning theory, which posits that learning is enhanced when students are involved in processes that allow them to reflect on their experiences and apply their knowledge to real-world scenarios.

The novelty of the Double-Loop Spatial Learning (DLSL) model lies in its recursive nature, allowing students to continuously revisit and refine their understanding of environmental issues. This iterative process represents a departure from linear educational models, enabling a more nuanced comprehension of the complexities inherent in environmental systems. Kwangmuang et al., (2021) underscore the efficacy of this approach in stimulating cognitive skills, particularly in problem-solving and critical thinking, which are vital for addressing the multifaceted challenges of environmental sustainability.

The Double-Loop Spatial Learning with Gamification on Critical Thinking Skills

Our data analysis reveals a significant improvement in the average critical thinking ability scores of students in the experimental class compared to the control class, with an increase in mean scores of 10 points. This higher average score indicates that the integration of the Double-Loop Spatial Learning model with gamification elements contributes positively to the enhancement of students' critical thinking and environmental decision-making skills. The statistical validity of these findings is reinforced by an independent t-test yielding a p-value of less than 0.05, affirming that the differences observed are statistically significant and not due to chance.

The consistency of these findings with the existing theoretical framework suggests that the interactive and reflective learning, characteristic of the Double-Loop Spatial Learning model, facilitates the enhancement of critical thinking skills (Daniel et al., 2020). The implemented learning syntax — encompassing observation, confirmation, representation, data processing, solution analysis, and conclusion — correlates directly with the cognitive processes involved in critical thinking as elucidated by Facione (Azzahra & Fauzan, 2023; Faiziyah & Priyambodho, 2022).

Learning activities such as the representation of findings and the analysis of solutions enrich students' learning experiences by engaging them in the encoding and storage of spatial information and the construction of data visualizations, which explicitly support the development of critical thinking (Lukic, 2022) and enhance problem-solving (Melinda & Rahmawati, 2021; Silviariza et al., 2021).

The application of gamification through GimKit, and specifically the Snowbrawl mode, has demonstrated effectiveness in enhancing student engagement through competitive and reward-based mechanisms, which support increased motivation and participation in the learning process (Putra et al., 2022). Although these activities are individual, elements such as leaderboards and point systems create a dynamic learning environment and encourage collaboration (Uz Bilgin & Gul, 2020).

These findings underscore the importance of integrating technology into geography education and provide evidence that learning involving gamification can be an effective tool for engaging students in a broader learning context. The reproduction and application of this model across various educational settings will yield additional insights into how technology and innovative learning methods can be adapted to support the development of critical thinking competencies and environmental decision-making abilities among students.

The Double-Loop Spatial Learning Model's Impact on Environmental Decision-Making

The Double-Loop Spatial Learning (DLSL) model has proven effective in integrating critical thinking and problem-solving learning, providing students with the means to critically analyze environmental issues and select the most appropriate solutions (Riana, 2020). Furthermore, this model invites students to reflect on and critique their problem-solving approaches by formulating and evaluating alternative solutions before making decisions (Clark, 2021). This iterative process is vital for effective environmental decision-making.

To gain a better understanding of the effectiveness of DLSL in the context of environmental decision-making, we aligned the environmental decision-scoring outcomes with an assessment rubric that had been developed. This rubric includes indicators derived from research variables for each involved class. In Table 9 and Table 10, not presented here, we compare the scores per indicator between the experimental class, which employed the DLSL model, and the control class, which followed the standard curriculum.

Tabel 9.
Experiment Group Scoring Results of Environmental Decision-Making Indicators

		Experiment Group	**N=30**
No.	**Indicator**	**Sub-Indicator**	**Scoring**
1.	Define Problem	Able to identify, delineate, and comprehend an issue with clarity	83
2.	Generate Alternatives	Capable of contemplating various problem-solving alternatives to select the most effective and efficient solution	85
3.	Check Risk and Consequences	Able to analyze risks and consequences based on the formulated alternatives	84
4.	Select Alternatives	Capable of selecting the most appropriate solution or alternative from the available options	83
5.	Evaluation	Able to ascertain the extent to which a solution or action successfully achieves the desired objective	73

Source: Data Analysis Results by the Researcher (2023)

Table 10.
Control Group Scoring Results of Environmental Decision Making Indicators

		Control Group	**N=30**
No.	**Indicator**	**Sub-Indicator**	**Scoring**
1.	Define Problem	Able to identify, detail, and understand an issue clearly	74
2.	Generate Alternatives	Capable of contemplating the formulation of various problem-solving alternatives in order to select the most effective and efficient solution to select the most effective and efficient solution	72
3.	Check Risk and Consequences	Able to analyze the risks and consequences based on the formulated alternatives	73,5
4.	Select Alternatives	Capable of selecting the most suitable solution or alternative from the available options	75
5.	Evaluation	Able to ascertain the extent to which a solution or action has succeeded in achieving the intended objectives	72

Source: Data Analysis Results by the Researcher (2023)

The implementation of the Double-Loop Spatial Learning (DLSL) model has demonstrated a significant enhancement in students' environmental decision-making capabilities. This is evidenced by higher scores in the 'generate alternatives' indicator, signifying that students engaging with this learning model are more adept at identifying a range of potential solutions. They tend to be more effective and efficient in selecting the most relevant solutions to the environmental issues at hand. Conversely, lower scores on the 'evaluation' indicator suggest an opportunity for improvement in the students' ability to assess the sustainability and effectiveness of the chosen solutions. This underscores the need to strengthen the evaluative aspect of the DLSL model, which would enable students to not only generate alternatives but also understand the long-term consequences of their decisions on the environment.

The control class, with a more uniform distribution of scores, displayed moderate ability in selecting options from available alternatives. Nonetheless, they tended to be less competent in generating and evaluating a range of alternatives. This condition underlines the added value of DLSL in facilitating the development of these capabilities.

The geographical context of the research, centered on the Kali Metro Malang Watershed area, was chosen due to its relevance to the students' real-life experiences, which heightens engagement and enriches the learning context (Putra et al., 2021). This relevance is anticipated to enhance student engagement and the applicability of their ndecision-making skills. The implications of these findings suggest that the contextualization of learning materials can strengthen the relevance and applicability of the knowledge and skills taught, particularly in environmental decision-making (Colomer et al., 2020).

CONCLUSION

Based on the results of this study, it can be concluded that in the context of inland water learning, critical thinking skills and environmental decision making are significantly affected by the application of the Double-Loop Spatial Learning model assisted by gamification. On analyzing the data, it clearly shows that this model helps to think critically and make decisions about the environment. By combining a deeper spatial understanding process and a framework that allows students to respond more thoughtfully to environmental challenges, this learning model is innovative. Therefore, this study adds to the literature on environmental learning and demonstrates that the gamification-assisted Double-Loop Spatial Learning model is beneficial for improving students' cognitive and decision-making abilities. These findings can be used to transform the curriculum with a focus on critical thinking and environmental decision-making.

REFERENCES

Alabas, R. (2021). The Ethical Value of Human and Environmental Relations: the Place of Environment. *International Journal of Education Technology and Scientific Researches*, *6*(16), 1851–1906. https://doi.org/10.35826/ijetsar.388.

Ardoin, N. M., Bowers, A. W., & Gaillard, E. (2020). Environmental Education Outcomes for Conservation: A Systematic Review. *Biological Conservation*, *241*(April 2019), 108224. https://doi.org/10.1016/j.biocon.2019.108224.

Azzahra, S., & Fauzan, S. (2023). Computational Thinking of Accounting Students in Terms of Critical Thinking and Problem-Solving Skills. *Jurnal Pendidikan Ilmu Sosial*, *33*(1), 96–117. https://doi.org/10.23917/jpis.v33i1.22689.

Burzynski, M., Deuster, C., & Docquier, F. (2020). Geography of Skills and Global Inequality. *Journal of Development Economics*, *142*(November 2017), 102333. https://doi.org/10.1016/j.jdeveco.2019.02.003.

Castro, E. A. M. (2023). Analysis of Problem Solving Ability of First Middle School Students in Learning Science. *Integrated Science Education Journal*, *4*(2), 43–53. https://doi.org/10.37251/isej.v4i2.329.

Clark, K. (2021). Double-Loop Learning and Productive Reasoning: Chris Argyris's Contributions to a Framework for Lifelong Learning and Inquiry. *Midwest Social Sciences Journal*, *24*(1), 33–52. https://doi.org/10.22543/0796.241.1042.

Colomer, J., Serra, T., Cañabate, D., & Bubnys, R. (2020). Reflective Learning in Higher Education: Active Methodologies for Transformative Practices. *Sustainability (Switzerland)*, *12*(9), 1–8. https://doi.org/10.3390/su12093827.

Daniel, S., Janansefat, S., Diamant, E. I., & Ren, Y. (2020). Single- and Double-Loop Learning. *ACM SIGMIS Database: The DATABASE for Advances in Information Systems*, *51*(4), 68–92. https://doi.org/10.1145/3433148.3433153.

Davies, R. S., Davies, M. J., Groves, D., Davids, K., Brymer, E., Trench, A., Sykes, J. P., & Dentith, M. (2021). Learning and Expertise in Mineral Exploration Decision-Making: An Ecological Dynamics Perspective. *International Journal of Environmental Research and Public Health*, *18*(18). https://doi.org/10.3390/ijerph18189752.

Delgado, J. A., Short, N. M., Roberts, D. P., & Vandenberg, B. (2019). Big Data Analysis for Sustainable Agriculture on a Geospatial Cloud Framework. *Frontiers in Sustainable Food Systems*, *3*(July), 1–13. https://doi.org/10.3389/fsufs.2019.00054.

Efendi, N., Baskara, R. S., & Fitria, Y. (2020). Implementasi Karakter Peduli Lingkungan Di Sdn 13 Lolong Belanti Padang. *Jurnal Pendidikan Ilmu Sosial*, *29*(2), 155–165. https://doi.org/10.23917/jpis.v29i2.9747.

Elsawah, S., Hamilton, S. H., Jakeman, A. J., Rothman, D., Schweizer, V., Trutnevyte, E., Carlsen, H., Drakes, C., Frame, B., Fu, B., Guivarch, C., Haasnoot, M., Kemp-Benedict, E., Kok, K., Kosow, H., Ryan, M., & van Delden, H. (2020). Scenario Processes for Socio-Environmental Systems Analysis of Futures: A Review of Recent Efforts and A Salient Research Agenda for Supporting Decision Making. *Science of the Total Environment*, *729*, 138393. https://doi.org/10.1016/j.scitotenv.2020.138393.

Faiziyah, N., & Priyambodho, B. L. (2022). Analisis Kemampuan Berpikir Kritis Dalam Menyelesaikan Soal HOTS Ditinjau dari Metakognisi Siswa. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *11*(4), 2823. https://doi.org/10.24127/ajpm.v11i4.5918.

Herawati, H. (2022). Critical Thinking and Meaningful Learnings in Online Learning: Do Both Make Increases? *Jurnal Pendidikan Ilmu Sosial*, *32*(1), 1–13. https://doi.org/10.23917/jpis.v32i1.17468.

Kalogiannakis, M., Papadakis, S., & Zourmpakis, A. I. (2021). Gamification in Science Education: A Systematic Review of The Literature. *Education Sciences*, *11*(1), 1–36. https://doi.org/10.3390/educsci11010022.

Kim, J., & Castelli, D. M. (2021). Effects of Gamification on Behavioral Change in Education: A Meta-Analysis. *International Journal of Environmental Research and Public Health*, *18*(7). https://doi.org/10.3390/ijerph18073550.

Kuhn, D. (2019). Critical Thinking as Discourse. *Human Development*, *62*(3), 146–164. https://doi.org/10.1159/000500171.

Kwangmuang, P., Jarutkamolpong, S., Sangboonraung, W., & Daungtod, S. (2021). The Development of Learning Innovation to Enhance Higher Order Thinking Skills for Students in Thailand Junior High Schools. *Heliyon*, *7*(6), e07309. https://doi.org/10.1016/j.heliyon.2021.e07309.

Lockwood, E., & De Chenne, A. (2020). Enriching Students' Combinatorial Reasoning through the Use of Loops and Conditional Statements in Python. *International Journal of Research in Undergraduate Mathematics Education*, *6*(3), 303–346. https://doi.org/10.1007/s40753-019-00108-2.

Lowrie, T., Logan, T., & Hegarty, M. (2019). The Influence of Spatial Visualization Training on Students' Spatial Reasoning and Mathematics Performance. *Journal of Cognition and Development*, *20*(5), 729–751. https://doi.org/10.1080/15248372.2019.1653298.

Lü, G., Batty, M., Strobl, J., Lin, H., Zhu, A. X., & Chen, M. (2019). Reflections and Speculations on The Progress in Geographic Information Systems (GIS): A Geographic Perspective. *International Journal of Geographical Information Science*, *33*(2), 346–367. https://doi.org/10.1080/13658816.2018.1533136.

Lukic, D. (2022). What are Organisations Even There For? A Call For Deeper Double-Loop Learning. *Learning Organization*, *29*(4), 408–414. https://doi.org/10.1108/TLO-05-2022-284.

Luo, Z. (2022). Gamification for Educational Purposes: What are The Factors Contributing to Varied Effectiveness? *Education and Information Technologies*, *27*(1), 891–915. https://doi.org/10.1007/s10639-021-10642-9.

Markus, T., Hillebrand, H., Hornidge, A. K., Krause, G., & Schlüter, A. (2018). Disciplinary Diversity in Marine Sciences: The Urgent Case for An Integration of Research. *ICES Journal of Marine Science*, *75*(2), 502–509. https://doi.org/10.1093/icesjms/fsx201.

Mattawang, M. R., & Syarif, E. (2023). Dampak Penggunaan Kahoot Sebagai Platform Gamifikasi Dalam Proses Pembelajaran. *Journal of Learning and Technology*, *2*(1), 33–42. https://doi.org/10.33830/jlt.v2i1.5843.

Matthies, B., & Coners, A. (2018). Double-loop Learning in Project Environments: An Implementation Approach. *Expert Systems with Applications*, *96*, 330–346. https://doi.org/10.1016/j.eswa.2017.12.012.

Melinda, C., & Rahmawati, I. (2021). Penerapan Metode Problem Based Learning Dalam Meningkatkan Keterampilan Berpikir Kritis Siswa Pada Mata Pelajaran Ilmu Pengetahuan Sosial. *Jurnal Pendidikan Ilmu Sosial*, *31*(1), 23–31. https://doi.org/10.23917/jpis.v31i1.12557.

Muhammad, M., & Purwanto, J. (2020). The Effect of Double Loop Problem Solving (DLPS) on Critical Thinking Skills and Mathematical Problem Solving Abilities. *Journal of Physics: Conference Series*, *1469*(1). https://doi.org/10.1088/1742-6596/1469/1/012172.

Oliveira, R. P., de Souza, C. G., Reis, A. da C., & de Souza, W. M. (2021). Gamification in E-Learning and Sustainability: A Theoretical Framework. *Sustainability (Switzerland)*, *13*(21), 2–20. https://doi.org/10.3390/su132111945.

Putra, A. K., Soekamto, H., Masruroh, H., Handoyo, B., Huda, I. A. S., & Syaibana, P. L. D. (2022). Pelatihan Gamification Berbasis Game-Based Virtual Learning Environment Sebagai Penunjang Immersive Learning. *SELAPARANG: Jurnal Pengabdian Masyarakat Berkemajuan*, *6*(4), 2075. https://doi.org/10.31764/jpmb.v6i4.12084.

Putra, A. K., Sumarmi, A. S., Fajrilia, A., Islam, M. N., & Yembuu, B. (2021). Effect of Mobile-Augmented Reality (MAR) in Digital Encyclopedia on The Complex Problem Solving and Attitudes of Undergraduate Student. *International Journal of Emerging Technologies in Learning*, *16*(7), 119–134. https://doi.org/10.3991/ijet.v16i07.21223.

Putra, A. K., Sumarmi, Deffinika, I., & Islam, M. N. (2021). The Effect of Blended Project-Based Learning with STEM Approach to Spatial Thinking Ability and Geographic Skill. *International Journal of Instruction*, *14*(3), 685–704. https://doi.org/10.29333/iji.2021.14340a.

Putra, A. K., Sumarmi, S., Handoyo, B., Fajrilia, A., Islam, M. N., & Attamimi, M. R. (2022). Pengaruh Digital Learning and Digital Games Training Terhadap Kompetensi Technological Pedagogical Content Knowledge Guru Sma. *Jurnal Praksis Dan Dedikasi Sosial (JPDS)*, *5*(1), 14. https://doi.org/10.17977/um032v5i1p14-20.

Riana, A. (2020). Analysis of The Achievement of Double Loop Problem Solving (DLPS) Learning Model on Multiple Selection Problems Reviewed from Mathematical Connection Ability of Vocational School. *(Jiml) Journal of Innovative Mathematics Learning*, *3*(2), 82–86. https://doi.org/10.22460/jiml.v3i2.p82-86.

Rizqiyah, S., Astutik, S., Apriyanto, B., Pangastuti, E. I., & Nurdin, E. A. (2023). Pengaruh Model Pembelajaran EXO-OLO Task dengan Bantuan Media Spinning Question Terhadap Kemampuan Berpikir Kritis dan Hasil Belajar Geografi Siswa SMA. *Majalah Pembelajaran Geografi*, *6*(1), 1. https://doi.org/10.19184/pgeo.v6i1.36600.

Santoso, A. (2022). Pengaruh Media Pembelajaran Google Earth Terhadap Kemampuan Berpikir Spasial Siswa SMA. *Geodika: Jurnal Kajian Ilmu Dan Pendidikan Geografi*, *6*(2), 152–162. https://doi.org/10.29408/geodika.v6i2.5998.

Schlömmer, M., Spieß, T., & Schlögl, S. (2021). Leaderboard Positions and Stress—Experimental Investigations into An Element of Gamification. *Sustainability (Switzerland)*, *13*(12), 1–20. https://doi.org/10.3390/su13126608.

Shaw, A., Liu, O. L., Gu, L., Kardonova, E., Chirikov, I., Li, G., Hu, S., Yu, N., Ma, L., Guo, F., Su, Q., Shi, J., Shi, H., & Loyalka, P. (2020). Thinking Critically About Critical Thinking: Validating The Russian Heighten® Critical Thinking Assessment. *Studies in Higher Education*, *45*(9), 1933–1948. https://doi.org/10.1080/03075079.2019.1672640.

Silviariza, W. Y., Sumarmi, & Handoyo, B. (2021). Improving Critical Thinking Skills of Geography Students with Spatial-Problem Based Learning (SPBL). *International Journal of Instruction*, *14*(3), 133–152. https://doi.org/10.29333/iji.2021.1438a.

Syaibana, P. L. D., Putra, A. K., Suharto, Y., Rizal, S., Chun, D. T. C., & Opoku, F. (2022). *Collaborative Creativity Learning: Analyzing Scientific Creativity and Problem Solving Watershed Conservation Studies in Learning Geography* (Vol. 1). Atlantis Press SARL. https://doi.org/10.2991/978-2-494069-63-3_6.

Tsutsui, Y., Mitake, Y., Funami, Y., & Shimomura, Y. (2022). A Strategic Double-Loop Learning Method for Organisational Decision-Making toward Servitisation. *Sustainability (Switzerland)*, *14*(2). https://doi.org/10.3390/su14020901.

Turohmah, F. D. A., Putra, A. K., & Suharto, Y. (2021). Improving Critical Thinking Ability: Earthcomm Learning For Watershed Conservation Materials. *IJIS Edu : Indonesian Journal of Integrated Science Education*, *3*(2), 99. https://doi.org/10.29300/ijisedu.v3i2.4336.

Uz Bilgin, C., & Gul, A. (2020). Investigating the Effectiveness of Gamification on Group Cohesion, Attitude, and Academic Achievement in Collaborative Learning Environments. *TechTrends*, *64*(1), 124–136. https://doi.org/10.1007/s11528-019-00442-x.

Vauras, M., Volet, S., & Nolen, S. B. (2019). Motivation in Education at A Time of Global Change: Theory, Research, and Implications for Practice. *Advances in Motivation and Achievement*, *20*, 1–12. https://doi.org/10.1108/S0749-742320190000020001.

Zhong, Y., Han, X., & Zhang, L. (2018). Multi-class Geospatial Object Detection Based on A Position-Sensitive Balancing Framework for High Spatial Resolution Remote Sensing Imagery. *ISPRS Journal of Photogrammetry and Remote Sensing*, *138*, 281–294. https://doi.org/10.1016/j.isprsjprs.2018.02.014.