JOURNAL OF INTERDISCIPLINARY PERSPECTIVES

ISSN Print: 2984-8288, ISSN Online: 2984-8385
Vol. 4 No. 4, pp. 217-223, April 2026

Original Article

Explorative Learning and Critical Thinking Skills of Students in Earth Science

Richel L. Arañes[1], Mauricia S. Bapilar[2]

Author Information:

[1]DepEd - Dagohoy National High School, Poblacion, Dagohoy, Bohol, Philippines

[2]Holy Name University, J.A. Clarin St, Tagbilaran City, Bohol, Philippines

Correspondence:
aranes.richel@hnu.edu.ph

Article History:

Date received: February 3, 2026
Date revised: March 10, 2026
Date accepted: March 18, 2026

Recommended citation:

Arañes, R., & Bapilar, M. (2026). Explorative learning and critical thinking skills of students in Earth Science. *Journal of Interdisciplinary Perspectives*, 4(4), 217-223. https://doi.org/10.69569/jip.2026.070

Abstract. This study examined the effectiveness of the Explorative Learning Approach in enhancing the critical thinking skills and summative assessment performance of Grade 11 Earth Science students. A quasi-experimental pretest–posttest control group design was employed. Forty-two students were assigned to experimental and control groups (n = 21 each). Results showed that the experimental group obtained significantly higher posttest scores on critical thinking (M = 27.00, SD = 6.30) than the control group (M = 17.86, SD = 8.24), t(40) = 4.04, $p < .001$. Within-group analysis also revealed significant improvements in the experimental group, t (20) = 10.52, $p < .001$. Findings indicate that the Explorative Learning Approach significantly enhances critical thinking and academic performance compared to traditional instruction. The results suggest that structured inquiry-based instruction can improve higher-order thinking skills in secondary science education contexts. Implications for instructional practice and future research across subject areas are discussed.

Keywords: *Critical thinking; Earth Science education; Exploratory learning; Inquiry-based learning; Quasi-experimental design.*

In a rapidly changing, information-driven world, critical thinking has become an essential skill for analyzing evidence, solving problems, and making informed decisions. In science education, particularly in Earth Science, critical thinking enables students to interpret complex natural processes, evaluate scientific claims, and construct conclusions based on empirical evidence. Despite its importance, classroom instruction in many contexts continues to rely on teacher-centered approaches, such as lectures and rote memorization. While such approaches may facilitate content coverage, they often provide limited opportunities for students to engage in deeper analytical thinking (Petersen et al., 2020).

Recent research has emphasized the value of inquiry-based and experiential learning strategies in strengthening students' analytical abilities. Agustini et al. (2024) reported that experiential and inquiry-driven approaches significantly improve students' capacity to analyze and interpret scientific information. Similarly, findings from the Programme for International Student Assessment (PISA) indicate that education systems that emphasize explorative and student-centered learning—such as those in Finland and Singapore—consistently demonstrate stronger science literacy outcomes (De Bortoli et al., 2024). These findings indicate that instructional approaches that actively involve students in learning are associated with improved higher-order thinking skills.

Explorative learning is grounded in constructivist theory, which posits that learners construct knowledge through active engagement with their environment. Learning occurs as students interact with phenomena, reflect on experiences, and connect new information with prior knowledge. In Earth Science education, exploratory learning may involve field investigations, hands-on experiments, simulations, collaborative tasks, and data analysis. Through these experiences, students do not merely receive information; rather, they participate in the construction of understanding.

This study is also informed by Active Learning Theory, which posits that meaningful learning occurs when students are cognitively and behaviorally engaged in the learning process. When learners participate in discussions, problem-solving activities, and investigative tasks, they analyze evidence, evaluate ideas, and synthesize information. These cognitive processes are central to the development of critical thinking skills. Within this framework, explorative learning serves as an instructional approach that operationalizes both constructivist and active learning principles in classroom practice (Lutsenko & Lutsenko, 2022).

Guided by these theoretical perspectives, the present study conceptualizes explorative learning as a structured instructional condition that promotes active knowledge construction and student engagement. Critical thinking is viewed as a cognitive outcome that develops when learners are given opportunities to investigate, analyze, and reflect on scientific concepts. Based on constructivist and active-learning assumptions, students exposed to exploratory learning are expected to demonstrate measurable improvement in critical thinking compared with those receiving traditional instruction. This theoretical grounding informed the adoption of a quasi-experimental pretest–posttest design to determine whether differences in instructional approach would result in significant differences in critical thinking performance.

In the Philippines, the Department of Education (DepEd) has incorporated critical thinking into the K–12 curriculum, with Earth Science in Senior High School intended to strengthen students' scientific inquiry skills. However, the continued dominance of rote learning and teacher-directed instruction has limited opportunities for many Filipino students to develop higher-order thinking skills (Santos, 2017; Aniceto, 2023). The 2018 National Achievement Test results reflected this concern, revealing weak performance in tasks requiring analysis and evaluation (Francisco & Caingcoy, 2022; Galgao et al., 2025).

This concern is also evident at Dagohoy National High School. The Quarterly Report on Assessment (QRA) for the fourth quarter of School Year 2024–2025 in Grade 11 Earth Science showed that only 31 out of 214 students achieved an "Outstanding" rating, while 81 were rated "Fairly Satisfactory," and 14 did not meet expectations (QRA, 2025). Although most students met the minimum standard, a substantial proportion remained at the lower levels of performance. These results suggest the need for instructional approaches that strengthen analytical thinking rather than rely primarily on memorization. Public secondary schools in the Philippines often face challenges in implementing student-centered instruction due to large class sizes and limited resources. As a result, students may rely more on recall than on analysis, limiting their ability to apply scientific concepts in authentic contexts. This situation reinforces the need to examine structured instructional approaches grounded in established learning theories.

Given these considerations, this study examined the effectiveness of the Explorative Learning Approach in enhancing the critical thinking skills and summative assessment performance of Grade 11 Earth Science students. Specifically, it investigated students' critical thinking skills before and after the implementation of the approach, both within and between groups. It also determined whether there were significant differences in students' critical thinking skills between the experimental and control groups, and within each group across testing periods. By addressing these questions, the study contributes empirical evidence on structured exploratory instruction as a strategy for improving higher-order thinking skills in secondary science education.

Methodology

Research Design

This study employed a quasi-experimental pretest–posttest control group design to examine the effectiveness of an Explorative Learning Approach in improving Grade 11 students' critical thinking skills in Earth Science. Two intact General Academic Strand (GAS) sections were assigned as the experimental group (n = 21) and the control group (n = 21). Prior to the intervention, both groups completed identical pretests measuring knowledge and critical thinking skills. An independent samples t-test indicated no significant baseline difference between groups, t (40) = 0.47, p = .64, Cohen's d = 0.14, establishing initial equivalence.

The experimental group received instruction using an Explorative Learning Approach aligned with the Most Essential Learning Competencies (MELCs), emphasizing inquiry-based learning, collaborative exploration, and hands-on investigation. The control group received conventional teacher-centered instruction covering the same Earth Science competencies. The intervention lasted six weeks. To reduce threats to internal validity, both groups were taught by the same teacher, followed the same schedule, and used identical assessment instruments. Posttests identical to the pretests were administered following the intervention.

Participants and Sampling Technique

The participants consisted of 42 Grade 11 students enrolled in the General Academic Strand (GAS) at Dagohoy National High School during the School Year 2025–2026. Complete enumeration was used, including all students in the two intact classes. Each class consisted of 21 students. Eligibility criteria included official enrollment in Grade 11 Earth Science, regular class attendance during the intervention period, and submission of signed parental consent and student assent forms. Students with prolonged absences that significantly affected participation were excluded from the final dataset.

Since intact classes were used, random assignment was not feasible. However, group comparability was established through pretest analysis, which confirmed no statistically significant difference in initial critical thinking performance between the experimental and control groups ($t(40) = 0.47$, $p = .64$). Establishing empirical baseline equivalence helped minimize potential selection bias and strengthened the internal validity of the quasi-experimental design.

Research Instrument

Two assessment instruments were used to measure students' knowledge and critical thinking skills in Earth Science. The first instrument was a 40-item multiple-choice test adapted from the Department of Education – Division of Bohol and aligned with the Grade 11 Earth Science Most Essential Learning Competencies (MELCs). Minor revisions were made to ensure alignment with the intervention's instructional content. The instrument assessed cognitive processes, including recall, application, and analytical reasoning. Content validity was established through expert evaluation by three science educators, yielding a Content Validity Ratio (CVR) of 0.86. Reliability analysis conducted during pilot testing with a comparable group of students not included in the main study (n = 30) produced a Cronbach's alpha coefficient of 0.88, indicating high internal consistency.

To assess higher-order thinking skills (HOTS), a researcher-developed nine-item essay test was constructed across the domains of HOTS: applying, evaluating, and creating. Each domain was represented by three essay questions requiring analytical reasoning, justification of ideas, and evidence-based explanations. Students' essay responses were evaluated using the CTEE Test Rubric originally developed by Finken and Ennis (1993) and later modified by Zubaidah et al. (2020), whose adapted version served as the basis for the rubric used in this study. The rubric used a five-point scoring scale ranging from 0 to 5, with lower scores indicating limited reasoning and higher scores reflecting well-developed critical thinking. Two trained raters independently evaluated the responses to ensure scoring reliability. Inter-rater reliability analysis yielded a Cohen's kappa coefficient of 0.91, indicating excellent agreement between raters. Internal consistency reliability for the essay instrument was calculated at Cronbach's $\alpha = 0.84$. Pilot testing further confirmed item clarity and acceptable discrimination indices (≥ 0.30). Both instruments were administered as pretest and posttest measures.

Data Gathering Procedure

The data collection process followed three sequential phases: preparation, implementation, and evaluation. During the preparation phase, an Explorative Learning Plan aligned with the MELCs in Earth Science was developed to guide the instructional intervention. The learning design incorporated inquiry-based activities, collaborative investigations, and real-world problem-solving tasks intended to promote analytical thinking. The instructional materials and assessment instruments underwent expert validation by experienced science teachers to ensure content accuracy and curricular alignment. Pilot testing was conducted with non-participant students to verify reliability and item clarity, and revisions were made accordingly.

The implementation phase began after securing ethical clearance and institutional approval. Participants and their parents were oriented regarding the study procedures, and written informed consent and student assent were obtained. Pretests were administered to both groups under standardized conditions to establish baseline knowledge and critical thinking levels.

The instructional intervention lasted six weeks, with three 60-minute sessions conducted each week (approximately 18 contact hours). During this period, the experimental group received instruction through the Explorative Learning Approach, which emphasized student-centered inquiry, collaborative discussion, and investigative learning activities. In contrast, the control group received traditional teacher-centered instruction delivered primarily through lectures and textbook-guided lessons. The same teacher conducted instruction in both groups to maintain consistency. At the end of the intervention, posttests were administered under the same testing conditions as the pretests. The collected data were subsequently organized and coded for statistical analysis.

Data Analysis Procedure

Data were analyzed using IBM SPSS Statistics Version 23. Descriptive statistics, including the mean and standard deviation, were calculated to summarize students' critical thinking performance before and after the intervention. Inferential analyses were conducted to determine whether significant differences existed between and within groups. An independent samples t-test was used to compare the posttest scores of the experimental and control groups to determine whether the Explorative Learning Approach yielded significantly different outcomes than those of traditional instruction. Paired samples t-tests were also performed to examine changes in critical thinking scores within each group by comparing pretest and posttest results.

Prior to conducting inferential tests, assumptions of normality and homogeneity of variance were evaluated using the Shapiro–Wilk test and Levene's test, respectively. The level of statistical significance was set at $\alpha = .05$. Bonferroni adjustment procedures were applied where necessary to control for potential inflation of Type I error resulting from multiple comparisons. In addition to statistical significance testing, effect sizes were calculated using Cohen's d to determine the magnitude of observed differences.

Ethical Considerations

Ethical clearance was granted by the Holy Name University Ethics Review Board (Ref. No. HNU-ERB-September_2025-180). Institutional approval was secured prior to data collection.

Key safeguards included:

- Written parental consent and student assent.
- Voluntary participation with the right to withdraw.
- No academic penalty for non-participation.
- Use of coded identifiers for anonymity.
- Secure storage of digital and printed data.
- Reporting of aggregated results only.

The study posed minimal risk and adhered to principles of respect for persons, beneficence, and justice.

Results and Discussion

Descriptive Results

This section presents the students' critical thinking skills before and after the implementation of the Explorative Learning Approach. Table 1 presents the pretest and posttest levels of students' critical thinking skills in both the control and experimental groups. In the control group, most students were initially at the Beginning level (66.7%), with the remaining at the Developing level (33.3%), and none at the Proficient or Advanced levels. After the instruction, results showed moderate improvement. The proportion of students at the Beginning level decreased to 28.6%, while 47.6% were at the Developing level and 23.8% reached the Proficient level. However, no students attained the Advanced level.

In the experimental group, pretest results indicated that most students were already at the Developing level (66.7%), followed by the Beginning level (23.8%) and Proficient level (9.5%), with none at the Advanced level. After implementing the Explorative Learning Approach, all students moved out of the Beginning level. A majority

(66.7%) reached the Proficient level, while 33.3% remained at the Developing level, demonstrating a substantial improvement in students' critical thinking skills.

Table 1. *Descriptive Results on Students' Critical Thinking Skills (n=21)*

Level (Control Group)	Control Group				Experimental Group			
	Pretest		Posttest		Pretest		Posttest	
	f	%	*f*	%	*F*	%	*f*	%
Beginning (Low Performance)	14	66.7%	6	28.6%	5	23.8%	0	0%
Developing (Fair Performance)	7	33.3%	10	47.6%	14	66.7%	7	33.3%
Proficient (Satisfactory Performance)	0	0%	5	23.8%	2	9.5%	14	66.7%
Advanced (High Performance)	0	0%	0	0%	0	0%	0	0%

Between-group comparisons indicate that the experimental group demonstrated slightly stronger critical thinking skills at pretest. However, posttest results revealed a more pronounced difference between the two groups. A significantly higher proportion of students in the experimental group achieved the Proficient level (66.7%) compared to the control group (23.8%). Both groups improved from pretest to posttest, but gains were considerably greater among students exposed to the Explorative Learning Approach, suggesting its effectiveness in enhancing critical thinking skills compared to traditional instruction.

These findings are consistent with previous studies indicating that critical thinking skills may improve through regular classroom experiences but rarely reach higher proficiency levels without targeted instructional strategies. Students may develop basic analytical abilities through routine classroom exposure, yet advanced levels of critical thinking often require structured and intentional instructional approaches (Galgo & Balbaguio, 2022; Golden, 2023). Similarly, Barta et al. (2022) and Sirianansopa (2024) reported that meaningful improvements in higher-order thinking skills occur when learning environments actively engage students in inquiry, analysis, and reflection.

The substantial improvement observed in the experimental group supports findings from contemporary research emphasizing the impact of structured interventions on students' development of critical thinking. Dumitru et al. (2023) and Muhibbuddin et al. (2023) demonstrated that targeted programs to enhance critical thinking significantly improved students' analytical reasoning skills. Likewise, Guo et al. (2024) reported that reflective and collaborative learning models effectively strengthened students' critical thinking abilities beyond traditional instruction. These studies reinforce the present findings, suggesting that the Explorative Learning Approach provided meaningful opportunities for students to engage in deeper cognitive processing and problem-solving activities. Nevertheless, the absence of students reaching the Advanced level suggests that additional instructional strategies may be necessary to develop higher levels of critical thinking.

Difference in Critical Thinking Skills

Table 2 presents the comparison of posttest scores between the two groups. The control group obtained a mean score of 17.86 (*SD* = 8.24), while the experimental group obtained a higher mean score of 27.00 (*SD* = 6.30). The computed *t-value* of 4.042 with $p < 0.01$ indicates that the difference between the two groups is statistically significant. The computed effect size (*Cohen's d* = 1.25) indicates a very large effect, suggesting that the Explorative Learning Approach had a strong impact on students' critical thinking skills. These findings suggest that the Explorative Learning Approach contributed to improvements not only in critical thinking skills but also in overall academic performance.

Table 2. *Difference in the Critical Thinking Skills Between Groups after the Implementation (n=21)*

Variables	Groups	*Mean*	*SD*	*t-value*	*p-value*	*Cohen's d*	Decision
Critical Thinking Skills	Control	17.86	8.24	4.04	.000	1.25	Statistically Significant
	Experimental	27.00	6.30				

The results align with recent research demonstrating that explorative learning strategies enhance students' cognitive and academic development. Galgo (2020) and Guo et al. (2024) reported that explorative and reflective learning approaches significantly strengthened students' analytical reasoning and problem-solving abilities, resulting in measurable academic gains. Similarly, Ramakrishnan and Sylvia (2024) and Zhang and Ahmed (2020) found that structured instructional interventions improved students' decision-making abilities, emotional coping skills, and practical problem-solving capacity. These studies support the present findings, indicating that explorative learning approaches provide meaningful learning experiences that promote higher-order thinking and improved academic outcomes.

Table 3 presents the comparison of pretest and posttest scores for both groups. In the control group, the analysis yielded an average difference of 5.86 (*SD* = 10.19). The computed *t-value* of 2.634, with p = 0.016, indicates a statistically significant improvement in critical thinking skills following instruction. The computed effect size (*Cohen's d* = 0.57) indicates a moderate effect, suggesting that students in the control group experienced modest gains in their critical thinking skills during the study period.

Table 3. *Difference in Critical Thinking Skills Within Pretest and Posttest Performance of Both Control and Experimental Groups (n=21)*

Variables	Groups	*Avg.* of Differences	*SD* of Differences	*t-value*	*p-value*	*Cohen's d*	Decision
Control Group	Pre-test Posttest	5.85	10.18	2.63	.016	0.57	Statistically Significant
Experimental Group	Pre-test Posttest	14	6.09	10.51	.000	2.30	Statistically Significant

In contrast, the experimental group demonstrated a substantially greater improvement. The average difference between pretest and posttest scores was 14.00 (*SD* = 6.10). The computed *t-value* of 10.519 with $p < 0.01$ indicates a highly significant improvement in students' critical thinking skills. The calculated effect size (*Cohen's d* = 2.30) represents an extremely large effect, highlighting the strong influence of the Explorative Learning Approach on students' cognitive development. These findings indicate that while both groups improved over time, the magnitude of improvement was considerably greater among students exposed to the Explorative Learning Approach. This suggests that the intervention provided a more effective learning environment for developing critical thinking skills compared to standard instructional practices.

These results are supported by previous research emphasizing the effectiveness of inquiry-based and explorative learning strategies. Dewi et al. (2021), in a systematic review and meta-analysis, concluded that inquiry-based learning approaches consistently produce positive effects on students' critical thinking skills in science education. Such approaches encourage learners to actively investigate problems, analyze evidence, and reflect on their reasoning processes, leading to deeper cognitive engagement. These findings support the results of the present study, in which students exposed to the Explorative Learning Approach demonstrated substantially greater improvements in critical thinking than those taught through conventional instruction.

Conclusion

The findings confirm that the Explorative Learning Approach significantly enhances students' critical thinking skills and academic performance in Earth Science. The structured integration of inquiry-based and collaborative activities enables students to actively engage with scientific concepts, resulting in measurable improvements in higher-order thinking compared with traditional instruction. From a practical perspective, science teachers may incorporate structured exploratory tasks—such as guided investigations, collaborative problem-solving, and concept-based discussions—into regular instructional units to strengthen students' analytical reasoning and conceptual understanding. At the institutional level, school administrators and curriculum planners may support the integration of exploratory learning strategies through targeted professional development, provision of inquiry-based instructional resources, and inclusion of exploratory learning activities in science curriculum planning aligned with DepEd's learner-centered instructional frameworks.

Future research may further investigate the long-term retention effects of exploratory learning, its applicability across other science disciplines and grade levels, and its effectiveness in larger and more diverse educational contexts. Additional studies may also explore how exploratory learning interacts with factors such as teacher instructional competence, classroom environment, and learner characteristics to further strengthen the generalizability and sustainability of this instructional approach.

Contributions of Authors

Author 1: conceptualization, data gathering, data analysis
Author 2: research supervision

Funding
This research received no external funding.

Conflict of Interests
The authors declare no conflict of interest.

Acknowledgment
The authors express their sincere appreciation to Dr. Jean J. Roy, Fr. Ruel F. Lero, SVD, PhD, Vera G. Villacido, MAEd, and Rachel B. Mende, MA, for their valuable feedback and constructive comments that improved the quality of this research. Appreciation is also extended to the School Head of Dagohoy National High School for granting permission and support in conducting the study. The College of Education of Holy Name University is likewise acknowledged for its academic support. Finally, the authors express their gratitude to the Grade 11 students of Dagohoy National High School for their participation in this research.

References
Agustini, R., Meilanie, R.S.M., & Pujiastuti, S.I. (2024). Enhancing critical thinking and curiosity in early childhood through inquiry-based science learning. Aulad: Journal on Early Childhood, 7(3), 734–743. https://tinyurl.com/57e25kms

Aniceto, R. (2023). Higher-order thinking skills-based assessment in English for academic and professional purposes. Journal of International Education, 5, 1–23. https://tinyurl.com/rf74aty8

Barta, A., Fodor, L.A., Tamas, B., & Szamoskozi, I. (2022). The development of students' critical thinking abilities and dispositions through the concept mapping learning method–A meta-analysis. Educational Research Review, 37, 100481. https://doi.org/10.1016/j.edurev.2022.100481

De Bortoli, L., Underwood, C., Friedman, T., & Gebhardt, E. (2024). PISA 2022. Reporting Australia's results. Volume II: Student and school characteristics. https://doi.org/10.37517/978-1-74286-726-7

Dewi, D.K., Ardhana, W., Irtadji, T.C., & Sulianti, A. (2021). Inquiry-based learning implementation to improve critical thinking of prospective teachers. International Journal of Information and Education Technology, 11(12), 638–645. https://doi.org/10.18178/ijiet.2021.11.12.1575

Dumitru, D., Minciu, M., Mihaila, R.A., Livinti, R., & Paduraru, M.E. (2023). Experimental programs of critical thinking enhancement: A worked-based, blended learning higher education curriculum for economics. Education Sciences, 13(10), 1031. https://doi.org/10.3390/educsci13101031

Francisco, R., & Caingcoy, M. (2022). Competencies of basic education teachers and performance of learners in 2017-2018 National Achievement Test in the Philippines. http://dx.doi.org/10.23960/jpp.v12.i2.202212

Galgao, C., Galgo, J., Hibaya, A.J., Sotil, S.F., & Doliente, J. (2025). Lived experiences of 21st century teachers in inclusive education. Journal of Interdisciplinary Perspectives, 3(10), 598–604. https://doi.org/10.69569/jip.2025.658

Galgo, J. (2020). Endeavours towards academic success: An investigation of underprivileged student's life experience. Middle Eastern Journal of Research in Education and Social Sciences, 1(2), 94–106. https://doi.org/10.47631/mejress.v1i2.46

Galgo, J., & Balbaguio, R. (2022). Utilization of EvalBee application in improving learners' performance assessment recording. International Journal of Open-access, Interdisciplinary & New Educational Discoveries of ETCOR Educational Research Center, 1(3), 124–129. https://tinyurl.com/3pma6h36

Golden, B. (2023). Enabling critical thinking development in higher education through the use of a structured planning tool. Irish Educational Studies, 42(4), 949–969. https://doi.org/10.1080/03323315.2023.2258497

Guo, R., Jantharajit, N., & Thongpanit, P. (2024). Enhancing analytical and critical thinking skills through reflective and collaborative learning: A quasi-experimental study. Journal of Education and Educational Development, 11(2), 200–223. https://tinyurl.com/y763ccra

Lutsenko, O., & Lutsenko, G. (2022). Active learning: Theory and practice. BoD–Books on Demand. https://tinyurl.com/5n8u7tx7

Muhibbuddin, Artika, W., & Nurmaliah, C. (2023). Improving critical thinking skills through Higher Order Thinking Skills (HOTS)-based science. International Journal of Instruction, 16(4), 283–296. https://doi.org/10.29333/iji.2023.16417a

Petersen, C., Baepler, P., Beitz, A., Ching, P., Gorman, K., Neudauer, C., Wingert, D., et al. (2020). The tyranny of content: "Content Coverage" as a barrier to evidence-based teaching approaches and ways to overcome it. CBE—Life Sciences Education, 19(2), ar17. https://doi.org/10.1187/cbe.19-04-0079

Ramakrishnan, B., & Sylvia, J. (2024). Enhancing critical thinking and emotional coping of nursing students through life skills training. Bioinformation, 20(12), 2091. https://tinyurl.com/bdf5897d

Santos, L.F. (2017). The role of critical thinking in science education. Journal of Education and Practice, 8(20), 159–173. https://tinyurl.com/mmm6t8c6

Sirianansopa, K. (2024). Evaluating students' learning achievements using the formative assessment technique: A retrospective study. BMC Medical Education, 24(1), 1373. https://doi.org/10.1186/s12909-024-06347-5

Zhang, B.H., & Ahmed, S. (2020). Systems thinking—Ludwig Von Bertalanffy, Peter Senge, and Donella Meadows. Science Education in Theory and Practice: An Introductory Guide to Learning Theory, 419–436. https://doi.org/10.1007/978-3-030-43620-9_28

Zubaidah, S., Mahanal, S., & Fauzi, A. (2020). Critical thinking embedded essay test. In International Conference on Biology, Sciences and Education (ICoBioSE, 2019) (pp. 171–177). Atlantis Press. https://doi.org/10.2991/absr.k.200807.036