INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT
OPEN ACCESS JOURNAL
Vol 14, Issue 01, (2025) E-ISSN: 2226-6348

ISTEM and 5E Learning Module for Geometric Thinking

Sumaiyah Mohd Zaid*, Norulhuda Ismail
Faculty of Educational Sciences and Technology, Universiti Teknologi Malaysia, Johor, Malaysia
Email: p-norulhuda@utm.my
Corresponding Author Email: sumaiyahmohdzaid@graduate.utm.my

To Link this Article: http://dx.doi.org/10.6007/IJARPED/v14-i1/24724 DOI:10.6007/IJARPED/v14-i1/24724

Published Online: 26 February 2025

Abstract
The 5E Learning Cycle model, integrating STEM education and metacognitive strategies, fosters active learning, critical thinking, and problem-solving in geometry through hands-on activities and collaborative learning. Its incorporation of technology and higher-order thinking skills enhances students' spatial reasoning, academic performance, and ability to plan, monitor, and evaluate problem-solving strategies effectively. This study explores the effectiveness of integrating the iSTEM-5E Learning Cycle with the Van Hiele model to enhance geometric thinking among fifth-year students. The research aims to assess students' levels of geometric understanding in visual, analytical, and abstract reasoning and examine the impact of instructional interventions. A needs analysis conducted on 400 students revealed that while 49.8% demonstrated high-level visual perception, a majority struggled with analytical (54.5% at a low level) and abstract (58.3% at a low level) reasoning. Hypothesis testing using ANOVA indicated a significant difference in pre-test scores among three groups: the control group, the treatment group using the Van Hiele method, and the treatment group using the iSTEM-5E-Van Hiele-based module ($F(2, 87) = 15.032$, $p < 0.05$). These findings highlight the need for structured, inquiry-based instructional methods to improve students' transition from visual recognition to higher-order geometric reasoning. The study concludes that the iSTEM-5E-Van Hiele-based module is an effective pedagogical approach to fostering deeper geometric understanding and recommends its integration into mathematics education.
Keywords: iSTEM Education, 5E Learning Cycle, Geometric Thinking, Van Hiele Model, Mathematics Education.

Introduction
The incorporation of the 5E Learning Cycle model with STEM education principles has demonstrated considerable potential in enhancing geometric reasoning among pupils. The 5E model, comprising five phases—Engagement, Exploration, Explanation, Elaboration, and Evaluation—facilitates active learning and student-centered methodologies, crucial for cultivating critical thinking and problem-solving abilities in mathematics and geometry (Wiriani & Ardana, 2022; Halidin et al., 2023; Rahmawati et al., 2021). This paradigm promotes student comprehension through experiential activities and cooperative learning, which is

especially advantageous for geometric topics necessitating spatial thinking and visualisation (Pavlovičová & Bočková, 2021; Rahmawati et al., 2021). Studies demonstrate that the 5E Learning Cycle model enhances students' academic achievement and cultivates a favourable disposition towards learning (Lin et al., 2014; Çakır, 2017). The use of this strategy across many disciplines, such as mathematics, has been associated with heightened motivation and engagement among students, resulting in improved learning results (Wahyuningsih, 2023; Resmol & Leasa, 2022). Research indicates that students who engage in exploration and inquiry during the learning process are more adept at understanding and applying intricate geometric concepts (Wikara et al., 2022; Aşıksoy & Özdamlı, 2017).

Furthermore, the integration of metacognitive methods inside the 5E framework can significantly augment students' geometric reasoning. Metacognition, encompassing self-regulation and reflection on personal learning processes, is essential for acquiring geometric concepts (Shivam & Mohalik, 2022). Incorporating metacognitive elements into the 5E model allows instructors to facilitate students' comprehension of geometry, empowering them to successfully plan, monitor, and assess their problem-solving strategies (Shivam & Mohalik, 2022). The integration of the 5E Learning Cycle model with technology, including ICT tools, has demonstrated an improvement in higher-order thinking skills essential for addressing intricate geometric issues (Shivam & Mohalik, 2022). This technological integration facilitates a more dynamic learning environment, enabling students to visualise and manipulate geometric concepts, therefore reinforcing their comprehension (Shivam & Mohalik, 2022). The 5E Learning Cycle model, especially when integrated with STEM education and metacognitive methods, constitutes an effective framework for improving geometric reasoning in pupils. The focus on active learning, teamwork, and technological integration enhances academic performance while cultivating a deeper understanding for mathematics and geometry.

While the 5E Learning Cycle model has been widely recognized for its ability to enhance active learning and problem-solving, students often face challenges in progressing from basic visual recognition to more complex geometric reasoning. The needs analysis conducted in this study highlights these difficulties, revealing that a significant percentage of students struggle with analytical and abstract reasoning. Motivated by this learning gap, this study integrates the iSTEM-5E Learning Cycle with the Van Hiele model to provide a structured, inquiry-based approach that enhances students' geometric thinking. By merging STEM education principles, metacognitive strategies, and interactive learning experiences, this study aims to develop an effective instructional framework that fosters deeper mathematical understanding. The findings will offer valuable insights for educators, curriculum designers, and policymakers seeking to improve geometry education through innovative, research-backed methodologies.

Literature Review

Hassan et al. (2018) examine the incorporation of STEM education into early childhood mathematics curricula, highlighting the significance of the 5E instructional paradigm (Engage, Explore, Explain, Extend, Evaluate) in cultivating children's curiosity and problem-solving abilities. This corresponds with the objective of improving geometric reasoning in mathematics education, as the 5E model promotes active learning and the study of mathematical concepts, including geometry. Through the application of this instructional design, educators can cultivate compelling learning experiences that enhance young learners' comprehension of geometric principles. The study emphasises the imperative for curriculum development that integrates various techniques to effectively cultivate mathematical skills from a young age, hence establishing a robust basis for further learning in geometry and other mathematical disciplines (Hassan et al., 2018).

The problems and requirements of elementary educators in incorporating iSTEM education are essential for the implementation of effective teaching methodologies in geometric reasoning within mathematics education (Arnone & Hanuscin, 2018). It emphasises that elementary educators frequently possess insufficient topic expertise in STEM fields, which may impede their capacity to successfully instruct integrated STEM concepts, such as geometry (Arnone & Hanuscin, 2018). The research underscores the imperative for professional development specifically aimed at bridging these gaps, therefore guiding the formulation of educational programs that improve teachers' instructional methodologies in iSTEM education (Arnone & Hanuscin, 2018). This comprehension is essential for creating a 5E Learning Module that aids educators in promoting geometric reasoning in students via integrative and inquiry-driven learning experiences.

Hamami (2024) examines cognitive biases in geometric thinking, emphasising that educated individuals may erroneously accept faulty inferences concerning points and circles in Euclidean geometry. This research is particularly pertinent to the incorporation of the 5E Learning Cycle model in mathematics education, as it highlights the significance of comprehending cognitive mechanisms that affect geometric reasoning. By recognising these biases, educators can create instructional techniques that rectify any misconceptions and improve deductive reasoning abilities in geometry, in accordance with the exploratory and evaluative stages of the 5E model (Hamami, 2024). The findings indicate that effective teaching methods must consider students' representations of geometric concepts, which is essential for promoting deeper knowledge and rectifying intuitive reasoning errors (Hamami, 2024).

Simultaneously, Martins (2024) examines the importance of integrated STEM education (iSTEM) in improving students' learning experiences and cultivating their enthusiasm in STEM-related professions. The scholar emphasises the difficulties encountered by educators in executing iSTEM, especially regarding the integration of the Arts, which complicates the instructional methodology. The research underscores the significance of teacher professional development (TPD) in enhancing teachers' Pedagogical Content Knowledge (PCK), particularly for the instruction of intricate subjects like electrical circuits (Martins, 2024). This pertains to the development of a 5E Learning Module for geometric reasoning in mathematics education, as proficient teacher training in iSTEM can improve the presentation of geometric concepts through an integrated methodology. The results indicate that teachers possessing robust pedagogical content knowledge (PCK) can more effectively enhance student engagement and comprehension in geometry, along with the 5E model's focus on active learning and exploration (Martins, 2024). Consequently, the findings from this study can guide the development of professional training programs that assist educators in efficiently applying the 5E Learning Cycle in the realm of geometric reasoning.

In summary, the incorporation of STEM education with the 5E Learning Cycle model offers a revolutionary method for enhancing geometric reasoning in children. The research underscores its efficacy in cultivating problem-solving abilities and conceptual comprehension; yet, the primary obstacle resides in its execution. A significant number of educators lack the requisite training and pedagogical content knowledge (PCK) to proficiently implement STEM-integrated curricula, potentially impeding their effectiveness. Cognitive biases in geometric reasoning, as observed by Hamami (2024), indicate that even well-structured instructional models necessitate further enhancement to rectify students' misconceptions. While professional development programs for educators are advocated, systemic alterations in curriculum design are essential to ensure that STEM-based learning is not merely supplementary but a fundamental component of early education. Moreover, technology ought to have a more prominent role in facilitating interactive and inquiry-based learning, rendering abstract geometric concepts more concrete for pupils. In summary, the efficacy of the 5E model and iSTEM methodologies relies on adequately prepared instructors, meticulously crafted curricula, and a dedication to promoting profound, inquiry-based learning experiences in mathematics education.

Research Methodology

A total of 400 respondents were used in this needs analysis study. The majority of students involved in this needs analysis phase consisted of female students with a number of 92 or 61.3 percent of the total number of respondents. While the remaining 58 students or 38.7 percent were male students. To test the level of needs of the iSTEM-5E-Van Hiele-based module among fifth year students, a needs analysis was conducted on 400 students. The students involved were given 30 questions divided into three parts, namely visual, analytical and abstract, where each part consisted of 10 questions. The level classification was divided into three levels based on the number of correct answers. The number of correct answers 0 to 4 is a low level, while the number of correct answers 5 to 6 is a medium level and the number of correct answers 7 to 10 is a high level.

Findings

Referring to Table 1 the findings of the needs analysis carried out show that the percentage of students who are at a high level for the visual section is high compared to the moderate and low levels. The findings for the visual section show that 49.8 percent of students excel in that section, with the average respondent obtaining a score of 7 to 10 for the visual section. Only 18.8 percent are at a low level and the remaining 31.5 percent are at a moderate level. Next, referring to Table 1 above, it is found that the findings analysis section shows that 54.5 percent of students are still weak in that section, with them only obtaining a score between 0 and 4. Only 4.5 percent of respondents are at a moderate level and 41.0 percent of respondents are at a high level.

Table 1
Analysis of the Levels of Geometric Thinking of Fifth-Year Students for the Visual, Analytical, and Abstract Sections

Section	Interpretation	Correct Answers	Frequency	Percentage (%)
Visual (1 – 10)	Low	0 to 4	75	18.80%
	Medium	5 to 6	126	31.50%
	High	7 to 10	199	49.80%
Total			400	100.00%
Analysis (11 – 20)	Low	0 to 4	218	54.50%
	Medium	5 to 6	18	4.50%
	High	7 to 10	164	41.00%
Total			400	100.00%
Abstract (21 – 30)	Low	0 to 4	233	58.30%
	Medium	5 to 6	12	3.00%
	High	7 to 10	155	38.80%
Total			400	100.00%

Finally, the abstract section shows that 58.3 percent of students are still at a low level. They only obtain a score between 0 and 4. Followed by only 3.0 percent being at a moderate level and the remaining 38.8 percent being at a high level. These three sections show that the majority of students' geometric levels are still at a low level. The most notable is the analysis and abstract sections where the findings show that more than 50.0 percent of students are at a low level for that section. Overall, it was found that the geometric thinking level of Year Five students is still at a low and moderate level. The percentage shows that 61.3 percent of students have a low and moderate level of geometric thinking.

Hypothesis Testing 1 using the ANOVA test aims to assess whether there is a significant difference in the mean pre-test scores among the three groups in this study: the control group, the treatment group using the Van Hiele method, and the treatment group using the iSTEM-5E-Van Hiele-based module. The proposed null hypothesis (Ho1) states that there is no significant difference in the mean pre-test scores among the three groups. The study findings are presented in Table 2.

Table 2
Descriptive Analysis of Mean Pre-Test Scores of Fifth-Year Students by Group

Group	**N**	**Mean**	**Standard Deviation**	**df1**	**df2**	**Sig.**
Control	30	6.5	2.14556			
Treatment (Van Hiele Method)	30	7.3333	3.75393	2	87	0.023
Treatment (iSTEM-5E-Van Hiele-Based Module)	30	10.6	3.06931			
Overall	90	8.1444	3.51101			

Based on Table 2, the distribution of mean pre-test scores for fifth-year students shows that the control group obtained the lowest mean score of 6.5000 with a standard deviation of 2.14556, indicating relatively low variation in the pre-test scores within this group. This suggests that students in the control group had a more homogeneous level of understanding prior to the intervention.

In contrast, the treatment group using the Van Hiele method achieved a slightly higher mean score of 7.3333 with a larger standard deviation of 3.75393. This reflects greater variation in the initial understanding of students within this group, possibly influenced by heterogeneity in how they received and processed the learning materials presented through the Van Hiele method. The most notable result is from the group using the iSTEM-5E-Van Hiele-based module, which had the highest pre-test mean score of 10.6000 with a standard deviation of 3.06931. These higher scores suggest that students in this group had a better initial understanding compared to the other two groups, or that the module used was more effective in preparing students for the pre-test.

The results of the ANOVA test, with a significant value of .023, indicate a statistically significant difference among the three groups, thereby rejecting the null hypothesis. The presence of this significant difference highlights the importance of the learning approach employed and its impact on students' initial understanding. It also implies that the use of the iSTEM-5E-Van Hiele-based module may be more effective in enhancing students' initial conceptual understanding before encountering more advanced or complex learning materials.

Therefore, these findings support the integration of the iSTEM-5E-Van Hiele-based module in mathematics teaching, particularly in geometry, as a means to improve initial understanding and better prepare students for more advanced learning. This suggests that the iSTEM-5E-Van Hiele module, with its rich content integration and innovative learning approach, has significant potential to enhance students' academic achievement at the early stages of the learning process.

Table 3
One-Way Variance Analysis (ANOVA) Results for Fifth-Year Students' Pre-Test Scores

Source of Variation	Sum of Squares	df	Mean Squares	F Value	Sig.
Between Groups	281.756	2	140.878	15.032	0
Within Groups	815.367	87	9.372		
Total	1097.122	89			

Based on Table 3, the results of the ANOVA test analysis show that the obtained F-value is $F(2, 87) = 15.032$, and the significance value is sig. = .000, which is less than .05 ($p < .05$). These results indicate that there is a significant difference in the mean pre-test scores of fifth-year students among the control group, the treatment group using the Van Hiele method, and the treatment group using the iSTEM-5E-Van Hiele-based module. This can also be observed in Table 5.56, where the findings show that the mean pre-test scores for each group are different.

Overall, based on the results of the ANOVA test, it can be concluded that there is a significant difference in the mean pre-test scores of fifth-year students based on their respective groups. Thus, the null hypothesis (H_{o1}), which states that there is no significant difference in the mean pre-test scores among the control group, the treatment group using the Van Hiele method, and the treatment group using the iSTEM-5E-Van Hiele-based module, is rejected. This is because the actual findings indicate that there is a significant difference in the mean pre-test scores among these groups. To further analyze the comparisons of mean pre-test scores among the groups, the Post Hoc Tukey HSD test is used to provide more detailed results shown in Table 4.

Table 4
Post Hoc Tukey HSD Mean Comparison Results for Fifth-Year Students' Pre-Test Scores

(I) Group	**(J) Group**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**
Treatment (Van Hiele Method)	Control (KW)	0.83333	0.79044	0.545
Treatment (Van Hiele Method)	Treatment (Module Based on iSTEM-5E-Van Hiele)	4.10000*	0.79044	0
Treatment (Module Based on iSTEM-5E-Van Hiele)	Control (KW)	3.26667*	0.79044	0

The control group (M = 6.5000, SD = 2.14556) exhibits a significant difference from the treatment group utilising the Van Hiele approach (M = 7.3333, SD = 3.75393) and the treatment group employing the iSTEM-5E-Van Hiele-based module (M = 10.6000, SD = 3.06931). The significance value for the comparison between the treatment group utilising the Van Hiele method and the control group indicates no significant difference in pre-test mean scores, with a significance value of sig. = .545. The significance value for the difference between the treatment group utilising the Van Hiele method and the treatment group employing the iSTEM-5E-Van Hiele-based module is sig. = .000, signifying a substantial difference in the pre-test mean scores. The observed mean difference is M = 4.10000. The results indicate a substantial disparity between the treatment group utilising the iSTEM-5E-Van Hiele-based module and the control group, with a significance value of sig. = .000 and a mean difference of M = 3.26667.

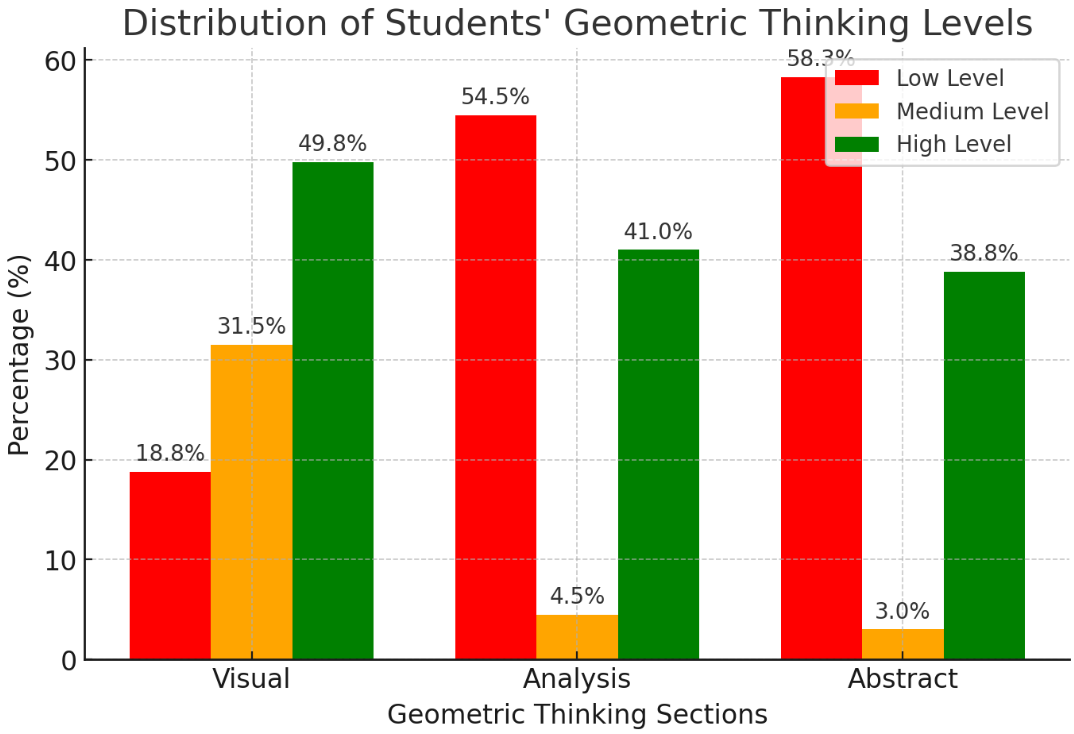

Figure 1 Distribution of Students' Geometric Thinking Levels

The bar chart in Figure 1 visually represents the distribution of students' geometric thinking levels across three sections: Visual, Analytical, and Abstract. The data reveals that nearly half of the students (49.8%) perform at a high level in visual perception, indicating strong shape recognition skills. However, the proportion of students performing at a high level decreases significantly in the Analytical (41.0%) and Abstract (38.8%) sections. Conversely, the percentage of students at a low level increases as complexity grows, with 54.5% struggling with analytical reasoning and 58.3% performing poorly in abstract reasoning. These findings suggest that while students excel in recognizing geometric figures, they struggle with deeper conceptual understanding and reasoning. This trend underscores the need for targeted instructional strategies to strengthen analytical and abstract reasoning skills.

Discussion

The findings emphasize the effectiveness of the iSTEM-5E-Van Hiele-based module in enhancing students' geometric understanding. This method, which integrates STEM principles with the 5E instructional model (Engage, Explore, Explain, Elaborate, Evaluate), provides structured inquiry-based learning experiences that are likely to contribute to improved conceptual understanding.

Given that students demonstrated the highest proficiency in visual perception but struggled with analytical and abstract reasoning, future instruction should Incorporate more problem-solving tasks that require deductive reasoning, Use interactive and inquiry-based teaching methods to deepen students' conceptual understanding, Provide scaffolding to help students transition from visual recognition to higher-order geometric thinking, and Leverage technology, such as dynamic geometry software, to facilitate exploration and conceptual development.

Overall, the findings indicate that while students demonstrate strong visual perception skills, their analytical and abstract reasoning in geometry remain underdeveloped. The iSTEM-5E-Van Hiele-based module proves to be a significantly more effective approach in fostering initial geometric understanding, supporting its further implementation in mathematics education. Future research should explore long-term effects of this instructional approach and its impact on students' progression through higher levels of geometric reasoning.

Conclusions

This study highlights the effectiveness of integrating the iSTEM-5E Learning Cycle model with the Van Hiele framework in enhancing geometric thinking among fifth-year students. The findings indicate that while students demonstrate strong visual perception skills, their analytical and abstract reasoning remain underdeveloped. The needs analysis revealed that a significant portion of students struggle with higher-order geometric reasoning, emphasizing the necessity for structured, inquiry-based instructional methods.

The statistical analysis, particularly the ANOVA results, confirms that students who engaged with the iSTEM-5E-Van Hiele-based module showed significantly higher improvement in their geometric understanding compared to those taught using traditional methods or the Van Hiele approach alone. These results support the hypothesis that the integration of STEM principles, metacognitive strategies, and the 5E instructional model fosters deeper conceptual understanding and problem-solving skills in geometry.

Given these findings, it is recommended that mathematics educators incorporate the iSTEM-5E framework into their teaching practices to facilitate students' transition from basic visual recognition to advanced geometric reasoning. Future research should explore the long-term impact of this instructional approach, including its effectiveness across different student demographics and its potential for improving other areas of mathematical cognition. Furthermore, professional development programs should be designed to equip teachers with the necessary skills and pedagogical knowledge to implement STEM-integrated learning strategies effectively.

In conclusion, the iSTEM-5E-Van Hiele-based module presents a promising pedagogical approach for enhancing geometric thinking. Its emphasis on active learning, problem-solving, and technological integration makes it a valuable tool for improving students' mathematical competencies and preparing them for more complex learning challenges

References

Arnone, K. A. (2017). *An exploratory cross-sectional survey study of elementary teachers' conceptions and methods of STEM integration* [Unpublished doctoral dissertation]. University of Missouri-Columbia. https://doi.org/10.51355/jstem.2018.43

Aşıksoy, G., & Özdamlı, F. (2017). *The flipped classroom approach based on the 5e learning cycle model – 5elfa/nastavni pristup obrnute učionice uutemeljen na 5e modelu ciklusa učenja*. Croatian Journal of Education - Hrvatski Časopis Za Odgoj I Obrazovanje, 19(4). https://doi.org/10.15516/cje.v19i4.2564

Çakır, N. (2017). *Effect of 5e learning model on academic achievement, attitude and science process skills: Meta-analysis study*. Journal of Education and Training Studies, 5(11), 157. https://doi.org/10.11114/jets.v5i11.2649

Hassan, M. N., Abdullah, A. H., Ismail, N., Suhud, S. N. A., & Hamzah, M. H. (2019). *Mathematics curriculum framework for early childhood education based on science, technology, engineering and mathematics (STEM)*. International Electronic Journal of Mathematics Education, 14(1), 15–31. https://doi.org/10.12973/iejme/3960

Lin, J., Cheng, M., Chang, Y., Li, H., Chang, J., & Lin, D. (2014). *Learning activities that combine science magic activities with the 5e instructional model to influence secondary-school students' attitudes to science*. Eurasia Journal of Mathematics Science and Technology Education, 10(5). https://doi.org/10.12973/eurasia.2014.1103a

Martins, I., & Baptista, M. (2024). *Teacher professional development in integrated STEAM education: A study on its contribution to the development of the PCK of physics teachers*. Education Sciences, 14(2), 164. https://doi.org/10.3390/educsci14020164

Pavlovičová, G., & Bočková, V. (2021). *Geometric thinking of future teachers for primary education—An exploratory study in Slovakia*. Mathematics, 9(23), 2992. https://doi.org/10.3390/math9232992

Rahmawati, F., Achdiani, Y., & Maharani, S. (2021). *Improving students' learning outcomes using 5e learning cycle model*. ASEAN Journal of Science and Engineering Education, 1(2), 97–100. https://doi.org/10.17509/ajsee.v1i2.33389

Resmol, K., & Leasa, M. (2022). *The effect of learning cycle 5e+powtoon on students' motivation: The concept of animal metamorphosis*. JPBI (Jurnal Pendidikan Biologi Indonesia), 8(2), 121–128. https://doi.org/10.22219/jpbi.v8i2.18540

Shivam, P., & Mohalik, P. (2022). *Effectiveness of ICT integrated 5e learning model on higher order thinking skills in biology at secondary level*. Current Research Journal of Social Sciences and Humanities, 5(1), 34–41. https://doi.org/10.12944/crjssh.5.1.05

Subawo, M., & Arbain, A. (2023). *Improving student mathematics learning outcomes with the learning model cycle 5e class VII*. JME (Journal of Mathematics Education), 8(1), 66–75. https://doi.org/10.31327/jme.v8i1.1907

Wahyuningsih, R. (2023). *Penerapan model pembelajaran learning cycle 5e terhadap hasil belajar IPA siswa sekolah dasar*. Jurnal Elementaria Edukasia, 6(2), 844–857. https://doi.org/10.31949/jee.v6i2.5087

Wikara, B., Sutarno, S., Suranto, S., & Sajidan, S. (2022). *Implementation of 5e plus learning model on energy subject matter to improve students' argumentation skills*. Jurnal Pendidikan IPA Indonesia, 11(2), 237–245. https://doi.org/10.15294/jpii.v11i2.30567

Wiriani, N., & Ardana, I. (2022). *The impact of the 5e learning cycle model based on the STEM approach on scientific attitudes and science learning outcomes*. Mimbar PGSD Undiksha, 10(2), 300–307. https://doi.org/10.23887/jjpgsd.v10i2.48515

Hamami, Y., & Amalric, M. (2024). *Going round in circles: A cognitive bias in geometric reasoning*. Open Mind, 8, 1312–1329. https://doi.org/10.1162/opmi_a_00169