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Bringing Science to Life: STEM-Based Instructional Strategies for Primary Students in Thailand

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Abstract

Many students in Grade 5 struggle to make sense of science lessons, especially when the material feels abstract and far from their everyday experience. Although science holds an important place in Thailand's education system as one of the eight main subjects, young learners often find it difficult to stay engaged or fully grasp the concepts. STEM education, a contemporary and productive instruction to science. This study aimed to investigate the implementation of STEM-based science learning activities for Grade 5 students in terms of learning outcomes and student satisfaction. The one group pre-test and post-test design was employed. This study involved eight Grade 5 students who were chosen through purposive sampling. They took part in a series of STEM-based science lessons, with data gathered through lesson plans, achievement tests, and a student satisfaction questionnaire. The results showed a significant improvement in post-test scores compared to pre-test scores ($p < 0.05$), and student satisfaction was rated at the highest level ($M = 4.79$, $SD = 0.34$). These findings highlight the potential of STEM-based instruction to improve learning outcomes and engagement in primary science education

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INTRODUCTION

Education serves as a fundamental driver of societal advancement and individual growth. It enhances one's capacities, molds attitudes, and makes a substantial contribution to improving one's quality of life (Powdthavee et al., 2015; Váradi, 2022). As such, education stands as one of the most vital instruments for empowering communities and driving national advancement. The quality of education requires students to learn to adapt to new technologies and live with others in a diverse learning environment. It requires a well-developed education process and prepares citizens to face uncertainty. Consequently, the current Thai education system must be designed to be both inclusive and of high quality, ensuring that students receive a well-rounded education. The emphasis lies in fostering students' potential across various dimensions (Inprasitha, 2022; Sangwanglao, 2024).

Science is one of the 8 subject groups in the Thai education system. Students need to have creative thinking skills and the necessary learning skills to deal with science (Kwangmuang et al., 2021). Through a variety of academic areas, students gain fundamental knowledge and useful skills connected to scientific processes. Additionally, scientific knowledge enhances the potential for economic growth (Eisenmenger et al., 2020; Lehmann-Hasemeyer et al., 2023). That research greatly improves human wellbeing, and Thailand wants to become self-sufficient in both science and technology. In order to accelerate the growth of the country's human capital, the younger generation should be prepared with competencies in two scientific areas. By encouraging scientific

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thinking, this program seeks to improve academic achievement and facilitate more efficient learning (Wei, 2024). Along with collaborative skills, students are urged to hone their critical thinking talents in order to foster a feeling of accountability and appropriate behavior in group situations (Dias-Oliveira et al., 2024; Guo et al., 2024).

The researchers aim to enhance and modify teaching methods to fit the backgrounds of students and the changing social environment in order to increase academic achievement. STEM education places a strong emphasis on educating students to handle challenging and complicated real-world scenarios (Panergayo & Prudente, 2024; Uyanik & Benzer, 2023). As a result, as indicated in previous studies, students examine and evaluate data derived from provided issues while participating in a variety of cognitive tasks. During this process, kids gain critical skills and share viewpoints with peers, which enables them to independently find correct information or fix problems. Habits of careful analysis and evidence-based research are fostered by this experience. Therefore, the teaching strategy creates a strong foundation for enhancing students' critical thinking and problem-solving skills (Panergayo & Prudente, 2024; Uyanik & Benzer, 2023).

Many Grade 5 students face challenges in learning science because the material is often abstract, and the teaching tends to focus too much on the teacher (Akerson & Buck, 2023). This situation makes it harder for students to think scientifically, be creative, and stay motivated in the classroom. Modern students must enhance critical thinking and problem-solving skills, in particular to succeed in an increasingly information-driven and modern culture; therefore, addressing this issue is crucial. To aid with this, the researchers created a set of STEM-based science learning exercises educational approach (Akerson & Bartels, 2020; Akerson & Buck, 2023). The integration of technological concepts and engineering design, core components of the STEM education framework, plays a key role in transforming abstract science content into concrete, experiential learning. This approach strengthens the process of teaching and learning, increasing the efficacy of education. The STEM framework, which organically blends scientific and mathematical ideas, is especially pertinent to the situation. Therefore, it makes sense to incorporate engineering design and technological components. Furthermore, STEM education promotes active participation and autonomy in the learning process by emphasizing a student-centered paradigm (Nuangchalerm, 2018; Suebsing & Nuangchalerm, 2021). Where students are encouraged to take initiative and actively show their understanding. The unique contribution of this research demonstrates the use of STEM education in a way that suits the needs of primary school students in Thailand. This approach helps students become more engaged, improve their learning, and enjoy the learning process through hands-on and connected activities.

Many researchers have shown that STEM-based learning encourages students to be more engaged and helps them understand science in a deeper and more lasting way (Freeman et al., 2014; Prince, 2004; Fortus et al., 2022). These approaches often include hands-on experiments, teamwork, and tasks that connect science to real-world situations (Beer & Moneta, 2011; Dare et al., 2021). While these findings are promising, most of the research has focused on older students in secondary or high school settings. There is still very little known about how young learners at the primary level, particularly in Thailand, respond to structured STEM lessons, especially when the topic involves abstract content like force and friction. The goal of this project is to close the current gap by creating and evaluating STEM-focused educational activities specifically for fifth-graders. The researchers were inspired to investigate teaching methods based on STEM education because of the previously mentioned importance. To promote meaningful involvement with science, it is essential to improve students' academic achievement and guarantee their pleasure. Thus, this study sought to investigate how STEM-based scientific activities may be implemented for fifth-grade students, with an emphasis on learning objectives and student satisfaction.

METHOD

This study employed a pre-test and post-test design. The participants were Grade 5 students from Ban Buke Khala School (Boon Saksakakarin) during the first semester of the 2024 academic year. The school is located in Budi Subdistrict, Mueang District, Yala Province. A total of eight students were selected as the sample using purposive sampling.

Research instruments were science lesson plans based on the STEM education topic, force and friction. The lesson plans were created for 10 hours, using 10 different plans, and validated through 3 experts in the various fields of education and STEM education activities. The learning accomplishment exam consists of 10 pre- and post-test questions, each of which is 4-multiple question. A survey of perceptions on STEM-based scientific learning activities with 10 items of 5-Likert scale was used to investigate students' satisfaction.

Collected data through the experimental design, a one pretest/posttest design for one group. Measure the results by using the scores from the pretest and posttest. Using a paired sample t-test, the analysis compared the mean science accomplishment scores before and following the implementation. The survey also evaluated Grade 5 students' average satisfaction with STEM-related scientific learning activities, interpreting mean results based on predetermined criteria. The satisfaction scale was divided into the following categories: Very high is 4.51–5.00, high is 3.51–4.50, moderate is 2.51–3.50, low is 1.51–2.50, and very low is 1.00–1.50.

RESULTS AND DISCUSSION

This study created a STEM lesson plan consisting of ten learning hours and ten structured activities, focusing on the topic of force and friction. Each activity was designed to encourage meaningful learning by using teaching strategies that help students stay involved. The plan included problem-solving tasks and group discussions to promote active learning. Simple experiments and demonstrations were used to give students hands-on experience and help them understand scientific ideas more clearly. The lesson also connected science with basic math skills and real-life technology, making the content easier to relate to everyday situations. The design follows the core ideas of STEM education and aims to improve students' ability to think critically and solve problems.

Efficiency of Learning Activity

The study found that an efficiency criterion of science learning activities based on STEM education was 87.14/77.50 (Table 1). The process of learning activities meets the requirement of students' achievement at 87.14 by learning through mind-on and hands-on activities. The study reported that the efficiency of the product meets the criteria of 77.50.

Table 1. Process and Product of Science Learning Activities based on STEM Education

Number of student	Process efficiency	Product efficiency	E_1/E_2
8	87.14	77.50	87.14/77.50

The average score indicated the efficiency rate of the STEM-based scientific learning activities was 87.14/77.50. The dataset provides insight into an evaluation strategy that makes use of student learning outcomes (E2) and instructional efficiency (E1) as important evaluation metrics. This approach most likely seeks to evaluate the degree to which instructional tactics and educational interventions provide the desired results for students. Effective teaching strategies are indicated by a high ratio between instructional efficiency and learning outcomes. However, even when those strategies are methodically planned and implemented, this might also point to a possible discrepancy between the actual student performance and the instructional tactics used.

Such information can serve as a valuable tool for pinpointing weaknesses within the curriculum or instructional design. When instructional process efficiency (E1) surpasses learning outcome efficiency (E2), it may indicate that, although the teaching strategies are delivered effectively, they might fall short in enabling students to attain the targeted learning objectives. Similarly, Fraser and Walberg (2005) highlight that effective instruction must consider learners' cognitive engagement, background knowledge, and learning context. Without such alignment, even structured lessons may yield limited results. Therefore, further investigation, such as through classroom observations, student feedback, and formative assessment, is necessary to understand why the outcomes deviate. Efficiency metrics alone may oversimplify instructional effectiveness unless contextualized with variables such as content complexity, student readiness, and learning environment (Guskey, 2002; van Merriënboer, 2007).

Academic Achievement

Following the STEM learning activities, students' academic performance increased, as evidenced by post-test results that, at the 0.05 level of statistical significance, were considerably higher than their pre-test results (Table 2). This mismatch indicates the need to reconsider how teaching strategies align with students' learning needs and engagement levels. As suggested by Joyce and Weil (1972), instructional design should emphasize not only well-organized delivery but also deep understanding and meaningful learning.

Table 2. Academic Achievement before and after Implementation

Numbers of Student	Pre-test		Post-test		df	t
	Mean	SD	Mean	SD		
8	2.88	1.13	7.75	1.39	7	16.52*

The average score of the students increased from 2.88 before the intervention to 7.75 following it, indicating that they successfully participated in the STEM learning activities. This development demonstrates how well the STEM-based teaching strategy raises student success. The observed increases were attributed to the influence of the STEM learning activities as opposed to chance fluctuations, as demonstrated by the 0.05-level statistically significant difference between pre-test and post-test results.

Students' successful completion of the STEM learning activities suggests that the assignments were suitably challenging but doable. This shows that the exercises were carefully planned to accommodate students' current ability levels, encouraging deeper conceptual comprehension and active engagement. These findings support the importance of instructional strategies that incorporate active learning, hands-on experience, and interdisciplinary approaches. Previous studies have shown that such strategies promote higher engagement and conceptual understanding (Freeman et al., 2014; Prince, 2004). The integration of STEM disciplines fosters meaningful knowledge acquisition by encouraging analytical thinking, collaboration, and the real-world application of theoretical concepts (Beer & Moneta, 2011; Dare et al., 2021). The following components are crucial in helping students understand how different subjects are related and how to use that knowledge to solve everyday problems.

According to this research, STEM learning activities have the potential to greatly boost student development, making them a compelling case for inclusion in educational strategies that aim to foster both academic achievement and practical abilities.

Satisfaction Towards Science Learning Activities based on STEM Education

Students had a level of learning satisfaction towards STEM-based scientific learning activities at the highest level (Table 3).

Table 3. Satisfaction towards science learning

No.	Item	Mean	SD	Level of satisfaction
1	The statement of learning activities is easy to understand	4.50	0.71	High
2	The activities is fun and engaging students in learning	5.00	0.00	Highest
3	Learning management is interesting	4.88	0.33	Highest
4	The learning content on force and friction is clear and easy to understand	4.75	0.43	Highest
5	Analytical thinking and problem-solving are promoted in activities	4.25	0.83	High
6	The sequencing of the content in the learning activity series has continuous and clear	4.75	0.66	Highest
7	The STEM learning activity helps students to	4.75	0.43	Highest

* Statistically significant difference at 0.5

No.	Item	Mean	SD	Level of satisfaction
	have a good attitude			
8	Students are ready to engage within groups	5.00	0.00	Highest
9	Teacher help student to learning during the learning process	5.00	0.00	Highest
10	Overall, students are satisfied with the learning management	5.00	0.00	Highest
	Overall	4.79	0.34	Highest

Students' satisfaction was determined to be at its best level. The results highlight how effective STEM education can increase students' interest, comprehension, and disposition toward learning. According to Suriyabutr & Williams (2021), delve into the difficulties and potential solutions linked to introducing STEM integration to secondary schools in Thailand. Because students can engage in STEM classes, this is crucial for both long-term memory and conceptual understanding (Margot & Kettler, 2019).

The results indicating scores for group involvement highlight the high levels of motivation and engagement among students. STEM education consistently shows that active participation enhances both conceptual understanding and the retention of information in long-term memory (Fortus et al., 2022; Maceiras et al., 2025). When students find learning enjoyable and collaborative, they are more likely to immerse themselves in the subject matter, improving academic results. While previous research has largely focused on broader or older student populations, this study provides additional evidence that similar outcomes can be observed even at the primary level when activities are carefully structured and age-appropriate.

Moreover, the program's well-structured activities and the clear, comprehensible material emphasize the careful design of the learning experience. Simplified yet effective instructional approaches are vital for introducing challenging concepts in physics, such as force and friction, which can be abstract and complex for many students. Simplification not only reduces cognitive load but also allows students to focus on applying these concepts in practical scenarios, thereby fostering deeper understanding (Skulmowski & Xu, 2022; Song et al., 2023). This approach conforms to the ideals of scaffolding in education, where students are gradually guided through increasingly complex material. (Dai et al., 2023; Dominguez & Svihla, 2023)

Students who receive a flawless score in this area demonstrate how much they value the advice that their teachers have given them. It is crucial to have knowledgeable facilitators present because they help students navigate challenging material and assignments, improving the overall quality of the learning process (Anning, 2025; Martin et al., 2022). According to the assessment, the STEM learning activities were very successful in fostering an environment in the classroom where kids could learn well and feel supported and engaged (Almuharomah et al., 2023; Bun-aran & Prasertsang, 2024). These results offer a useful perspective on how structured STEM programs, when implemented at the primary level, can deliver outcomes comparable to what previous studies have reported in higher education contexts. Teachers may make these exercises even more effective learning tools by focusing on skills like critical thinking and problem solving. The high satisfaction levels underscore the program's success and its potential as a model for mainstream STEM education.

LIMITATION

The study employed a group pre-test and post-test design due to the limitations of classroom and school contexts. The future study should expand the research to include a control group pre-test and post-test design. The number of participants seems to be limited for investigation due to the small-sized school; this is, statistical data was also limited due to the school context. The next investigation could use non-parametric statistics or switch to another research design.

CONCLUSION

This study explored how STEM-based science learning activities could help improve academic performance and student satisfaction among Grade 5 learners. A total of eight students were involved, selected through purposive sampling. A questionnaire measuring student happiness, an achievement exam, and 10 lesson plans were among the research instruments. Data were examined using basic statistical tools such as percentages, means, standard deviations, and a dependent t-test. The findings suggest that the learning activities had a meaningful impact. Students performed better after the intervention, showing clear progress compared to their initial results. They also responded positively to the process of learning, expressing a high level of satisfaction. These findings suggest that STEM-based lessons can make science more accessible and enjoyable, especially when the content is presented through active, hands-on tasks that connect across subjects. This study adds to the understanding of how classroom strategies can be made more engaging for younger students. Teachers may consider applying similar approaches to improve students' comprehension of abstract scientific ideas while promoting teamwork and critical thinking.

AUTHOR CONTRIBUTIONS

In addition to helping with paper writing, KN started, reviewed, and verified the analytical processes. The study was conceived by PN, who also managed the research and contributed to the manuscript's composition. Building the theoretical foundation, doing the calculations, monitoring the study findings, and helping to produce the publication were all under RS's purview. Each author actively participated in the manuscript's finalization and examined the findings together.

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REFERENCES

Akerson, V. L., & Bartels, S. L. (2020). *Critical questions in STEM education*. Springer Nature Switzerland. https://doi.org/10.1007/978-3-030-57646-2

Akerson, V. L., & Buck, G. A. (2023). *Elementary science teaching*. Routledge. https://doi.org/10.4324/9780367855758-21

Almuharomah, F., Sunarno, W., & Masykuri, M. (2023). The implementation of the integrated STEAM approach to improve students' interest in science. *International Journal of STEM Education for Sustainability*, *3*, 319–335. https://doi.org/10.53889/ijses.v3i2.249

Anning, A. S. (2025). Professional learning facilitators' contribution to sustainable STEM teacher learning in regional contexts. *International Journal of Educational Research Open*, *8*, 100406. https://doi.org/10.1016/j.ijedro.2024.100406

Beer, N., & Moneta, G. B. (2011). Positive metacognitions and positive meta-emotions questionnaire. *Metropolitan University, London*, *7*(10), 5–6. https://doi.org/10.1037/t10305-000

Bun-aran, C., & Prasertsang, P. (2024). Creative development of 4th graders by using a set of learning management activities based on the STEAM concept. *International Journal of STEM Education for Sustainability*, *4*(2), 202-212. https://doi.org/10.53889/ijses.v4i2.384

Dai, Yun, Lin, Ziyan, Liu, Ang, Dai, Dan, & Wang, Wenlan. (2023). Effect of an analogy-based approach of artificial intelligence pedagogy in upper primary schools. *Journal of Educational Computing Research*, *61*(8), 1695–1722. https://doi.org/10.1177/07356331231201342

Dare, E. A., Keratithamkul, K., Hiwatig, B. M., & Li, F. (2021). Beyond content: The role of stem disciplines, real-world problems, 21st century skills, and stem careers within science teachers' conceptions of integrated stem education. *Education Sciences*, *11*(11). 1-6 https://doi.org/10.3390/educsci11110737

Davies, D., Jindal-Snape, D., Collier, C., Digby, R., Hay, P., & Howe, A. (2013). Creative learning environments in education—A systematic literature review. *Thinking Skills and Creativity*, *8*, 80–91. https://doi.org/10.1016/j.tsc.2012.07.004

Dias-Oliveira, E., Pasion, R., Vieira da Cunha, R., & Lima Coelho, S. (2024). The development of critical thinking, team working, and communication skills in a business school–A project-based learning approach. *Thinking Skills and Creativity*, *54*, 101680. https://doi.org/10.1016/j.tsc.2024.101680

Dominguez, S., & Svihla, V. (2023). A review of teacher implemented scaffolding in K-12. *Social Sciences & Humanities Open*, *8*(1), 100613. https://doi.org/10.1016/j.ssaho.2023.100613

Eisenmenger, N., Pichler, M., Krenmayr, N., Noll, D., Plank, B., Schalmann, E., Wandl, M. T., & Gingrich, S. (2020). The Sustainable development goals prioritize economic growth over sustainable resource use: a critical reflection on the SDGs from a socio-ecological perspective. *Sustainability Science*, *15*(4), 1101–1110. https://doi.org/10.1007/s11625-020-00813-x

Fortus, D., Jing, L., Knut, N., & and Sadler, T. D. (2022). The role of affect in science literacy for all. *International Journal of Science Education*, *44*(4), 535–555. https://doi.org/10.1080/09500693.2022.2036384

Fraser, B. J., & Walberg, H. J. (2005). Research on teacher–student relationships and learning environments: Context, retrospect and prospect. *International Journal of Educational Research*, *43*(1), 103–109. https://doi.org/10.1016/j.ijer.2006.03.001

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Guo, R., Jantharajit, N., & Thongpanit, P. (2024). Enhancing analytical and critical thinking skills through refl ective and collaborative learning : A quasi-experimental study. *Journal of Education and Educational Development*, *11*(2), 200–223. http://dx.doi.org/10.22555/joeed.v11i2.1166

Guskey, T. R. (2002). Professional development and teacher change. *Teachers and Teaching*, *8*(3), 381–391. https://doi.org/10.1080/135406002100000512

Inprasitha, M. (2022). Lesson study and open approach development in Thailand: A longitudinal study. *International Journal for Lesson and Learning Studies*, *11*(5), 1–15. https://doi.org/10.1108/IJLLS-04-2021-0029

Joyce, B., & Weil, M. (1972). Conceptual complexity, teaching style and models of teaching. *Internasional*, *1*(1), 1–25. https://files.eric.ed.gov/fulltext/ED073965.pdf

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

Lehmann-Hasemeyer, S., Prettner, K., & Tscheuschner, P. (2023). The scientific revolution and its implications for long-run economic development. *World Development*, *168*, 106262. https://doi.org/10.1016/j.worlddev.2023.106262

Maceiras, R., Feijoo, J., Alfonsin, V., & Perez-Rial, L. (2025). Effectiveness of active learning techniques in knowledge retention among engineering students. *Education for Chemical Engineers*, *51*, 1–8. https://doi.org/10.1016/j.ece.2025.01.003

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, *6*(1). 1-7 https://doi.org/10.1186/s40594-018-0151-2

Martin, M. M., Goldberg, F., McKean, M., Price, E., & Turpen, C. (2022). Understanding how facilitators adapt to needs of STEM faculty in online learning communities: A case study. *International Journal of STEM Education*, *9*(1). https://doi.org/10.1186/s40594-022-00371-x

Nuangchalerm, P. (2018). Investigating views of stem primary teachers on stem education. *Chemistry*, *27*(2), 208-215. https://www.researchgate.net/publication/324657096

Panergayo, A., & Prudente, M. (2024). Effectiveness of design-based learning in enhancing scientific creativity in stem education: A meta-analysis. *International Journal of Education in Mathematics, Science and Technology*, *12*, 1182–1196. https://doi.org/10.46328/ijemst.4306

Powdthavee, N., Lekfuangfu, W. N., & Wooden, M. (2015). What's the good of education on our overall quality of life? A simultaneous equation model of education and life satisfaction for Australia. *Journal of Behavioral and Experimental Economics*, *54*, 10–21. https://doi.org/10.1016/j.socec.2014.11.002

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Sangwanglao (จตุพล สังวังเลาว์), Jatupol. (2024). Competency-based education reform of Thailand's basic education system: A policy review. *ECNU Review of Education*, 20965311241240490. https://doi.org/10.1177/20965311241240486

Skulmowski, A., & Xu, K. M. (2022). Understanding cognitive load in digital and online learning: A new perspective on extraneous cognitive load. *Educational Psychology Review*, *34*(1), 171–196. https://doi.org/10.1007/s10648-021-09624-7

Song, C., Shin, S. Y., & Shin, K. S. (2023). Optimizing foreign language learning in virtual reality: A comprehensive theoretical framework based on constructivism and cognitive load theory (VR-CCL). *Applied Sciences (Switzerland)*, *13*(23). https://doi.org/10.3390/app132312557

Suebsing, S., & Nuangchalerm, P. (2021). Understanding and satisfaction towards stem education of primary school teachers through professional development program. *Jurnal Pendidikan IPA Indonesia*, *10*(2), 171–177. https://doi.org/10.15294/jpii.v10i2.25369

Suriyabutr, A., & Williams, J. (2021). Integrated STEM education in the thai secondary schools: Challenge and addressing of challenges. *Journal of Physics: Conference Series*, *1957*(1). https://doi.org/10.1088/1742-6596/1957/1/012025

Uyanik, S., & Benzer, E. (2023). Developing and evaluating a design for online stem education on environment for secondary school students. *International Journal on Social and Education Sciences*, *5*(4), 787–821. https://doi.org/10.46328/ijonses.562

van Merriënboer, J. J. G. (2007). Ten steps to complex learning. A systematic approach to four-component instructional design. *(1st ed.). Routledge.* https://doi.org/10.4324/9781410618054

Váradi, Judit. (2022). A review of the literature on the relationship of music education to the development of socio-emotional learning. *SAGE Open*, *12*(1), 21582440211068500. https://doi.org/10.1177/21582440211068501

Wei, W. (2024). Research on strategies for cultivating scientific thinking in high school biology teaching. *Curriculum and Teaching Methodology*, *7*(1), 77–82. https://doi.org/10.23977/curtm.2024.070712