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Elementary School Students' Metacognitive Awareness: PBL Study with HPC Strategy in Science Learning

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Abstract: The results of previous studies show that biological science learning for elementary school students is in the sufficient category. This is because teachers do not familiarize students with being trained in high-level thinking in the form of life skills, namely metacognitive awareness. Therefore, effective strategies are needed to increase students' metacognitive awareness. One model that can increase students' metacognitive awareness is the problem-based learning (PBL) model with the homogeneity psychocognition (HPC) strategy. The aim of the research is to analyze differences in elementary school students' metacognitive awareness in learning biological science using the PBL model, PBL with HPC strategies, and conventional models. This research used a quasi experiment with a pretest-posttest nonequivalent control group design. The number of samples participating in the research was 155 students where sampling was carried out randomly. The instrument used was the metacognitive awareness inventory which was adapted from the Junior Metacognitive Inventory (Jr. MAI) by Sperling et al (2002). The inventory consists of 18 questions with 9 items each on the aspects of knowledge of cognition and regulation of cognition. The research results found that there were significant differences in metacognitive awareness in the PBL learning model, PBL with HPC strategies compared to conventional learning. This research recommends that teachers can optimize PBL, as well as PBL with HPC strategies in increasing students' metacognitive awareness.

Keywords: Biological Science; HPC; Metacognitive Awareness; PBL

Introduction

Throughout the country, studies show that some students experience failure in science learning. Biology learning is one area of science that is still considered difficult for students. For many students, studying biology is a complex and linguistically challenging endeavor (Gomez et al., 2016). Students tend to carry their misconceptions about biological science from elementary education to college. Previous research shows that biology learning in elementary education has a close relationship with biology learning in higher education (Shen et al., 2018). The basic education level has special importance because at this level students first begin to become familiar with biology and its problems even though there is no special subject entitled biology. Students' first impressions of biology subjects are actually an important factor in shaping their interest in biology subjects in the future (Köksal, 2011). Therefore, the fundamental goal of biology education is to encourage the development of independent learning (Johann et al., 2022).

Students' success in society depends on themselves. Therefore, learning abilities and core competencies need to be prioritized (Jagals & van der Walt, 2018). In the 21st century, knowledge will continue to develop and become increasingly specialized, and expand exponentially. The increase and dissemination of

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information will bring many changes in the social, economic, political, and technological fields. These changes also affect the education system, and the need to make changes in the acquisition of knowledge, skills, and individual competencies. People must have life skills in order to be able to adapt to rapid changes and transformations (Karatas & Arpaci, 2021).

The results of international studies report that students in America are less prepared to study biology due to a lack of reading and lack of study skills. In a survey of 1,100 lecturers from various campuses, only 10% felt that their students were very ready to read and understand lecture material (Hill et al., 2014). In addition, a study in Nigeria reported that high school students had poor metacognitive awareness (Okoza, 2013). Thinking skills are one of the life skills for students to use metacognition in dealing with various changes (Ilma et al., 2022). Metacognition refers to a person's knowledge regarding cognitive processes and products or anything related to them. Metacognition is reported to have an influence on students' academic performance (Stanton et al., 2015; Siqueira et al., 2020). It has been proven that assignments designed by teachers to improve metacognition can have an impact on students throughout the semester and can provide the greatest benefits for low-achieving students (Dang et al., 2018).

The results of previous research show that metacognitive awareness has an important role in learning. This is because learning can be interpreted as students' ability to identify their strengths and weaknesses and deepen their knowledge. Learning is interpreted as an effort to understand how, when, and why to use these strategies (Harrison & Vallin, 2018; Wei, 2020). There is also some evidence that metacognitive awareness is related to students' learning processes (Beccaria et al., 2014) and better academic achievement (Vosniadou et al., 2021). However, the relationship between metacognitive awareness and student learning remains under-examined in the context of primary education. So far, many studies have further explored metacognitive awareness in higher education and more specifically in the teacher education (Kallio et al., 2018).

Learners who are metacognitively aware are able to design more strategic independent learning. Apart from that, it can also predict students' performance more accurately and excel further than students who are not aware of (Fu et al., 2023). Students with good metacognitive awareness will use their study time efficiently, narrow their focus to certain areas, and maximize their readiness to learn (Martirosov & Moser, 2021).

Metacognitive abilities appear to continue to develop with age. Children aged 6 years will be able to develop cognitive knowledge and reflect on their cognition. Additionally, children between the ages of 8 and 10 appear to gain a fair understanding of how the mind actively processes information. Ultimately, monitoring and evaluating cognition may or may not develop substantial improvements later in life, along with metacognitive constructs (Breed & Bailey, 2018).

It has been reported that students who are metacognitively aware will be enthusiastic and organize their learning (Payaprom, 2023). Therefore, students who have high motivation will be involved in all phases of learning which include understanding concepts and solving problems (Mamon et al., 2020). Teachers with high metacognitive awareness will be more motivated to teach and improve the quality of their learning (Karimi & Ziaabadi, 2019). The results of other research reveal that students in urban areas have better metacognitive awareness than students in rural areas (Bakkaloglu et al., 2020).

Many students have difficulty reflecting on themselves in learning due to a lack of metacognitive skills (Räisänen et al., 2021). Metacognitive skills are also determined by metacognitive awareness. Metacognitive awareness is often ignored even though it is important in achieving educational goals. Metacognitive awareness is not easy to obtain because it requires a thorough understanding of metacognition and its methods (Salviana et al., 2021). Researchers suggest that metacognition contributes approximately 17% to students' success in school, while intelligence contributes approximately 10% (Zion & Cohen, 2021). So, schools need to help and encourage students' metacognitive awareness effectively. In this spirit, metacognition serves as a predictor in problem-solving regarding everyday problems (Perry et al., 2019).

Previous studies have reported that one of the main factors influencing student performance in science is the metacognition (Wonjoon Hong, Matthew L. Bernacki, 2020). Metacognitive awareness can improve elementary school students' conceptual understanding of science. This is because students who have high metacognitive awareness know what they are supposed to do in the task and find the task easier, especially when they are faced with collaborating (Çini et al., 2023). One subject that has the potential to empower students' metacognition is biology (Hindun et al., 2020). Various studies have also supported this statement. By choosing the right learning strategy, students' metacognition will be empowered optimally when studying biology. Apart from that, the application of several innovative learning models and strategies can also improve students' metacognition (Leasa et al., 2023).

Problem-based learning (PBL) is one model that can be recommended for increasing students' metacognitive awareness. One study at the high school level on chemistry subjects has proven that PBL can improve students' metacognitive regulation skills (Kuvac & Koc, 2019). Metacognitive awareness when integrated into PBL helps students improve cognitive strategies and learning performance (Nizlel et al., 2022). Students with solid metacognitive experiences tend to perform better in science learning (Valladares, 2021). Metacognitive activities positively influence problem-solving strategies (Zhao et al., 2019). The problem-solving process includes the use of metacognition during the orientation, organizing, implementation, and verification phases. PBL with metacognitive instructions will involve students carrying out investigations to clarify problems and reflect on their actions (Marthaliakirana et al., 2022).

PBL is a student-centered learning model, where students take an active role in their own learning (Haruehansawasin & Kiattikomol, 2017). PBL refers to a learning environment in which problems drive learning, not competencies. During the problem-solving process, students first interpret the problem, then gather the necessary information, identify possible solutions, evaluate options, and present conclusions (Zotou et al., 2020). Problem-solving in heterogeneous groups is generally taken over by students with high academic abilities, while low academic abilities are less considered and paid attention to. Teachers tend to not involve the potential of students with low academic abilities because it is difficult for them to deal with the way they learn. As a result, they are less considered and favored in completing problem-solving tasks. Teachers are sometimes apathetic about students' learning progress. Therefore, another learning strategy is needed that can encourage the participation of students with low academic abilities so that they do not fall further behind. This effort is made in order to reach a balance point in learning, including in treating them. One of them is the homogeneity psychocognition (HPC) learning strategy.

HPC is based on a homogeneous grouping of students, especially regarding cognition, so that there is no gap between students with high and low abilities. HPC is considered to be able to encourage the participation of students with low academic performance so that students are enthusiastic about learning. HPC prioritizes collaboration between students in cooperative groups. The aim of forming homogeneous groups, between students with low, medium, and high academic abilities, is to provide opportunities for students to be actively involved in the thinking process and express themselves in learning activities without feeling burdened by the characteristics of other students who are smarter or more aggressive. This makes them respect each other and respect various differences in views and thoughts (Fenanlampir et al., 2021). HPC is a strategy that facilitates this (Batlolona & Kalean, 2023). Through HPC, students' metacognitive awareness can increase because students become happy and comfortable in learning which supports their learning progress. This also has an impact on the development of students' thinking skills. Thus, the aim of this research is to analyze differences in metacognitive awareness based on the PBL learning model with HPC, PBL, and conventional learning strategies for elementary school students in biological science learning.

Method

Research Design

This research is a quasi-experimental research with a pretest-posttest nonequivalent control group design. The procedure for implementing the treatment based on the research design is shown in Table 1.

Table 1. Treatment Groups Based on Variables

Pretest	Treatment	Posttest
O1	S1	O2
O3	S2	O4

Description
O1, O3 : Metacognitive awareness pretest scores
O2, O4 : Metacognitive awareness posttest scores
S1 : PBL group with HPC strategy
S2 : PBL group

Population and Sample

The population of this study was 5th-grade elementary school students at 8 elementary schools in Nusaniwe District, Ambon City. Determination of the research sample was carried out by random sampling using a lottery technique. Each treatment group is represented by 2 treatment classes, so there are 6 treatment classes used in the experimental group (PBL, PBL with HPC strategy) and the control group (conventional learning model), so the total sample reaches 155 people. This meets the requirements for data analysis techniques.

Instrument

The main instrument of this research is the Junior Metacognitive Awareness Inventory (Jr. MAI) which was adapted from Sperling et al (2002). The inventory consists of 18 questions which are divided into 2 main aspects, namely knowledge of cognition, 9 items and regulation of cognition, also 9 items. Knowledge of cognition consists of declarative knowledge in items 1, 4, and 12; conditional knowledge items 2, 5, 13, 14; procedural knowledge items 3, 16. Regulation of cognition consists of planning items 9, 18; information management skills items 6, 11; monitoring items 8, 10, 15; and evaluation items 7, 17.

Data Analysis Technique

The research data were analyzed quantitatively through one-way covariate analysis (ANCOVA). This analysis is needed to test the hypothesis which states "there is a difference in metacognitive awareness in biological science learning in elementary school between the PBL model with HPC strategies, PBL, and conventional models". Hypothesis testing was carried out after the metacognitive awareness data had met the criteria for homogeneity and normality, as shown in Tables 2 and 3.

Table 2. Metacognitive Awareness Data Homogeneity Test Results

F	df1	df2	Sig.
1.635	2	152	0.198

Test the null hypothesis that error variance og the dependent variable is equal groups.
a.design: intercept + X_MA+ Kelas

The homogeneity test with Levene's Test shows that the significance value = 0.198, meaning that it is greater than 0.05 indicating homogeneous metacognitive awareness data.

Table 3. Normality Test Results of Metacognitive Awareness Data

	Statistic	df	Sig.
Residual for Y_MA	.059	150	.200*

a. Lilliefors Significance Correction
*. This is a lower bound of the true significance.

Referring to Table 3, it is concluded that the data meets the Kolmogorov-Smirnov normality test because the significance value is 0.200 or greater than 0.05.

Result and Discussion

Anacova is used to test hypotheses related to the dependent variable, namely metacognitive awareness in treatment with different learning models. Anacova test results are shown in Table 4.

Anacova test results in Table 4 show that the significance value (class) = 0.028 (smaller than 0.05), thus, H0 is rejected and Ha is accepted, meaning that there is a significant difference in metacognitive awareness in the PBL learning model with HPC, PBL and conventional strategies. The large differences in metacognitive awareness in the three treatment classes are shown through the LSD test in Table 5.

Table 4. ANACOVA Test of the Effect of Learning Models on Metacognitive Awareness

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3178.517a	3	1059.506	9.272	.000	.156
Intercept	8835.470	1	8835.470	77.323	.000	.339
X_MA	2378.329	1	2378.329	20.814	.000	.121
Kelas	835.492	2	417.746	3.656	.028	.046
Error	17254.370	151	114.267			
Total	917827.719	155				
Corrected Total	20432.887	154				

a.R Squared = .156 (Adjused R Squared = .139

Increasing metacognitive awareness can equip students to think logically, analytically, critically, and creatively (Kallio et al., 2021). Therefore, students' metacognitive awareness will be enhanced if real-life problems are used in the classroom. Hargrove & Nietfeld, (2015) argue that PBL can be developed when concrete problems are taught in class with metacognitive strategies. Apart from that, Setiawan & Supiandi (2019) stated that PBL was successfully emphasized when students developed their own knowledge. In this regard, this research uses PBL learning with HPC strategies which offer many opportunities for students to solve concrete problems during learning. This is used in an effort to help students increase their metacognitive awareness in learning biological science (Keliat et al., 2021)

Table 5. LSD Metacognitive Awareness Test Results Based on Learning Model Treatment

Learning model	X-MA	Y-MA	Difference	Enhancement	MA Corrected	LSD Notation
Convensional	62.96	73.11	10.15	16.12%	72.57	a
PBL-HPC	59.50	75.85	16.35	27.48%	76.71	b
PBL	62.95	79.00	16.05	25.50%	78.42	b

Table 5 informs that the lowest corrected mean is in the conventional learning model, while the highest corrected mean is in the PBL learning model. Apart from that, it was found that students' metacognitive awareness in the PBL learning model with HPC and PBL was not significant, but the two learning models were significantly different from the conventional model. In addition, it was found that the increase in metacognitive awareness was in PBL learning with HPC followed by the PBL model alone, while in conventional learning it was lower than both. This finding is in line with previous findings which state that PBL can be an effective intervention in promoting metacognitive awareness of procedural knowledge, planning, and evaluation (Kuvac & Koc, 2019). Further metacognitive awareness is needed to solve a problem from available information and is developed critically by analyzing contextual problems in small collaborative groups.

PBL and PBL with HPC strategies are student-centered pedagogical models that offer a learning environment with a focus on problem-solving (Fenanlampir et al., 2021). The general pattern of PBL learning with the HPC strategy is to present real-life problems (related to broader curricular content and objectives) to students at the beginning of the lesson. Learners are then given time to work collaboratively in small groups to identify what they need to know to solve the problem while engaging in self-directed learning to seek answers report back to the group and apply the new knowledge to the problem. Finally, the groups present their proposed solutions to the problem and conclude the activity by reflecting on what they have learned and the effectiveness of the strategies used. The entire learning process in PBL with HPC strategies occurs around the problem-solving (Scholkmann, 2020). So, PBL with the HPC strategy is used in this research to provide as wide an opportunity as possible for students to solve problems during learning.

Several studies document the effectiveness of PBL models in different contexts (Valdez & Bungihan, 2019). They have shown that PBL promotes conceptual understanding and improves higher-order thinking skills, self-confidence, knowledge retention, motivation, academic achievement, and problem-solving. Seshan et al., (2021) show that students develop transferable skills while analyzing problems, constructing their knowledge and applying concepts in PBL with HPC strategies. However, other research shows that PBL can lead to poor performance when practiced based on the facts of the learning environment (Leasa et al., 2023). PBL with HPC strategies can also facilitate students who are not familiar with problems to participate in group activities.

In line with this, several studies have used different learning strategies and focused on key factors to improve fifth to eighth-grade students' problem-solving abilities (Haleem et al., 2022). Other findings reveal an increase in students' problem-solving abilities in terms of understanding problems, implementing resolution plans and verifying answers, as well as increasing achievement and attitudes. Several other studies have exposed students to biology learning using PBL to improve problem-solving abilities. The general result of their study was the positive impact of PBL on students' abilities in terms of problem solving. However, learning that applies PBL in high schools to improve problem solving abilities is still not promoted enough (Priemer et al., 2020); (Molina & Forlales, 2022). In addition, research using PBL to strengthen elementary school students' problem-solving abilities has not been widely reported. The current research will document the literature on this aspect and add to the body of knowledge. In contrast to these findings, Tosun & Senocak (2013) reported that PBL had no significant effect on the level of metacognitive awareness of prospective teachers who had a strong science background (Gholami et al., 2016).

The results of previous research show that there is a relationship between metacognitive skills and students' cognitive retention. The four teaching strategies applied (PBL, Jigsaw, PBLJigsaw, and direct teaching) in Biology class are significant, having a relatively high contribution value (30.1%, 36, 5%, 63.9%, and 83.0%) (Palennari, 2016). Therefore, using learning models in classroom learning is actually beneficial for students. One of them is PBL, as well as PBL with HPC strategies which have a significant effect on increasing metacognitive awareness in the future.

Conclusion

Based on the existing findings, it can be concluded that there is a significant difference in metacognitive awareness between conventional models compared to PBL learning, as well as PBL and HPC strategies. This research recommends that teachers are expected to prepare lessons using PBL models and HPC strategies consistently to increase students' metacognitive awareness. The suggestions that can be conveyed from the results of this research are 1) a learning environment that supports problem-based learning with HPC strategies needs to be pursued for elementary school students, 2) teachers can use PBL learning models, or PBL with HPC strategies to promote metacognitive awareness so as to support learning outcomes biological science students, 3) in order to support the development of metacognitive awareness, problem-based learning and HPC strategies can be trained in a more guided manner and implemented continuously, 4) more specific studies need to be conducted to explore the use of HPC strategies in learning over a longer period of time for get more information about the development of metacognitive awareness, as well as problem-solving abilities in learning biological sciences and other thematics in elementary school.

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Author Contributions

In this research, each author provided a different contribution. Theoretical analysis, data collection, data analysis, and writing of scientific articles were carried out by authors 1 and 2, while data collection in the field was carried out by authors 2, 3, and 4.

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Conflicts of Interest

The authors declare no conflict of interest.

References

Bakkaloglu, S., Faculty, E., & Faculty, E. (2020). Analysis of metacognitive awareness of primary and secondary school students in terms of some variables. *Journal of Education and Learning*, *9*(1), 156–163. https://doi.org/10.5539/jel.v9n1p156

Beccaria, L., Kek, M., Huijser, H., Rose, J., & Kimmins, L. (2014). The interrelationships between student approaches to learning and group work. *Nurse Education Today*, *34*(7), 1094–1103. https://doi.org/10.1016/j.nedt.2014.02.006

Breed, B., & Bailey, R. (2018). The influence of a metacognitive approach to cooperative pair problem-solving on self-direction in learning. *The Journal for Transdisciplinary Research in Southern Africa*, *14*(1), 1–11. https://doi.org/10.4102/td.v14i1.516

Çini, A., Malmberg, J., & Järvelä, S. (2023). How individual metacognitive awareness relates to situation-specific metacognitive interpretations of collaborative learning tasks. *Educational Studies*, *49*(1), 54–75. https://doi.org/10.1080/03055698.2020.1834359

Dang, N. V., Chiang, J. C., Brown, H. M., & McDonald, K. K. (2018). Curricular Activities that Promote Metacognitive Skills Impact lower-performing students in an introductory biology course. *Journal of Microbiology & Biology Education*, *19*(1), 1–9. https://doi.org/10.1128/jmbe.v19i1.1324

Fenanlampir, A., Leasa, M., & Batlolona, J. R. (2021). The development of homogeneity psycho cognition learning strategy in physical education learning. *International Journal of Evaluation and Research in Education*, *10*(3), 1047–1059. https://doi.org/10.11591/IJERE.V10I3.21713

Fu, Y., Wang, M., Min, S., Zhou, S., & Pan, X. (2023). Exploring the relationship between metacognitive awareness and Chinese EFL learners' listening skills. *Frontiers in Psychology*, *14*, 1–12. https://doi.org/10.3389/fpsyg.2023.1148610

Gholami, M., Moghadam, P. K., Mohammadipoor, F., Tarahi, M. J., Sak, M., Toulabi, T., & Pour, A. H. H. (2016). Comparing the effects of problem-based learning and the traditional lecture method on critical thinking skills and metacognitive awareness in nursing students in a critical care nursing course. *Nurse Education Today*, *45*, 16–21. https://doi.org/10.1016/j.nedt.2016.06.007

Gomez, K., Gomez, L. M., Cooper, B., Lozano, M., & Mancevice, N. (2016). Redressing science learning through supporting language : the biology credit recovery course. *Urban Education*, 1–31. https://doi.org/10.1177/0042085916677345

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, *3*, 275–285. https://doi.org/10.1016/j.susoc.2022.05.004

Hargrove, R. A., & Nietfeld, J. L. (2015). The impact of metacognitive instruction on creative problem solving. *Journal of Experimental Education*, *83*(3), 291–318. https://doi.org/10.1080/00220973.2013.876604

Harrison, G. M., & Vallin, L. M. (2018). Evaluating the metacognitive awareness inventory using empirical factor-structure evidence. *Metacognition and Learning*, *13*(1), 15–38. https://doi.org/10.1007/s11409-017-9176-z

Haruehansawasin, S., & Kiattikomol, P. (2017). Scaffolding in problem-based learning for low-achieving learners. *The Journal of Educational Research*, *0*(0), 1–8. https://doi.org/10.1080/00220671.2017.1287045

Hill, K. M., Brözel, V. S., & Heiberger, G. A. (2014). Examining the delivery modes of metacognitive awareness and active reading lessons in a college nonmajors introductory biology course. *Journal of Microbiology & Biology Education*, *15*(1), 5–12. https://doi.org/10.1128/jmbe.v15i1.629

Hindun, I., Nurwidodo, N., & Wicaksono, A. G. C. (2020). Metacognitive awareness components of high-academic ability students in biology hybrid learning: Profile and correlation. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *6*(1), 31–38. https://doi.org/10.22219/jpbi.v6i1.11097

Ilma, S., Al-Muhdhar, M. H. I., Rohman, F., & Sari, M. S. (2022). Promoting students' metacognitive awareness and cognitive learning outcomes in science education. *International Journal of Evaluation and Research in Education*, *11*(1), 20–30. https://doi.org/10.11591/ijere.v11i1.22083

Jagals, D., & van der Walt, M. (2018). Metacognitive awareness and visualisation in the imagination: The case of the invisible circles. *Pythagoras*, *39*(1), 1–10. https://doi.org/10.4102/pythagoras.v39i1.396

Johann, L. I., Rusk, F. K. H., Reiss, M. J., & Groβ, J. (2022). Upper secondary students' thinking pathways in cell membrane biology–an evidence-based development and evaluation of learning activities using the Model of Educational Reconstruction.

Journal of Biological Education, *00*(00), 1–22. https://doi.org/10.1080/00219266.2022.2026805

Kallio, H., Kallio, M., Virta, K., Iiskala, T., & Hotulainen, R. (2021). Teachers' support for learners' metacognitive awareness. *Scandinavian Journal of Educational Research*, *65*(5), 802–818. https://doi.org/10.1080/00313831.2020.1755358

Kallio, H., Virta, K., & Kallio, M. (2018). Modelling the components of metacognitive awareness. *International Journal of Educational Psychology*, *7*(2), 94–122. https://doi.org/10.17583/ijep.2018.2789

Karatas, K., & Arpaci, I. (2021). The role of self-directed learning, metacognition, and 21st century skills predicting the readiness for online learning. *Contemporary Educational Technology*, *13*(3), 1–13. https://doi.org/10.30935/cedtech/10786

Karimi, M. N., & Ziaabadi, F. (2019). Teachers ' motivation to teach , teacher credibility , metacognitive awareness , and students ' motivation and affective learning : a structural equation modeling analysis. *Teaching English Language*, *13*(1), 147–176. https://doi.org/10.22132/tel.2019.89275

Keliat, R. N., Susilo, H., & Sri Hastuti, U. (2021). Metacognitive awareness profile of students in indonesia: initial study on the development of biology learning models to support improvement of metacognitive skills. *Hong Kong Journal of Social Sciences*, *57*, 45–56.

Köksal, M. S. (2011). Epistemological predictors of "self efficacy on learning biology" and "test anxiety related to evaluation of learning on biology" for pre-service elementary teachers. *Journal of Science Teacher Education*, *22*(7), 661–677. https://doi.org/10.1007/s10972-010-9205-0

Kuvac, M., & Koc, I. (2019). The effect of problem-based learning on the metacognitive awareness of pre-service science teachers. *Educational Studies*, *45*(5), 646–666. https://doi.org/10.1080/03055698.2018.1509783

Leasa, M., Fenanlampir, A., Pelamonia, J., Talakua, M., & Education, P. (2023). Contribution of metacognition awareness to critical thinking skills with pbl model and hpc strategy: A food digestion system study. *Biosfer : Jurnal Pendidikan Biologi*, *16*(2), 467–480. https://doi.org/10.21009/biosferjpb.29921

Mamon, M. A. C., Esperanza, A. G., & Vital, J. A. T. (2020). Research-based learning: effects on the metacognitive awareness of senior high school students. *IJIET (International Journal of Indonesian Education and Teaching)*, *4*(2), 277–285. https://doi.org/10.24071/ijiet.v4i2.2540

Marthaliakirana, A. D., Suwono, H., Saefi, M., & Gofur, A. (2022). Problem-based learning with metacognitive prompts for enhancing argumentation and critical thinking of secondary school students. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(9), 1–15. https://doi.org/10.29333/ejmste/12304

Martirosov, A. L., & Moser, L. R. (2021). Team-based learning to promote the development of metacognitive awareness and monitoring in pharmacy students. *American Journal of Pharmaceutical Education*, *85*(2), 131–136. https://doi.org/10.5688/ajpe848112

Molina, G. M., & Forlales, ester L. (2022). Performance of senior high school in physics problem-solving using blended learning strategies. *Res Militaris*, *12*(6), 361–370.

Nizlel, S., Amirul, H., & Kamid, M. (2022). Using a metacognitive learning approach to enhance students ' critical thinking skills through mathematics education. *SN Social Sciences*, *2*(4), 1–26. https://doi.org/10.1007/s43545-022-00325-8

Okoza, J. (2013). Assessing students ' metacognitive awareness of learning strategies among secondary school students in Edo State , Nigeria. *Research in Education*, *90*(1), 82–97. https://doi.org/10.7227/RIE.90.1.6

Palennari, M. (2016). Exploring the corelation between meta cognition and cognitive retention of students using some biology teaching strategies. *Journal of Baltic Science Education*, *15*(5), 617–629. https://doi.org/10.33225/jbse/16.15.617

Payaprom, S. (2023). Investigating the relationship among metacognitive awareness , self-efficacy , and EFL learners ' listening comprehension performance. *Theory and Practice in Language Studie*, *13*(1), 27–34. https://doi.org/10.17507/tpls.1301.04

Perry, J., Lundie, D., & Golder, G. (2019). Metacognition in schools: what does the literature suggest about the effectiveness of teaching metacognition in schools? *Educational Review*, *71*(4), 483–500. https://doi.org/10.1080/00131911.2018.1441127

Priemer, B., Eilerts, K., Filler, A., Pinkwart, N., Rösken-Winter, B., Tiemann, R., & Zu Belzen, A. U. (2020). A framework to foster problem-solving in STEM and computing education. *Research in Science and Technological Education*, *38*(1), 105–130. https://doi.org/10.1080/02635143.2019.1600490

Räisänen, M., Postareff, L., & Lindblom-Ylänne, S. (2021). Students' experiences of study-related exhaustion, regulation of learning, peer learning and peer support during university studies. *European Journal of Psychology of Education*, *36*(4), 1135–1157. https://doi.org/10.1007/s10212-020-00512-2

Salviana, M., Ulfa, A. U. T., & Nurmaliah, C. (2021). The

Implementation of problem-based learning model to increase students ′ metacognitive awareness of environmental change. *IOSR Journal Of Pharmacy And Biological Sciences*, *16*(2), 20–24. https://doi.org/10.9790/3008-1602022024

Scholkmann, A. (2020). Why don’t we all just do the same? Understanding variation in PBL implementation from the perspective of translation theory. *Interdisciplinary Journal of Problem-Based Learning*, *14*(2), 1–15. https://doi.org/10.14434/ijpbl.v14i2.28800

Seshan, V., Matua, G. A., Raghavan, D., Arulappan, J., Al Hashmi, I., Roach, E. J., Sunderraj, S. E., & Prince, E. J. (2021). Case study analysis as an effective teaching strategy: perceptions of undergraduate nursing students from a middle eastern country. *SAGE Open Nursing*, *7*, 1–10. https://doi.org/10.1177/23779608211059265

Setiawan, B., & Supiandi, M. I. (2019). The contribution of metacognitive skills and reasoning skills on problem solving ability based on problem based learning (PBL) model. *Anatolian Journal of Education*, *3*(2), 75–86. https://doi.org/10.29333/aje.2018.327a

Shen, K. M., Li, T. L., & Lee, M. H. (2018). Learning biology as ‘Increase ones’ knowledge and understanding’: studying Taiwanese high school students’ learning strategies in relation to their epistemic views and conceptions of learning in biology. *International Journal of Science Education*, *40*(17), 2137–2157. https://doi.org/10.1080/09500693.2018.1522013

Siqueira, M. A. M., Gonçalves, J. P., Mendonça, V. S., Kobayasi, R., Arantes-Costa, F. M., Tempski, P. Z., & Martins, M. de A. (2020). Relationship between metacognitive awareness and motivation to learn in medical students. *BMC Medical Education*, *20*(1), 1–10. https://doi.org/10.1186/s12909-020-02318-8

Sperling, Rayne A; Howard, Bruce C; Miller, Lee Ann; Murphy, Cheryl (2002). Measures of Children's Knowledge and Regulation of Cognition. *Contemporary Educational Psychology, 27*(1), 51–79. https://doi.org/10.1006/ceps.2001.1091

Stanton, J. D., Neider, X. N., Gallegos, I. J., & Clark, N. C. (2015). Differences in metacognitive regulation in introductory biology students: When prompts are not enough. *CBE Life Sciences Education*, *14*(2), 1–12. https://doi.org/10.1187/cbe.14-08-0135

Tosun, C., & Senocak, E. (2013). The effects of problem-based learning on metacognitive awareness and attitudes toward chemistry of prospective teachers with different academic backgrounds. *Australian Journal of Teacher Education*, *38*(3), 61–73. https://doi.org/10.14221/ajte.2013v38n3.2

Valdez, J. E., & Bungihan, M. E. (2019). Problem-based learning approach enhances the problem solving skills in chemistry of high school students. *Journal of Technology and Science Education*, *9*(3), 282–294. https://doi.org/10.3926/JOTSE.631

Valladares, L. (2021). Scientific literacy and social transformation: critical perspectives about science participation and emancipation. In *Science and Education*, *30*(3), 557–587. https://doi.org/10.1007/s11191-021-00205-2

Vosniadou, S., Darmawan, I., Lawson, M. J., Van Deur, P., Jeffries, D., & Wyra, M. (2021). Beliefs about the self-regulation of learning predict cognitive and metacognitive strategies and academic performance in pre-service teachers. *Metacognition and Learning*, *16*(3), 523–554. https://doi.org/10.1007/s11409-020-09258-0

Wei, X. (2020). Assessing the metacognitive awareness relevant to L1-to-L2 rhetorical transfer in L2 writing: The cases of Chinese EFL writers across proficiency levels. *Assessing Writing*, *44*, 1–12. https://doi.org/10.1016/j.asw.2020.100452

Wonjoon Hong, Matthew L. Bernacki, H. N. P. (2020). A Latent profile analysis of undergraduates’ achievement motivations and metacognitive behaviors, and their relations to achievement in science. *Journal of Educational Psychology*, *112*(7), 1409–1430. https://doi.org/10.1037//0022-0663.94.4.659

Zhao, N., Teng, X., Li, W., Li, Y., Wang, S., Wen, H., & Yi, M. (2019). A path model for metacognition and its relation to problem-solving strategies and achievement for different tasks. *ZDM - Mathematics Education*, *51*(4), 641–653. https://doi.org/10.1007/s11858-019-01067-3

Zion, M., & Cohen, H. (2021). Drinking-related metacognitive guidance contributes to students’ expression of healthy drinking principles as part of biology teaching. *Sustainability (Switzerland)*, *13*(4), 1–19. https://doi.org/10.3390/su13041939

Zotou, M., Tambouris, E., & Tarabanis, K. (2020). Data-driven problem based learning: enhancing problem based learning with learning analytics. In *Educational Technology Research and Development 68*(6), 3393–3424. https://doi.org/10.1007/s11423-020-09828-8