Schrödinger:Journal of Physics Education
Vol. 6, No. 1, June 2025, pp. 72~78
ISSN: 2716-1587, DOI: 10.37251/sjpe.v6i2.1528

Linking Pre-existing Metacognition Practices and Students' Performance in High School Physics

Kim P. Diate[1], Rayyanah R. Benasing[2] Krystine Mae R. Tee-Pastidio[3]
[1]Integrated Developmental School, College of Education, Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines
[2]College of Education, De La Salle University, Taft. Ave., Manila, Philippines
[3]Department of Education, Kiwalan National High School, Iligan City, Philippines

Article Info

Article history:

Received Mar 2, 2025
Revised May 13, 2025
Accepted Jun 17, 2025
Online First Jun 21, 2025

Keywords:

Knowledge of Cognition
Metacognitive Dimensions
Physics Metacognition
Pre-existing Metacognition
Regulation of Cognition

ABSTRACT

Purpose of the study: This research aims to provide insight on how student's pre-existing metacognitive strategies influences their academic performance, specifically in learning physics.

Methodology: This research administered the Physics Metacognition Inventory (PMI) scale to 117 Grade 9 students of the laboratory high school of MSU-Iligan Institute of Technology. PMI scale has an internal consistency of 0.90, indicating high-reliability of the instrument in measuring the constructs it intends to measure. Shapiro-Wilk's test for normality reveals non-normal distribution (p-values < 0.05) , thus a non-parametric test (i.e., spearman rank correlation) is utilized to establish statistical correlation among the variables of interest (i.e, level of proficiency and factors on Physics Metacognition Inventory). Statistical analysis is done using RStudio Version 2023.06.0+421 (2023.06.0+421).

Main Findings: Results suggest that student's knowledge of cognition exhibits a strong positive correlation with their physics academic performance. Moreover, all five components of regulation of cognition showed positive correlation with the level of physics performance. However, the strongest predictor is the dimension of evaluation.

Novelty/Originality of this study: This research highlights the role of pre-existing metacognitive strategies and how it is correlated to academic performance in a physics classroom. Understanding how each of the dimensions of metacognition correlates to physics performance can have an important implications on how physics instruction might be productively given to junior high school students especially with the goal of honing critical evaluation of one's thinking, conceptual conclusions, and physical sensibility of solutions.

Corresponding Author:
Kim P. Diate,
Integrated Developmental School, College of Education, Mindanao State University – Iligan Institute of Technology,
Andres Bonifacio Ave., Tibanga, Iligan City, 9200, Philippines
Email: kim.diate@g.msuiit.edu.ph

1. INTRODUCTION

Literature upholds a strong belief on the effectiveness of employing metacognition in science classrooms [1]-[3]. However, it is vague how it is practiced in the classroom which can be attributed to the teacher's insufficient understanding of the concept of metacognition, and amplified by the preconceived notion of metacognitive practice being applicable only for adult learners, and already highly-achieving learners [4]. This literature finding highlights a critical challenge in the implementation of metacognition into the classroom which has diverse learners with different levels of learning abilities. One reason is that an effective teaching of metacognition in a classroom assumes teacher's robust understanding of metacognition, coupled with the appropriate pedagogical knowledge [5], [6]. Second, successful integration of metacognition into classroom practice requires the teachers explicit embedding of metacognitive knowledge and skills to allow learners creation of connections, direct instruction of its benefits, and prolonged training and practice [7]-[9]. While metacognition researches increases in popularity in science education, several research gap exists. One of it is the lack of empirical studies exploring the development of learner's metacognitive knowledge [5].

Although this research article does not directly explore on how to develop learners metacognitive knowledge, it seeks to establish how the student's pre-existing physics performance is determined by their exercise or non-exercise of metacognitive practices, even when they are not explicitly trained to employ it. This is essential to be explored by science educators to present the current state which is necessary for later comparison, when explicit instruction on metacognitive knowledge is given to the learners. This current research paper aids in this gap by establishing the strength of association between specific dimensions of metacognition (i.e., knowledge of cognition, information management, monitoring, evaluation, debugging, and planning) and academic performance in physics.

Once this is established, empirically-based suggestions on the delivery of physics instruction can be put forth to allow for a classroom experience that enriches the practice of these metacognitive dimensions. It is also important to note that the point of view adopted in this research article is mainly cognitive, in contrast to other works on metacognition which takes a more broader psychological-cognitive perspective such as that of Ben-David, A., and Orion, N. As such, it is limited in its analysis since it does not take into account the social context with which learning happens.

In addressing the main goal of this article: establishing how students' pre-existing metacognitive practice in physics problem solving correlates with their physic grade, the Physics Metacognition Inventory developed by Taasoobshirazi and Farley [10] is utilized. The scale has an internal consistency of 0.90, indicating high-reliability of the instrument in measuring the constructs it intends to measure. It is administered to the laboratory high school of the Mindanao State University-Iligan Institute of Technology. The results show that students' level of proficiency shows strong positive correlation with knowledge of cognition, while evaluation and planning shows weak-positive correlation.

2. RESEARCH METHOD

This research employs a cross-sectional research design. Cross-sectional research is ideal for this research's goal of establishing how high school students' performance in physics across the entire academic year is influenced by their exercise of the metacognitive dimensions (i.e., knowledge of cognition, information management, monitoring, evaluation, debugging, and planning) without necessarily influencing each of these factors through direct instruction from the teacher. This provides an unbiased perspective of the potential of students' exercise of metacognitive dimension, and how it translates into measurable outcomes in their physics performance.

Data is collected after the fourth quarter physics class of the Grade 9 students in the laboratory high school of the university. This is intended to allow the students a larger time frame to develop and exercise their own approach in learning physics, particularly in solving physics problem. Informed consent form is given to the parents asking for their consent to include their child in the research. In addition, assent form is also accomplished by the students in consideration that they are still minors. In accomplishing the instrument used in this study (i.e., Physics Metacognitive Inventory), students are well oriented with the nature of their participation on the study, how their aninomity is protected, how their data will be used, and how it will be discarded. Also it is emphasized that they may leave some item unanswered if they are uncomfortable to disclose it or unable to objectively assess themselves. The initial number of respondents tallied to 121 Grade 9 students, while only 117 (N =117) were considered for data analysis after removing data with missing values (i.e., skipped items).

2.1 Research Instrument

Physics Metacognition Inventory (PMI) scale developed by Taasoobshirazi and Farley [10] is utilized. The scale is a 5-point likert scale consisting of 26 questions covering the six dimensions of metacognition. Six (6) questions for the knowledge of cognition, four (4) for information management, four (4) for monitoring, four (4) for evaluation, two (2) for debugging, and six (6) for planning. The scale is phase validated and is found to exhibit lexical attributes suited for the intended student participants. In addition, the scale has an internal consistency of 0.90, indicating high-reliability of the instrument in measuring the constructs it intends to measure.

2.2 Statistical Analysis

For statistical analysis, students are categorized according to their level of proficiency, which is adopted according to the standards of the Department of Education. Shapiro-Wilk's test for normality reveals non-normal distribution (p-values < 0.05) of the grades across different levels of proficiency. Thus a non-parametric test (i.e., spearman rank correlation) is utilized to establish statistical correlation among the variables of interest (i.e, level of proficiency and factors on Physics Metacognition Inventory). Analysis is performed on RStudio Version 2023.06.0+421 (2023.06.0+421).

3. RESULTS AND DISCUSSION

Student respondents are categorized by its level of proficiency according to the standards of the Department of Education. Grades above 90% are classified as advanced, those within the range of 85 % - 89 % are classified as proficitient, 80% -84% as approaching proficiency, 75% - 79% as developing, and 74% and below as beginning. The initial number of respondents tallied to 121 Grade 9 students, while only 117 (N =117) were considered for data analysis after removing data with missing values (i.e., skipped items). Out of the 117, 20 were advanced (17.09%), 33 are proficient (28.21%), 46 are approaching proficiency (39.32 %), and 18 are developing (15.38%) . Shapiro-Wilk's test for normality reveals non-normal distribution (p-values < 0.05) of the grades across different levels of proficiency. In the analysis of this data, the scores on the Likert scale is treated to be in the ordinal scale. Although likert scale is often treated in the interval scale, it is appropriately treated as an ordinal scale where arithmetic operations is not applicable [11]-[13].

3.1. Student's proficiency in physics and their knowledge of cognition

	Level of Proficiency	Knowledge of Cognition	Regulation of Cognition: information management	Regulation of Cognition: monitoring	Regulation of Cognition: evaluation	Regulation of Cognition: debugging	Regulation of Cognition: planning
Level of Proficiency	*	0.40*	0.09	0.13	0.23*	0.07	0.19*
Knowledge of Cognition		*	0.44*	0.30*	0.33*	0.21*	0.52*
Regulation of Cognition: information management			*	0.21*	0.23*	0.27*	0.49*
Regulation of Cognition: monitoring				*	0.28*	0.27*	0.36*
Regulation of Cognition: evaluation					*	0.24*	0.34*
Regulation of Cognition: debugging						*	0.45*
Regulation of Cognition: planning							*

*significant at 95% confidence interval. Spearman-rank correlation between level of proficiency and metacognitive dimensions.

Knowledge of cognition spans the individual's awareness about their own cognition, which scholars suggest to include declarative, procedural, and conditional knowledge [3]. This roots from Flavell's "metacognitive knowledge" , which is defined as the knowledge, ideas, and theories interacting with an individual's cognitive tasks and strategies. In this section, it is of prime importance to explicitly distinguish each of the components of the knowledge of cognition: declarative, procedural, and conditional knowledge. Declarative knowledge centers on the individual's knowledge of oneself as the learner and accounts an analysis of one's abilities in relation to the cognitive task. Procedural knowledge refers to the individual's knowledge on specific strategies and procedures. Conditional knowledge refers to the strategic and critical evaluation of the required declarative and procedural knowledge, in relation to a specific cognitive task [10], [14]

Knowledge of cognition exhibits strong, positive relationship (ρ=0.40) with the learner's level of proficiency. This implies that the physics students with better conscious awareness of their own abilities (declarative), better strategies in approaching a cognitive task (procedural), and better able to judge which approach works best for a particular task with consideration of one's own set of cognitive skills (conditional) tends to have higher grades. On the one hand, this also means that those with less awareness of their declarative, procedural, and conditional knowledge tends to perform poorly. Interestingly, similar findings can be drawn from a study whose subject concentration is diverged from physics, in specific physiology Shah & Modna [15], mathematics Mevarech & Amrany [16] and even in undergraduate teacher education [17], [18]. It might be the case where students' knowledge of cognition serves as a strong predictor of their learning regardless of the discipline in question.

Learning physics is coupled with problem solving as direct applications of the taught principles. More often than not, there exist multiple ways to solve a physics problem and it will always yield the same result, so long as the principles employed is applicable for the specific context in the problem, and the assumptions required by the principle are met. This then highlights the inevitable advantage of students who have clear conception of their own abilities (declarative), as they can avoid approaching the problem in an approach that they knew they have difficulty with, either in understanding the concept itself, or in the application of the principle. As a consequence, they are able to limit their choices on approaching the problem, while increasing the probability on getting the answer right since they can rechannel their time towards strategies that they know works for them. Although this is heavily polarized towards problem solving in physics, one can argue that this is equally applicable in the context of learning concepts and or principles. In learning physics concepts, students with better knowledge of cognition can decide against strategies which they know from conscious reflection of how they learn, are ineffective for them (e.g., they may or may not prefer taking notes while on class).

If learners are not aware of how he/she best learn, or equivalently the learner has low knowledge of their own cognition, they tend to learn in ways, that may be counterproductive for them, even without them realizing it. This suggest that one of the teacher's role in science classroom is to enable student's metacognitive practice either through direct instruction or by modelling of these metacognitive strategies [19], [20]. Although this seems to be an implied practice inside the classroom, unfortunately literature suggests otherwise. Teachers exhibit deficiency of knowledge as well as skills in bringing the concept of metacognition into classroom instruction [4], [21].

An important implication for teacher education institutions is to check the trainings provided for the undergraduate science teachers, to include direct instruction along with practical professional development training in the use of metacognition in the classroom [22]. Needless to say, sufficient and curriculum-supported exercise of metacognitive practices in science teaching is paramount in supporting students who are in the lower profiency range. In addition, learners should be provided with an opportunity to reflect on what they understood, what they find challenging to understand, and what they have not understand [23] This may be in terms of taught concept and principles, and even on steps or processes when applying the taught principles. The balance between learning space and structure given to students in a form of guided-inquiry can potentially aid in this [21]. Specific to physics problem solving, it would be helpful to have probing questions prior to the actual problem solving [24]. These questions should allow the students to reflect on what they have understood of the concepts or principles and how it applies to the problem given. It would also help to provide probing questions which allows them to reflect on the method or process that they are confident in performing. In this way, they are allowed to exercise the knowledge of cognition, prior to actually solving the problem.

3.2. Student's proficiency in physics and their regulation of cognition

Scholars define regulation of cognition to encompass both cognitive and metacognitive strategies in learning performed by the learners in processing an information [25].It is important to note that in cognitive psychology, this is under the broad category of self-regulated learning (SRL). Self-regulated learning is defined as the active process employed by the students in the use of strategies to regulate their own learning [26]. Alongside regulation of cognition includes regulation of motivation, regulation of behavior, and regulation of context [26]. Each of these broad areas are distinct concepts yet interrelated and significantly interacts to influence how students learn in the context of their exercise of self-regulation. Studies documented that the self-regulatory processes can be impeded or facilitated by the student's motivational beliefs such as self-efficacy and the task value attributed to a particular task [25], [27]. With this being explicitly clear, the current paper singly explores regulation of cognition and its influence on student's physics grades without consideration on how regulation of behavior, motivation, and context might have influenced the research findings.

Regulation of cognition has five (5) distinct constructs; these are information management, monitoring, evaluation, debugging and planning. Information management encompasses students concious selection on their repertoire of strategies to solve a problem [10]. In a physics classroom, this is exhibited by the students through their conscious selection of specific physics principles and mathematical techniques that guarantee easier solution for the problem. Monitoring refers to the recurring assessment of the student's goal (solving the problem) , and their current performance on the given task [10]. This is evident in a physics classroom when students solving a problem, constantly check whether the solution is leading towards the expected answer, or their approach on the problem is deemed problematic since it led to unforeseen complexity, thereby necessating for alternative approach in solving. Although quite related with monitoring, evaluation is distinct. Evaluation is the appraisal given by the students only after their work is completed [10]. In the highschool physics classrooms, this is manifested when students check whether they are getting a sensible or realistic numerical values, or whether they are getting the appropriate unit for the quantity that is being solved. In connection to monitoring where students may find possible difficulties in their current approach in solving the problem, the actual resolution is actualized through debugging. Debugging refers to the students' act of correcting errors in their solution, and trying out the possible alternatives [10]. Lastly, planning is the setting and clarifying of goals prior to performing the task. In physics classroom practice, both in secondary and tertiary level, this is exemplified when students define the known quantities, identify applicable principles, and the quantity required to be solved.

While all of the five components of regulation of cognition showed positive correlation with the level of proficiency in Physics, only the constructs of evaluation and planning showed a statistically significant positive correlation with student's grade in physics. However, of the two, planning (ρ=0.19) showed negligible correlation while evaluation (ρ=0.23) showed weak correlation. Although these positive correlations are weak, it is essential to discuss it's implication for problem solving in high school physics.

This result implies that the student's grades in physics is correlated to how the student plans the approach in solving problem, and afterwards evaluating the physical sensibility of their answers [28], [29]. Highly-performing students tend to practice this frequently compared to their low-performing counterparts. Planning and monitoring as a metacognitive activity is associated with increase use in problem-solving in mathematics. It appears that planning and monitoring are standard practices assumed to be employed by the students in mathematics problem solving [16]. While this might also be true for problem solving in physics, it is noteworthy to establish that problems in physics are more cognitively demanding for the students since they have to appropriately utilize the principles in physics while navigating through the rules of mathematics. Thus, there might be significant differences between mathematics and physics on what cognitive tasks are deemed to be required more frequently [29]. Hence, in this paper between planning and monitoring which are associated with mathematics problem solving, planning shows stronger correlation with physics performance. This implies that highly performing students in Physics tends to capitalize more in appraising the sensibility and physical implication of their conclusions (conceptual questions) and solutions (problem solving).

This highlights the critical role for educator to provide support in shaping student's metacognitive ability to critically evaluate one's own thinking, as well as the physically sensibility of the conclusions they have reached. This support can be in a form of structure in the problem solving Ding et al. [30], where students are explicitly asked to reflect on the physical sensibility of their answers in connection to the learned concepts and principles. Interestingly, when students who are explicitly trained to employ metacognitive strategies (knowledge of cognition and regulation of cognition) is compared to those who were not explicitly trained, an interesting result is found. In problem solving, students with explicit training on metacognitive strategies reports to perform better in mathematics than their untrained counterparts. They reported that they are consciously thinking on making connections, using various strategies, and evaluation of their solutions [16]. It is clear that "making connections" and "using various strategies" are tasked categorized under regulation of cognition, specifically on planning. In addition, " evaluation of their solution" is categorized under regulation of cognition, specifically on evaluation. It is in agreement with our findings in this paper, although the context is different, the other one is in Mathematics, while this paper is on Physics.

It is also reported that most of the untrained students in metacognition employs "information management" than other components of the regulation of cognition. As Mevarech, and Amrany notes:

> *"Most of the control students (75%) did try to comprehend the problem before solving it. A control student said, for example: "I looked for the givens and wrote them down. I tried to find out as many givens as possible, and see what is requested". In contrast, most ofthe IMPROVE students referred in their responses only to the three other categories: finding connections, looking for appropriate strategies, and evaluating the solution, but did not try to comprehend the problem prior to solving it." [, p. 153]*

This is in agreement with the findings of this research article. Although information management and physics grades are positively correlated, nevertheless, it is not statistically significant.

In a Philippine physics classroom, it is a common practice in teaching the emphasis on establishing the known quantities and what is asked. These are tasks under "information management". While it is important in physics problem solving, students must be explicitly taught to go beyond this stage. This implies that in teaching problem solving in physics, teachers must go beyond comprehending the known and unknown quantites, instead teach the students to direct more of their cognitive attention towards making connections to come up with many alternative path in finding the answers, plans on how to solve the problem (planning), and measures on evaluating the accuracy of the solution (evaluation). This can be practically done through incorporating scaffolding questions [30] as part of the problem solving to force students to articulate what are the laws and principles they have learned, how these principles are connected to each other, and how to link them together to come up with a technique or approach in their solution that they are confident in doing.

4. CONCLUSION

This study highlights the role of metacognitive strategies employed by learners, even without direct instruction, in influencing their academic performance in physics. Using the Physics Metacognition Inventory, it was found that knowledge of cognition—specifically declarative, procedural, and conditional knowledge—has a strong positive correlation with physics performance. This suggests that science educators should help students develop conscious awareness of their cognitive abilities, effective strategies for approaching tasks, and sound judgment in selecting appropriate methods based on their skills. Interestingly, all five components of the regulation of cognition also showed positive correlation with proficiency in physics, though only evaluation and planning were statistically significant. Among these, evaluation demonstrated a stronger relationship, indicating the importance of guiding students to become critical evaluators of their thinking, conclusions, and the physical sensibility of their answers. The study recommends replication with different student cohorts to explore how behavior, motivation, and context interact with these findings. A key suggestion for physics classrooms is to embed structured problem-solving practices that go beyond identifying known quantities. Specifically, in the preliminary phase of problem-solving, students should reflect on what they understand, what confuses them, and what they fail to grasp, including principles and solution techniques. During problem-solving, teachers should prompt students to recall relevant concepts and eliminate irrelevant ones, helping them form meaningful connections. Finally, after calculations, teachers must include questions that prompt students to assess the physical reasonableness of their solutions, thus fostering deeper metacognitive engagement.

REFERENCES

[1] G. P. Thomas, "Metacognition in science education: past, present and future considerations," in *Second International Handbook of Science Education*, 2012. doi: 10.1007/978-1-4020-9041-7_11.

[2] G. P. Thomas and C. J. McRobbie, "Using a metaphor for learning to improve students' metacognition in the chemistry classroom," *J Res Sci Teach*, vol. 38, no. 2, 2001, doi: 10.1002/1098-2736(200102)38:2<222::AID-TEA1004>3.0.CO;2-S.

[3] G. Stephanou and M.-H. Mpiontini, "Metacognitive knowledge and metacognitive regulation in self-regulatory learning style, and in its effects on performance expectation and subsequent performance across diverse school subjects," *Psychology*, vol. 08, no. 12, 2017, doi: 10.4236/psych.2017.812125.

[4] A. Ben-David and N. Orion, "Teachers' voices on integrating metacognition into science education," *Int J Sci Educ*, vol. 35, no. 18, pp. 3161–3193, Dec. 2013, doi: 10.1080/09500693.2012.697208.

[5] A. Zohar and S. Barzilai, "A review of research on metacognition in science education: current and future directions," *Stud Sci Educ*, vol. 49, no. 2, pp. 121–169, Sep. 2013, doi: 10.1080/03057267.2013.847261.

[6] J. Perry, D. Lundie, and G. Golder, "Metacognition in schools: what does the literature suggest about the effectiveness of teaching metacognition in schools?," 2019. doi: 10.1080/00131911.2018.1441127.

[7] M. V. J. Veenman, B. H. A. M. Van Hout-Wolters, and P. Afflerbach, "Metacognition and learning: conceptual and methodological considerations," 2006. doi: 10.1007/s11409-006-6893-0.

[8] K. A. Ericsson, M. J. Prietula, and E. T. Cokely, "The making of an expert," 2007.

[9] A. H. Schoenfeld, "What's all the fuss about metacognition?," in *Cognitive Science and Mathematics Education*, 2013. doi: 10.4324/9780203062685.

[10] G. Taasoobshirazi and J. Farley, "Construct validation of the physics metacognition inventory," *Int J Sci Educ*, vol. 35, no. 3, 2013, doi: 10.1080/09500693.2012.750433.

[11] H. Wu and S. O. Leung, "Can likert scales be treated as interval scales?—a simulation study," *J Soc Serv Res*, vol. 43, no. 4, 2017, doi: 10.1080/01488376.2017.1329775.

[12] G. Norman, "Likert scales, levels of measurement and the 'laws' of statistics," *Advances in Health Sciences Education*, vol. 15, no. 5, 2010, doi: 10.1007/s10459-010-9222-y.

[13] K. A. Batterton and K. N. Hale, "The Likert scale: what it is and how to use it," *Phalanx*, vol. 50, no. 2, pp. 32–39, Jun. 2017, [Online], Available: http://www.jstor.org/stable/26296382

[14] P. R. Pintrich, "The role of metacognitive knowledge in learning, teaching, and assessing," *Theory Pract*, vol. 41, no. 4, 2002, doi: 10.1207/s15430421tip4104_3.

[15] D. K. Shah and Y. Modna, "The impact of medical students' metacognitive awareness level on their academic performance," *Int J Res Med Sci*, vol. 10, no. 11, p. 2363, Oct. 2022, doi: 10.18203/2320-6012.ijrms20222830.

[16] Z. R. Mevarech and C. Amrany, "Immediate and delayed effects of meta-cognitive instruction on regulation of cognition and mathematics achievement," *Metacogn Learn*, vol. 3, no. 2, pp. 147–157, Aug. 2008, doi: 10.1007/s11409-008-9023-3.

[17] A. Young and J. D. Fry, "Metacognitive awareness and academic achievement in college students," *Journal of the Scholarship of Teaching and Learning*, vol. 8, no. 2, 2008, [Online], Available: https://eric.ed.gov/?id=EJ854832

[18] Dr. Neena Sawhney and Dr. Sneh Bansal, "Metacognitive awareness of undergraduate students in relation to their academic achievement," *International Journal of Indian Psychology*, vol. 3, no. 1, 2015, doi: 10.25215/0301.136.

[19] J. J. Mintzes, J. H. Wandersee, and J. D. Novak, "*Teaching Science for Understanding: A Human Constructivist View*", Educational Psychology series. Academic Press, 2005, doi: 10.1016/B978-0-12-498360-1.X5000-4.

[20] L. Mason, "Cognitive and metacognitive aspects in conceptual change by analogy," *Instructional Science*, vol. 22, no. 3, pp. 157–187, May 1994, doi: 10.1007/BF00892241.

[21] A. Zohar, "The nature and development of teachers' metastrategic knowledge in the context of teaching higher order thinking," *Journal of the Learning Sciences*, vol. 15, no. 3, 2006, doi: 10.1207/s15327809jls1503_2.

[22] A. J. Hughes, "Educational complexity and professional development: teachers' need for metacognitive awareness," *Journal of Technology Education*, vol. 29, no. 1, 2017, doi: 10.21061/jte.v29i1.a.2.

[23] M. D. N. Lew and H. G. Schmidt, "Self-reflection and academic performance: Is there a relationship?," 2011. doi: 10.1007/s10459-011-9298-z.

[24] N. Erceg, I. Aviani, and V. Mešić, "Probing students' critical thinking processes by presenting ill-Defined physics problems," *Revista Mexicana de Fisica E*, vol. 59, no. 1, 2013, [Online], Available: https://scielo.org.mx/pdf/rmfe/v59n1/v59n1a8.pdf

[25] P. R. Pintrich and A. Zusho, "Student Motivation and Self-Regulated Learning in the College Classroom BT - Higher Education: Handbook of Theory and Research," J. C. Smart and W. G. Tierney, Eds., Dordrecht: Springer Netherlands, 2002, pp. 55–128. doi: 10.1007/978-94-010-0245-5_2.

[26] Y. eun Kim, A. C. Brady, and C. A. Wolters, "College students' regulation of cognition, motivation, behavior, and context: distinct or overlapping processes?," *Learn Individ Differ*, vol. 80, 2020, doi: 10.1016/j.lindif.2020.101872.

[27] H. K. Ning and K. Downing, "The reciprocal relationship between motivation and self-regulation: a longitudinal study on academic performance," *Learn Individ Differ*, vol. 20, no. 6, 2010, doi: 10.1016/j.lindif.2010.09.010.

[28] E. B. Coleman and B. Shore, "Problem–solving processes of high and average performers in physics," *Journal for the Education of the Gifted*, vol. 14, no. 4, 1991, doi: 10.1177/016235329101400403.

[29] J. Tuminaro, "Understanding students' poor performance on mathematical problem solving in physics," 2004. doi: 10.1063/1.1807267.

[30] L. Ding, N. Reay, A. Lee, and L. Bao, "Exploring the role of conceptual scaffolding in solving synthesis problems," *Physical Review Special Topics - Physics Education Research*, vol. 7, no. 2, 2011, doi: 10.1103/PhysRevSTPER.7.020109.