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EXPLORING THE CORRELATION BETWEEN METACOGNITIVE SKILLS AND COGNITIVE LEARNING OUTCOMES ACROSS VARIOUS BIOLOGY LEARNING MODELS IN HIGH SCHOOLS

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ABSTRACT

In Malang City, a notable observation within the realm of high school biology education suggests a prevalent lack of metacognitive knowledge among teachers, hindering their efficacy in nurturing students' metacognitive capacities. Such deficiency yields implications for diminished cognitive abilities among students. Recognizing this, there emerges a pressing need for an enhanced pedagogical framework capable of fostering metacognitive skills adeptly. One promising approach involves integrating inquiry-based learning and problem-based mindful pedagogy (PBMP). This amalgamation is anticipated to synergistically harness the potential of both methodologies in bolstering metacognitive skills alongside cognitive learning outcomes. This study adopts a correlational research design, wherein data encompassing metacognitive skills and cognitive learning outcomes are systematically gathered. Methodologically, the evaluation entails the integration of metacognitive skills assessments with cognitive learning outcome metrics. Subsequent analysis is conducted via regression analysis, employing a significance threshold of 5%. Statistical examination is facilitated through the utilization of SPSS 17.0 for Windows. The findings of the analysis unveil a discernible relationship between metacognitive skills and cognitive learning outcomes across distinct biology lessons. Notably, the extent of metacognitive skill contribution to cognitive learning outcomes exhibits variance. Particularly noteworthy is the pronounced impact observed within the Inquiry-PBMP class setting, indicating its superiority over alternative pedagogical models in cultivating metacognitive skills and subsequently augmenting students' cognitive learning achievements.

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INTRODUCTION

Conventional pedagogical methodologies continue to predominate within the biology education landscape of Malang City High Schools. This conventional approach, characterized by its teacher-centric nature, fails to fully harness the latent potential of students. The realization of students' capabilities hinges upon the educational processes they undergo, with particular emphasis on the learning models employed by teachers. Central to this discourse is the imperative of fostering meaningful learning experiences for students, defined as those which prioritize the cultivation of metacognitive abilities and the acquisition of self-directed learning strategies. Meaningful learning not only nurtures students' autonomy in the learning process but also fosters the development of their metacognitive competencies. The significance of metacognition in academic achievement is underscored by Kruger and Dunning (1999), wherein it was demonstrated that students with heightened metacognitive skills consistently exhibit superior scholastic performance. Thus, it is imperative for educational stakeholders to prioritize the implementation of pedagogical approaches that facilitate meaningful learning, thereby empowering students to realize their academic potential to the fullest extent.

Based on empirical observations conducted among high school biology teachers in the municipality of Malang, it is evident that a meager fraction, less than 10%, endeavor to cultivate students' metacognitive prowess. This deficiency in metacognitive cultivation is largely attributed to teachers' limited acquaintance with the concept of metacognition. As posited by Borich (2007), teachers' awareness of metacognitive principles significantly informs their selection of instructional methodologies. Regrettably, the effective integration of metacognitive strategies by students, contingent upon their acclimatization to the instructional paradigms espoused by teachers, remains markedly inadequate. Consequently, students remain inadequately equipped to engage in accurate self-assessment of their cognitive abilities and exhibit diminished capacity to regulate and oversee their cognitive functions, thereby yielding suboptimal cognitive learning outcomes. Hence, it is discernible that the metacognitive acumen of instructors substantially influences the pedagogical models they adopt, whereby the preferred modality of instruction prioritizes the cultivation of students' metacognitive faculties, thereby facilitating the attainment of commendable cognitive learning outcomes.

The diminished cognitive learning outcomes observed in high school biology education STEM from a multitude of contributory factors, chief among them being: (1) the deficiency in teachers' comprehension and utilization of metacognitive principles within the context of biology instruction, (2) the nascent development of students' metacognitive competencies, (3) students' paucity of foundational knowledge exacerbated by diminished interest in reading, (4) the persistence of unresolved learning impediments, particularly in the realm of junior high school biology curriculum, and myriad others. Yamin (2008) underscores the pivotal role of students' initial knowledge as the cornerstone upon which subsequent knowledge is erected, emphasizing the necessity of a robust foundational understanding to facilitate meaningful knowledge acquisition.

The aforementioned learning challenges are commonly encountered within the landscape of high school biology education in Malang City. Kristiani (2015) research findings underscore the pervasive nature of suboptimal cognitive learning outcomes, with a substantial 62.5% of students failing to meet the minimum completeness criteria (Kriteria Kompetensi Minimum - KKM) threshold. This deficiency in achievement is attributed to students' inadequate self-awareness of their cognitive abilities and their limited capacity to regulate and oversee these cognitive faculties, consequently yielding diminished cognitive learning outcomes. Therefore, in accordance with Corebima (2009) assertions, fostering critical thinking and metacognitive competencies is imperative to imbue students with the autonomy necessary for effective self-directed learning and the attainment of their educational objectives.

In light of identified challenges, the imperative for high school biology teachers in Malang City is to possess metacognitive expertise. This cognitive awareness holds significant implications for the selection of appropriate pedagogical approaches capable of nurturing students' metacognitive capabilities. As posited by Kristiani (2009), an teacher's possession of metacognitive proficiency facilitates the effective instillation of metacognitive processes in students through the employed instructional strategies. Thus, it is incumbent upon teachers to familiarize themselves with metacognitive principles and integrate them judiciously into their selection of pedagogical methodologies aimed at fostering students' metacognitive development.

Theoretical frameworks consistently suggest a significant association between metacognitive skills and cognitive learning outcomes. A plethora of research endeavors corroborates this assertion. For instance, studies by Bahri (2010) and Kristiani (2009) have underscored the correlation between metacognitive proficiency and students' cognitive learning achievements. Furthermore, investigations by Dunning et al. (2003) and Kruger and Dunning (1999) have highlighted the pivotal role of metacognitive skills in augmenting student learning outcomes. In alignment with these findings, Kristiani et al. (2015) elucidated the influence of metacognitive abilities and scientific attitudes on students' cognitive learning outcomes across various instructional paradigms. Notably, the preeminent determinant driving cognitive learning outcomes in these analyses was identified as metacognitive skills. These collective findings underscore the imperative of prioritizing the cultivation of students' metacognitive capacities within the domain of biology education, as they demonstrably impact the attainment of cognitive learning objectives.

Employing an appropriate biology learning model can effectively nurture students' metacognitive proficiencies. As asserted by Borich (2007), metacognitive competencies are acquirable through instruction. Research findings indicate that students who undergo explicit instruction in metacognitive skills demonstrate enhanced learning outcomes and exhibit proficiency in higher-order cognitive processes. Moreover, Boyle et al. (2005), Duffy et al. (1988), and Dunlosky and Metcalfe (2008) emphasize that metacognitive frameworks are best imparted to students through mental modeling techniques. Mental modeling facilitates the internalization of problem-solving strategies across diverse content domains. This process becomes imperative when students are tasked with tackling intricate assignments demanding advanced cognitive abilities to bolster their learning outcomes.

Moreover, Kristiani (2008), Sabilu (2009), and Syamsuri (2017) assert that biology, as a fundamental branch of science, embodies knowledge acquisition through systematic stages, commonly referred to as the scientific method. This pedagogical approach underscores the significance of discovery, akin to the principles of inquiry-based learning. Inquiry learning is characterized by the systematic construction of understanding, where students integrate novel information with pre-existing knowledge in an organized manner (Kristiani, 2005). It epitomizes constructive learning paradigms. According to Kanselaar (2002), learning grounded in constructivist principles is an active endeavor, wherein students actively construct new ideas or concepts based on their experiences and prior knowledge. Similarly, inquiry-based learning represents a student-centric methodology, encouraging learners to leverage their existing knowledge and experiences to explore inquiries and construct their understanding (Kahn & O'Rourke, 2005).

Corebima and Bahri (2011) highlights another effective pedagogical approach that enhances students' cognitive abilities, including metacognitive skills, known as the problem based metacognitive pedagogy (PBMP) pattern. Extensive empirical investigations, encompassing both standalone utilization and integration with other instructional models, have examined the efficacy of PBMP learning patterns through experimental research and classroom action research (penelitian tindakan kelas - PTK). Notably, Kristiani (2009) study elucidated that the PBMP-TPS (think pair share) learning model significantly enhanced cognitive learning outcomes among lower academic groups. This amalgamation demonstrated the remarkable capacity to elevate the performance of lower academic cohorts to the level commensurate with their higher-academic counterparts. These findings underscore the discernible advantages associated with PBMP pattern learning, further validating its efficacy in educational settings.

Both the inquiry-based and PBMP learning patterns boast distinct advantages and disadvantages. Inquiry learning offers the advantage of fostering systematic and sequential thinking akin to the scientific method, facilitating a structured approach to problem-solving. Conversely, the PBMP pattern excels in cultivating thinking patterns through a structured series of questions, prompting students to develop reasoning skills by treating questions as problems to solve.

The integration of these two learning models holds considerable promise, capitalizing on the strengths of each to maximize student potential. By amalgamating inquiry-based systematicity with the question-centric approach of PBMP, students can benefit from a comprehensive learning experience. This integration empowers students to engage in systematic thinking while constructing their understanding through the iterative process of questioning. Consequently, students are equipped not only to think critically but also to develop a deep and nuanced comprehension of the subject matter.

The educational material examined in this study lacks demonstrative elements, resulting in the absence of a conclusive section within the PBMP pattern. This deficiency is perceived as a notable shortcoming of the PBMP methodology, as the absence of closure may lead to a sense of incompleteness. However, this limitation can be mitigated by leveraging the strengths of the inquiry-based learning approach, particularly its emphasis on drawing conclusions within the final synthesis. While inquiry-based learning is inherently question-driven, its scope may be restricted, representing another imperfection.

The integration of these two pedagogical frameworks yields a novel hybrid model termed inquiry-PBMP. This innovative approach combines the structured questioning framework of PBMP with the conclusive synthesis characteristic of inquiry-based learning. By intertwining these methodologies, the limitations inherent in each approach are addressed, resulting in a more comprehensive and effective instructional model. Thus, the inquiry-PBMP model capitalizes on the strengths of both paradigms while mitigating their respective weaknesses, offering a promising avenue for optimizing student learning experiences.

The utilization of various biology learning models is anticipated to yield distinct associations between metacognitive skills and cognitive learning outcomes. Building upon previous research findings, it becomes imperative to elucidate these relationships within the context of three distinct biology learning models: inquiry-based, inquiry-PBMP hybrid, and standard learning models. Furthermore, it is essential to scrutinize the disparities in the relationships between metacognitive skills and cognitive learning outcomes stemming from the implementation of these diverse pedagogical frameworks.

The findings derived from this investigation hold considerable merit, as they provide valuable insights for teachers in selecting the most appropriate biology learning model. Not only can such insights enhance cognitive learning outcomes, but they also hold the potential to fortify students' metacognitive proficiencies. By discerning the nuanced relationships between metacognitive skills and cognitive learning outcomes within each learning model, teachers can make informed decisions regarding instructional strategies, thereby optimizing the learning experiences of their students. Ultimately, this study aims to equip teachers with the requisite knowledge to foster both cognitive and metacognitive development effectively within the realm of biology education.

METHOD

This study adopts a correlational research design aimed at elucidating the relationship between students' metacognitive skills, serving as predictors, and their cognitive learning outcomes, acting as criteria. Spanning a one-year duration, the research focused on class X high school students within the Malang City region. Sample selection encompassed three classes, each instructed using distinct learning models: the inquiry learning model, inquiry-PBMP model, and standard learning model.

Data collection employed an essay test integrated with cognitive learning outcomes, serving to gauge both metacognitive skills and cognitive learning outcomes. Prior to implementation, rigorous validation of the assessment instrument was conducted. Hypothesis testing commenced with a prerequisite assessment to ascertain the normal distribution of data. Subsequently, data analysis explored the relationship between students' metacognitive skills and cognitive learning outcomes within each learning model through simple linear regression. This analysis was further complemented by a comparison of regression equations to delineate similarities and disparities across models, ultimately identifying the learning model exhibiting the strongest correlation between metacognitive skills and cognitive learning outcomes.

RESULTS

Correlation Between Metacognitive Skills and Cognitive Learning Outcomes

The outcomes of the data analysis pertaining to the correlation between metacognitive skills and cognitive learning outcomes within the framework of the inquiry learning model are systematically delineated across Table 1, Table 2, and Table 3. The regression summary in Table 1 serves as a pivotal tool for quantifying the extent to which metacognitive skills influence students' cognitive learning outcomes in the inquiry learning model. Meanwhile, the ANOVA summary in Table 2 is employed to ascertain the significance and magnitude of the computed F value. Furthermore, the significance value and regression coefficient are utilized to establish the regression equation governing the inquiry learning model delineated in Table 3.

Upon scrutinizing the data presented in Table 2, it is evident that the F value stands at 49.387, accompanied by a significance value of 0.000, which is less than the critical threshold of 0.05. Consequently, the null hypothesis is unequivocally refuted, thus affirming the acceptance of the research hypothesis. This indicates a substantive relationship between metacognitive skills and students' cognitive learning outcomes within the pedagogical framework of the inquiry learning model. The derived regression equation from the data analysis manifests as $y = 0.647x + 19.607$, exhibiting a reliability coefficient of 0.655. This implies that metacognitive skills contribute significantly, encompassing 65.5% of the variance in students' cognitive learning outcomes, while the remaining 34.5% can be attributed to other factors. Visual representation of this correlation is depicted in Figure 1.

Table 1. Regression summary of the correlation between metacognitive skills and student cognitive learning outcomes in the inquiry learning model.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Inquiry learning	0.809	0.655	0.642	5.48094

Table 2. ANOVA summary of the correlation between metacognitive skills and cognitive learning outcomes in the inquiry learning model.

Model		Sum of Squares	Df	Mean Square	F	Sig.
Inquiry learning	Regression	1 483.612	1	1 483.612	49.387	0.000
	Residual	781.058	26	30.041		
	Total	2264.670	27			

Table 3. Regression coefficient of the correlation between metacognitive skills and student cognitive learning outcomes in the inquiry learning model.

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
Inquiry learning	(Constant)	19.607	3.581		5.475	0.000
	KetMetaInquiry	0.647	0.092	0.809	7.028	0.000

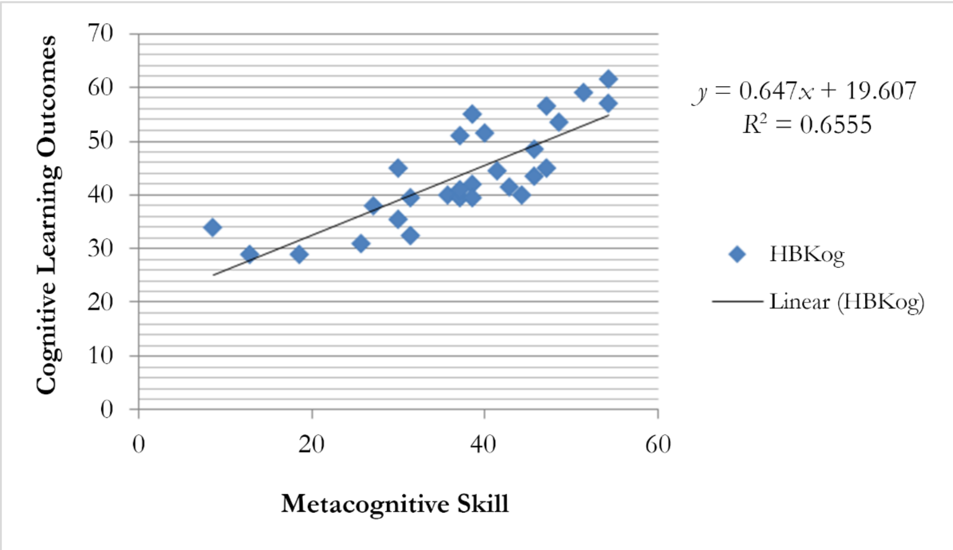

Figure 1. Correlation between metacognitive skills and cognitive learning outcomes in the inquiry leearning model.

Moreover, the findings from the regression analysis concerning the correlation between metacognitive skills and students' cognitive learning outcomes within the inquiry-PBMP learning model are elucidated across Table 4, Table 5, and Table 6. The regression summary in Table 4 serves as a means to gauge the extent of metacognitive skills' influence on students' cognitive learning outcomes in the inquiry-PBMP learning model. Similarly, the ANOVA summary in Table 5 aids in assessing the significance and magnitude of the F value. While also providing insights into the regression coefficients utilized to establish the regression equation within the inquiry-PBMP learning model delineated in Table 6.

Analysis of Table 5 reveals that the F value stands at 50.015, accompanied by a significance value of 0.000, which falls below the critical threshold of 0.05. Consequently, the null hypothesis is decisively rejected, affirming the acceptance of the research hypothesis. This underscores a substantial relationship between metacognitive skills and students' cognitive learning outcomes within the instructional context of the inquiry-PBMP learning model. The derived regression equation from the data analysis is represented as $y = 0.721x + 20.319$, demonstrating a reliability coefficient of 0.704. This suggests that metacognitive skills contribute significantly, constituting 70.4% of the variance in students' cognitive learning outcomes, while the remaining 29.6% can be attributed to other factors. Figure 2 provides a graphical depiction of this relationship within the framework of the inquiry-PBMP learning model.

Table 4. Regression summary of the correlation between metacognitive skills and student cognitive learning outcomes in the inquiry-PBMP learning model.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Inquiry-PBMP learning	0.839	0.704	0.690	5.03618

Table 5. Anova summary of the correlation between metacognitive skills and cognitive learning outcomes in the inquiry-PBMP learning model.

Model		Sum of Squares	Df	Mean Square	F	Sig.
Inquiry-PBMP learning	Regression	1 268.542	1	1 268.542	50.015	0.000
	Residual	532.626	21	25.363		
	Total	1 801.169	22			

Table 6. Regression coefficient of the correlation between metacognitive skills and student cognitive learning outcomes in the inquiry-PBMP learning model.

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
Inquiry-PBMP learning	(Constant)	20.319	4.881		4.163	0.000
	KetMetaInqPBMP	0.721	0.102	0.839	7.072	0.000

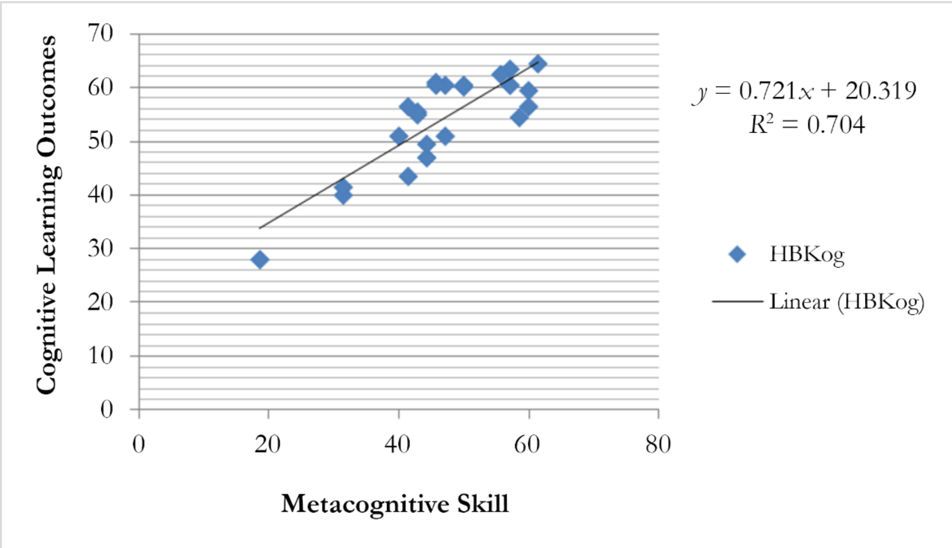

Figure 2. Correlation between metacognitive skills and cognitive learning outcomes in the inquiry-PBMP learning model.

The summary of the regression analysis pertaining to the association between metacognitive skills and students' cognitive learning outcomes in standard learning, as depicted in Table 7, Table 8, and Table 9. The regression summary in Table 7 serves as a tool for assessing the extent of metacognitive skills' impact on students' cognitive learning outcomes in standard learning model. Additionally, the ANOVA summary in Table 8 provides insights into the significance and magnitude of the computed F value, while also offering information on the regression coefficients employed to establish the regression equation within the standard learning model delineated in Table 9.

The data analysis from Table 8 indicates a notable F value of 30.381, coupled with a significance value of 0.000, which is below the threshold of 0.05. Consequently, the null hypothesis is decisively refuted, leading to the acceptance of the research hypothesis. This confirms a significant relationship between metacognitive skills and students' cognitive learning outcomes in standard learning settings. The derived regression equation, $y = 0.493x + 20.377$, based on the data analysis, reveals a reliability coefficient of 0.549. This suggests that metacognitive skills contribute substantially, accounting for 54.9% of the variance in students' cognitive learning outcomes, while the remaining 45.1% can be attributed to other factors. Figure 3 visually represents this relationship within the context of standard learning.

Table 7. Regression summary of the correlation between metacognitive skills and student cognitive learning outcomes in the standard learning model.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Standard learning	0.741	0.549	0.531	5.70606

Table 8. Anova summary of the correlation between metacognitive skills and cognitive learning outcomes in the standard learning model.

Model		Sum of Squares	Df	Mean Square	F	Sig.
Standard learning	Regression	989.189	1	989.189	30.381	0.000
	Residual	813.978	25	32.559		
	Total	1803.167	26			

Table 9. Regression coefficient of the correlation between metacognitive skills and student cognitive learning outcomes in the standard learning model.

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
Standard learning	(Constant)	20.377	2.504		8.139	0.000
	KetMetaStandar	0.493	0.090	0.741	5.512	0.000

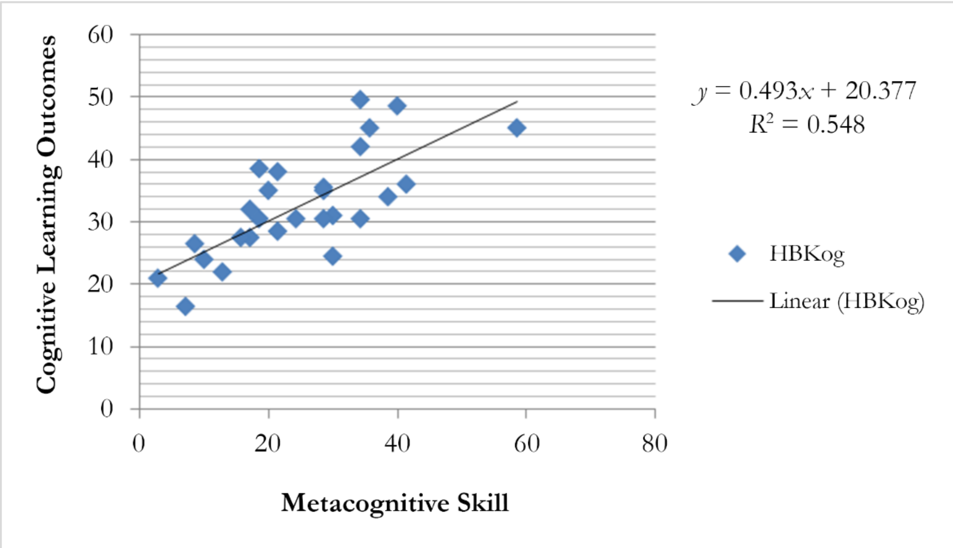

Figure 3. Correlation between metacognitive skills and cognitive learning outcomes in the standard learning model.

Differential Regression Test of the Relationship between Metacognitive Skills and Cognitive Learning Outcomes

The findings from various regression analyses investigating the correlation between metacognitive skills and cognitive learning outcomes across three distinct biology learning paradigms are synthesized in Table 10. Notably, the coefficients b3 and b5 exhibit values greater than 0.05, indicating a statistically significant relationship, while coefficients b2, b3, b4, and b5 are less than 0.05, denoting further significance. This delineates that the regression equations governing the interplay between metacognitive skills and cognitive learning outcomes within the Inquiry learning model, inquiry-PBMP, and standard learning model are distinct and non-coincident. These relationships are explicated graphically in Figure 4, which portrays the divergences in the association between metacognitive skills and cognitive learning outcomes across the aforementioned learning paradigms.

As depicted in Figure 4, the regression analysis reveals that the line representing the relationship between metacognitive skills and students' cognitive learning outcomes in classes instructed via the inquiry-PBMP model is positioned above those of the other two learning models. This distinction is underscored by a notable regression coefficient value of 0.721, indicating a stronger association compared to alternative instructional approaches.

Table 10. Summary of tests for differential of regression on the correlation between metacognitive skills and cognitive learning outcomes across different biology learning models

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	9 374.578	5	1 874.916	63.447	0.000
b3, b5	90.177	2	45.088	1.526	0.311
b2, b3, b4, b5	628.376	4	157.094	5.316	0.001
Residual	2 127.662	72	29.551		

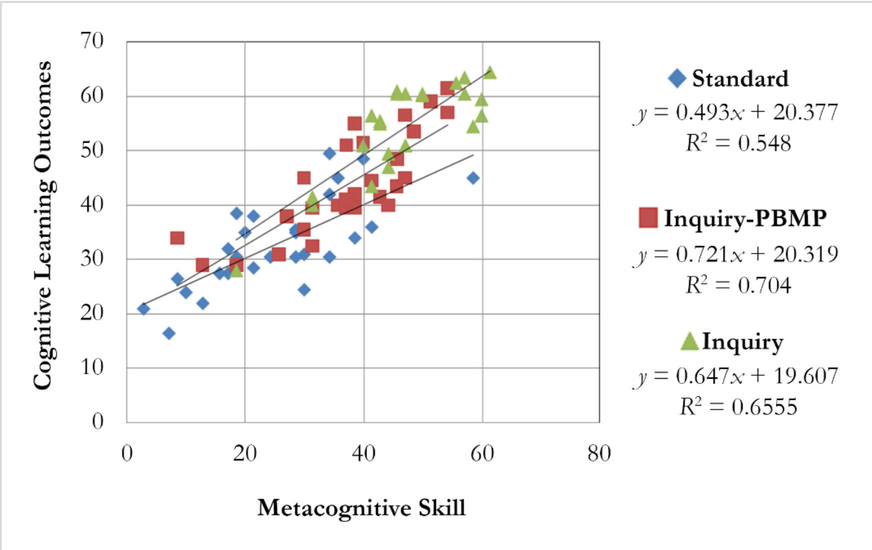

Figure 4. Correlation between metacognitive skills and cognitive learning outcomes

DISCUSSION

Analysis of Correlation between Metacognitive Skills and Cognitive Learning Outcomes

This study prioritizes an examination of the correlation between metacognitive skills and cognitive learning outcomes within the context of three distinct biology learning model: the inquiry learning, inquiry-PBMP, and standard learning model. Through meticulous data analysis, it becomes evident that a statistically significant relationship exists between metacognitive skills and cognitive learning outcomes across all three learning models. Specifically, the regression analysis reveals a positive correlation, as indicated by the positive regression coefficient values associated with each learning model. This suggests that an augmentation in metacognitive skill scores corresponds with heightened cognitive learning outcomes. Consequently, these findings underscore the significance of nurturing students' metacognitive abilities in the realm of biology education, as these skills demonstrably influence cognitive learning outcomes.

This discovery aligns with previous research findings as reported by Ardila (2013), Atunasikha (2010), Coutinho (2007), Kristiani (2009), and Mustaqim et al. (2013), all of which assert a discernible relationship between metacognitive skills and cognitive learning outcomes. Furthermore, the present study demonstrates that metacognitive skills exert a substantial influence on cognitive learning outcomes across the three distinct learning models. This observation is consistent with the findings of Kristiani (2015), through multiple regression analysis, concluded that the contribution of metacognition to cognitive learning outcomes significantly outweighs that of scientific attitudes, particularly within the framework of the TEQI (think empowerment by questioning and inquiry) model.

These findings are corroborated by the research findings of Ainley et al. (2006) and Camahalan (2006), who affirm a significant positive correlation between academic achievement and the application of the self-regulated model in learning. Moreover, it is well-established that self-regulation in learning serves as a potent tool for enhancing academic performance, as underscored by studies conducted by Howse et al. (2003) and Perry et al. (2007). Kosnin (2007) further supports this assertion, highlighting a substantial relationship between SRL (self-regulated learning) and academic achievement. Similarly, the work of Zimmerman and Pons (1986) elucidates that the self-regulated learning model correlates positively with academic achievement among K-12 students, thereby emphasizing the intrinsic link between self-regulated learning and academic success.

Moreover, Livingston (2003) posited that metacognitive activities, such as planning task completion, monitoring comprehension, and evaluating progress, serve as active mechanisms for regulating students' cognitive processes. Students endowed with high metacognitive skills are thus poised to attain superior cognitive learning outcomes. Similarly, Amnah (2011) documented that imparting training utilizing a metacognitive model effectively cultivates metacognitive control, thereby enhancing students' comprehension. Additionally, Listiani et al. (2014) underscored the impact of metacognitive learning on students' academic achievement. Sabilu (2009), drawing from Gagne's framework, delineated learning achievement as the culmination of students' learning endeavors, manifested through observable learning performances. Consistent with this notion, Mardana (2011) asserted that learning achievement correlates with an individual's mastery of specific knowledge or skills within a subject domain, often quantified by test scores or teacher-assigned ratings.

Sabilu (2009) delineates the factors influencing learning achievement into two categories: those amenable to modification and those immutable. The former category includes variables such as teaching methods, curriculum design, and assessment models, while the latter encompasses aspects such as students' backgrounds, intelligence levels, socioeconomic status, learning styles, and goal orientations. Furthermore, Sabilu (2009) asserts the existence of five distinct types of learning outcomes: verbal information, intellectual skills, cognitive models, attitudes, and skills. Notably, these learning outcomes are susceptible to the influence of modifiable factors, including the various learning models employed within educational contexts.

Metacognition stands as a pivotal facet of learning, serving as a robust predictor of academic attainment (Dunning et al., 2003; Kruger & Dunning, 1999). Notably, considerable individual variance exists in metacognitive abilities, with individuals characterized by lower levels of metacognition often deemed "incompetent" relative to their peers (Kruger & Dunning, 1999). Augmenting students' metacognitive capacities correlates positively with heightened learning outcomes (Baran & Maskan, 2011), as evidenced by the superior academic achievement demonstrated by students possessing strong metacognitive skills. El-Anzi (2005) posits academic achievement as a hallmark of success within the academic domain, a sentiment echoed by O'Neil and Abedi (1996), who underscore the profound impact of metacognitive skills across various dimensions on performance appraisal. This assertion aligns with Taylor (1999) assertion that metacognition entails a nuanced understanding of one's existing knowledge and the requisite skills needed for efficient and effective application in diverse contexts. Moreover, Lin (2001) elucidates metacognition as the faculty to comprehend and monitor one's cognitive processes, including the underlying assumptions and implications inherent in one's actions. As an endeavor that regulates and guides cognition, metacognition, as Livingston (2007) contends, shares commonalities with cognitive models, thereby affirming its integral role in facilitating effective learning and performance.

Flavell (1976) defines metacognition as an individual's comprehension of their cognitive operations. Metacognitive aptitude denotes a student's capacity to recognize and oversee their own learning procedures (Peters, 2000). Cultivating metacognitive competencies can foster autonomy in learners, consequently enhancing learning outcomes. These metacognitive skills constitute a crucial element of the knowledge domain essential for comprehending procedural methodologies (Rivers, 2001; Schraw, 1998). Such competencies are imperative for nurturing intellectually adept individuals, aligning with the requisites of the contemporary global (Permendikbud No. 59 Tahun 2014).

Variations in the Association Between Metacognitive Skills and Cognitive Learning Outcomes

The secondary objective of this study is to investigate variations in the association between metacognitive skills and cognitive learning outcomes across diverse biology learning models. Analysis across multiple studies reveals that the regression equations depicting students' metacognitive skills and cognitive learning outcomes within the three learning models are parallel yet distinct. This suggests that while the rate of improvement in cognitive learning outcomes remains consistent across the three learning models, the extent of enhancement in cognitive learning outcomes differs from one model to another. Thus, the occurrence of augmented cognitive learning outcomes attributable to metacognitive skills is evident across all three types of biology learning models utilized, albeit with varying degrees of magnitude. Comparable findings were documented by Siswati (2014), illustrating that while the rate of enhancement in learning outcomes among students with differing academic abilities remains uniform across various learning models, the magnitude of improvement in student learning outcomes varies across these models.

The observed discrepancies in the magnitude of enhanced cognitive learning outcomes are attributable to the utilization of distinct learning models. This assertion finds validation in the literature highlighting the variability in relationships between variables under different conditions (Baran & Maskan, 2011; Collins & Miller, 1994; Skaalvik & Skaalvik, 2010). Graphical representations of regression equations from various studies elucidate that within the realm of three distinct learning models, inquiry-PBMP learning consistently emerges as superior. Specifically, it occupies the apex position in relation to the other two biology learning models. This positioning signifies that inquiry-PBMP learning exhibits greater efficacy in fostering metacognitive skills, thereby concomitantly enhancing students' cognitive learning outcomes.

These findings underscore the pivotal role played by inquiry learning, particularly when coupled with the PBMP approach. The integration of these models has consistently demonstrated heightened efficacy in enhancing both metacognitive skills and cognitive learning outcomes, as expounded upon in preceding sections. Such outcomes can be attributed to the distinctive nature of the inquiry-PBMP model, which incorporates the PBMP pattern—a feature absent in the other two learning models. Within the PBMP model, students engage with meticulously structured questions presented through worksheets. These questions are designed to be hierarchical and logically sequenced, thereby effectively guiding students' cognitive processes. Corebima and Bahri (2011) affirms that the questions structured within the PBMP pattern facilitate critical thinking among students, thereby facilitating mastery of conceptual understanding.

Indeed, the inquiry-PBMP model not only incorporates the PBMP pattern but also integrates inquiry-based learning, which shares several common attributes with PBMP. Inquiry learning accentuates the development of critical thinking skills through investigative processes, while the PBMP pattern fosters critical thinking via structured and logically sequenced questioning. Consequently, both approaches serve to enhance students' cognitive abilities. As highlighted by Beyer (1997) and Dantonio and Beisenherz (2001), questions serve as a predominant technique for cultivating thinking skills, stimulating curiosity, and promoting mental engagement throughout the inquiry process. Moreover, Cuevas et al. (2005) suggest that questions play a pivotal role in consolidating material. This underscores the intrinsic relationship between questions and comprehension of material. The understanding garnered through an investigative process guided by systematically structured questions culminates in superior learning outcomes.

The regression analysis indicates that inquiry-based learning serves as the primary determinant in the relationship between students' metacognitive skills and second-order cognitive learning outcomes. Inquiry-based learning is characterized by students' active construction of understanding, wherein they integrate new information with existing knowledge in a structured and systematic manner. Kristiani (2005) elucidates that inquiry learning unfolds systematically, following a logical progression throughout the investigative process. This systematic approach inherent in inquiry-based learning aligns closely with the development of metacognitive skills. Consequently, inquiry-based learning serves as a platform for nurturing students' metacognitive abilities, thereby facilitating their contribution to enhanced cognitive learning outcomes.

The regression analysis reveals that the standard learning model serves as the primary determinant in the relationship between students' metacognitive skills and third-order cognitive learning outcomes. This model, characterized by its simplicity compared to inquiry learning and the inquiry-PBMP model, is commonly categorized as standard learning. Its sequential learning steps typically include observation, questioning, data collection, analysis, and communication, akin to the scientific method. The enduring prominence of the scientific method in shaping educational practices underscores its efficacy in cultivating both teachers' and students' understanding of scientific inquiry (Bencze & Bowen, 2001; Simmons et al., 1999; Palmquist & Finley, 1997). Thus, the standard learning model effectively facilitates the development of students' metacognitive skills, consequently enhancing their cognitive learning outcomes.

CONCLUSION

Based on the research findings and ensuing discussions, several conclusions can be drawn. Firstly, there exists a positive correlation between metacognitive skills and cognitive learning outcomes across classes employing the Inquiry, Inquiry-PBMP, and standard learning models. However, the magnitude of metacognitive skills' contribution to cognitive learning outcomes varies among these models. Notably, the most substantial contribution is observed in classes utilizing the Inquiry-PBMP learning model. This model stands out as superior in enhancing metacognitive skills, consequently exerting a pronounced positive impact on students' cognitive learning outcomes.

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AUTHOR CONTRIBUTIONS

Each author participated in the conception and design of the study, data collection, analysis, interpretation, writing, and revising of the manuscript. Additionally, all authors have given their approval for the final version of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors assert that they do not have any conflicts of interest related to the research, writing, and publication of this paper.

REFERENCES

Ainley, J., Pratt, D., & Hansen, A. (2006). Connecting engagement and focus in pedagogic task design. *British Educational Research Journal*, *32*(1), 23–38. https://doi.org/10.1080/01411920500401971

Amnah, S. (2011). Pembelajaran think pair share, keterampilan metakognitif, dan hasil belajar kognitif siswa SMA. *Jurnal Ilmu Pendidikan, 17*(6), 489–493. http://dx.doi.org/10.17977/jip.v17i6.2882

Ardila, C., Corebima, A. D., & Zubaidah, S. (2013). Hubungan keterampilan metakognitif terhadap hasil belajar biologi dan retensi siswa kelas X dengan penerapan strategi pemberdayaan berpikir melalui pertanyaan (PBMP) di SMAN 9 Malang (Undergraduated thesis, Universitas Negeri Malang, Malang, Indonesia). Retrieved from https://repository.um.ac.id/24892/

Atunasikha, L. (2010). Hubungan keterampilan metakognitif dan pemahaman konsep siswa laki-laki dan perempuan kelas IV SDN Penanggungan Malang pada pembelajaran sains dengan strategi pembelajaran PBMP dan think pair share (TPS) (Doctoral dissertation, Universitas Negeri Malang, Malang, Indonesia). Retrieved from https://repository.um.ac.id/24732/

Bahri, A. (2010). Pengaruh strategi pembelajaran RQA pada perkuliahan fisiologi hewan tehadap kesadaran metakognitif, keterampilan metakognitif dan hasil belajar kognitif mahasiswa jurusan biologi FMIPA UNM (Master thesis, Universitas Negeri Malang, Malang, Indonesia). Retrieved from http://mulok.lib.um.ac.id/index.php?p=show_detail&id=44446

Baran, M., & Maskan, A. K. (2011). A study of relationships between academic self concepts, some selected variables and physics course achievement. *International Journal of Education*, *3*(1), E2. https://doi.org/10.5296/ije.v3i1.586

Bencze, J. L., & Bowen, G. M. (2001). Learner-controlled projects in science teacher education: Planting seeds for revolutionary change. In *Annual Meeting of the American Educational Research Association, Seattle, WA*.

Beyer, B. K. (1997). *Improving student thinking: A comprehensive approach*. Boston, MA: Allyn and Bacon.

Borich, G. D. (2007). Introduction to the thinking curriculum. In A. C. Ong & G. D. Borich (Eds.), *Teaching strategies that promote thinking: Models and curriculum approaches*. Singapore: McGraw-Hill.

Boyle, B., Lamprianou, I., & Boyle, T. (2005). A longitudinal study of teacher change: What makes professional development effective? Report of the second year of the study. *School Effectiveness and School Improvement*, *16*(1), 1–27. https://doi.org/10.1080/09243450500114819

Camahalan, F. M. G. (2006). Effects of self-regulated learning on mathematics achievement of selected Southeast Asian children. *Journal of Instructional Psychology*, *33*(3), 194–205.

Collins, N. L., & Miller, L. C. (1994). Self-disclosure and liking: a meta-analytic review. *Psychological Bulletin*, *116*(3), 457.

Corebima, A. D. (2009). Jadikan peserta didik pebelajar mandiri. In *Seminar Nasional Pendidikan, Himpunan Mahasiswa Jurusan Biologi FMIPA UNM, Makassar, Indonesia*.

Corebima, A. D., & Bahri, A. (2011). Reading, questioning, and answering (RQA): A new learning strategy to enhance student metacognitive skill and concept gaining. In *International Symposium at Nanyang Technology University, Singapore*.

Coutinho, S. A. (2007). The relationship between goals, metacognition, and academic success. *Educate~*, *7*(1), 39–47.

Cuevas, P., Lee, O., Hart, J., & Deaktor, R. (2005). Improving science inquiry with elementary students of diverse backgrounds. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *42*(3), 337–357. https://doi.org/10.1002/tea.20053

Dantonio, M., & Beisenherz, P. C. (2001). *Learning to question, questioning to learn: A guide to developing effective teacher questioning practices*. Boston, MA: Allyn and Bacon.

Duffy, G. G., Roehler, L. R., & Herrmann, B. A. (1988). Modeling mental processes helps poor readers become strategic readers. *The Reading Teacher*, *41*(8), 762–767.

Dunlosky, J., & Metcalfe, J. (2008). *Metacognition*. Thousand Oaks, CA: Sage Publications.

Dunning, D., Johnson, K., Ehrlinger, J., & Kruger, J. (2003). Why people fail to recognize their own incompetence. *Current Directions in Psychological Science*, *12*(3), 83–87. https://doi.org/10.1111/1467-8721.01235

El-Anzi, F. O. (2005). Academic achievement and its relationship with anxiety, self-esteem, optimism, and pessimism in Kuwaiti students. *Social Behavior and Personality*, *33*(1), 95–104. https://doi.org/10.2224/sbp.2005.33.1.95

Flavell, J. H. (1976). Metacognitive aspects of problem solving. In L. B. Resnick (Ed.), *The nature of intelligence*. Hillsdale, NJ: Erlbaum.

Howse, R. B., Lange, G., Farran, D. C., & Boyles, C. D. (2003). Motivation and self-regulation as predictors of achievement in economically disadvantaged young children. *The Journal of Experimental Education*, *71*(2), 151–174. https://doi.org/10.1080/00220970309602061

Kahn, P., & O'Rourke, K. (2005). Understanding enquiry-based learning (EBL). In T. Barrett, I. MacLabhrainn, and H. Fallon, (Eds.), *Handbook of enquiry and problem-based learning: Irish case studies and international perspectives*. Galway, Ireland: Centre for Excellence in Learning and Teaching, National University of Ireland.

Kanselaar, G. (2002). *Constructivism and socio-constructivism*. Retrieved from http://kanselaar.net/wetenschap/files/Constructivism-gk.pdf

Kosnin, A. M. (2007). Self-regulated learning and academic achievement in Malaysian undergraduates. *International Education Journal*, *8*(1), 221–228.

Kristiani, N. (2005). Penerapan pembelajaran inkuiri untuk meningkatkan kerja ilmiah dan motivasi belajar siswa kelas II SMA Negeri 5 Malang pada pokok bahasan alat indera. In *Pelatihan PTK, MGMP Biologi Kota Malang, Malang, Indonesia*.

Kristiani, N. (2008). *Biologi kelas X*. Jakarta, Indonesia: Inter Mitra Group.

Kristiani, N. (2009). Pengaruh strategi pembelajaran dan kemampuan akademik serta interaksinya terhadap kemampuan metakognisi dan hasil belajar kognitif siswa kelas X di SMA Negeri 9 Malang (Doctoral dissertation, Universitas Negeri Malang, Malang, Indonesia). Retrieved from https://repository.um.ac.id/60282/

Kristiani, N. (2015). Hubungan keterampilan metakognitif dan hasil belajar kognitif siswa pada pembelajaran saintifik dalam mata pelajaran biologi SMA kurikulum 2013. In *Biologi, sains, lingkungan, dan pembelajarannya*. Proceedings of the Seminar Nasional XII Pendidikan Biologi FKIP UNS (pp. 513-519). Surakarta, Indonesia.

Kristiani, N., Susilo, H., Rohman, F., & Aloysius, D. C. (2015). The contribution of students' metacognitive skills and scientific attitude towards their academic achievements in biology learning implementing Thinking Empowerment by Questioning (TEQ) learning integrated with inquiry learning (TEQI). *International Journal of Educational Policy Research and Review*, *2*(9), 113–120. http://dx.doi.org/10.15739/IJEPRR.020

Kruger, J., & Dunning, D. (1999). Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. *Journal of Personality and Social Psychology, 77*(6), 1121–1134. https://doi.org/10.1037/0022-3514.77.6.1121

Lin, X. (2001). Designing metacognitive activities. *Educational Technology Research and Development*, *49*(2), 23–40. https://doi.org/10.1007/BF02504926

Listiani, N. W., Wiarta, I. W., & Darsana, I. W. (2014). Penerapan model pembelajaran metakognitif berbasis masalah terbuka berpengaruh terhadap hasil belajar matematika siswa kelas V SD Gugus 8 Blahbatuh. *MIMBAR PGSD Undiksha*, *2*(1). https://doi.org/10.23887/jjpgsd.v2i1.2264

Livingston, J. A. (2003). *Metacognition: An overview* (Reports Descriptive No. 141). https://files.eric.ed.gov/fulltext/ED474273.pdf

Mardana, I. G. (2011). Pengaruh model pembelajaran berbasis masalah (problem based learning) terhadap prestasi belajar fisika dan keterampilan berpikir kritis ditinjau dari bakat numerik. *Jurnal Pendidikan dan Pembelajaran IPA Indonesia*, *1*(1), 242.

Mustaqim, S. B., Abdurrahman, A., & Viyanti, V. (2013). Pengaruh keterampilan metakognitif terhadap motivasi dan hasil belajar melalui model problem based learning (PBL). *Jurnal Pembelajaran Fisika Universitas Lampung*, *1*(5), 120280.

O'Neil Jr, H. F., & Abedi, J. (1996). Reliability and validity of a state metacognitive inventory: Potential for alternative assessment. *The Journal of Educational Research*, *89*(4), 234–245. https://doi.org/10.1080/00220671.1996.9941208

Palmquist, B. C., & Finley, F. N. (1997). Preservice teachers' views of the nature of science during a postbaccalaureate science teaching program. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *34*(6), 595–615. https://doi.org/10.1002/(SICI)1098-2736(199708)34:6%3C595::AID-TEA4%3E3.0.CO;2-I

Peraturan Menteri Pendidikan dan Kebudayaan No. 59 Tahun 2014. (2014, July 02). Retrieved from https://peraturan.go.id/id/permendikbud-no-59-tahun-2014

Perry, N. E., Hutchinson, L., & Thauberger, C. (2007). Mentoring student teachers to design and implement literacy tasks that support self-regulated reading and writing. *Reading & Writing Quarterly*, *23*(1), 27–50. https://doi.org/10.1080/10573560600837636

Peters, M. (2000). Does constructivist epistemology have a place in nurse education?. *Journal of Nursing Education*, *39*(4), 166–172. https://doi.org/10.3928/0148-4834-20000401-07

Rivers, W. P. (2001). Autonomy at all costs: An ethnography of metacognitive self-assessment and self-management among experienced language learners. *The Modern Language Journal*, *85*(2), 279–290. https://doi.org/10.1111/0026-7902.00109

Sabilu, M. (2009). Pengaruh penggunakan jurnal belajar dalam pembelajaran multistrategi terhadap kemampuan kognitif dan metakognitif siswa SMA Negri 9 Nalang/Murni (Doctoral dissertation, Universitas Negeri Malang, Malang, Indonesia). Retrieved from https://repository.um.ac.id/60270/

Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Science*, *26*, 113–125. https://doi.org/10.1023/A:1003044231033

Simmons, P. E., Emory, A., Carter, T., Coker, T., Finnegan, B., Crockett, D., ... & Labuda, K. (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *36*(8), 930–954. https://doi.org/10.1002/(SICI)1098-2736(199910)36:8%3C930::AID-TEA3%3E3.0.CO;2-N

Siswati, B. H. (2014). Hubungan antara keterampilan metakognitif dengan hasil belajar siswa berkemampuan akademik berbeda pada pembelajaran biologi yang menerapkan beberapa model pembelajaran (Doctoral dissertation, Universitas Negeri Malang, Malang, Indonesia). Retrieved from https://repository.um.ac.id/60412/

Skaalvik, E. M., & Skaalvik, S. (2010). Teacher self-efficacy and teacher burnout: A study of relations. *Teaching and Teacher Education*, *26*(4), 1059–1069. https://doi.org/10.1016/j.tate.2009.11.001

Syamsuri, I. (2017). *ESPS & simple modern biologi untuk SMA/MA kelasa X (1)*. Jakarta, Indonesia: Erlangga.

Taylor, S. (1999). Better learning through better thinking: Developing students' metacognitive abilities. *Journal of College Reading and Learning*, *30*(1), 34–45. https://doi.org/10.1080/10790195.1999.10850084

Yamin, M. (2008). *Paradigma pendidikan konstruktivistik: Implementasi KTSP dan UU no. 14 tahun 2005 tentang Guru dan Dosen*. Jakarta, Indonesia: Gaung Persada Press.

Zimmerman, B. J., & Pons, M. M. (1986). Development of a structured interview for assessing student use of self-regulated learning strategies. *American Educational Research Journal*, *23*(4), 614–628. https://doi.org/10.3102/00028312023004614