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The effect of deep learning and problem based learning on active and independent learning with mediation variable

Fauziyah Qurrota A'yun Tamami[1,*], Muhammad Wildan Shohib[1], Muh. Nur Rochim Maksum[1], Md. Fajlay Rabbi[2], Zainora Dau[3], Nazar Fadli[4], Munshid Falih Wadi[5]

[1]Universitas Muhammadiyah Surakarta, Indonesia
[2]Khulna University, Bangladesh
[3]Universiti Sains Islam Malaysia, Malaysia
[4]Necmettin Erbakan University, Turkey
[5]University of Diyala, Iraq

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Abstract: This study aims to analyze the influence of deep learning (DL) and problem based learning (PBL) on the active and independent learning of students with the mediation variable of self-regulated learning (SRL) at high school in Surakarta. The research method used was an explanatory quantitative approach with data collection through a closed questionnaire distributed to 157 students in grades X and XI. Data were analyzed using the structural equation modeling (SEM) approach SmartPLS 4.0 software. The analysis stage includes evaluating the measurement model (outer model) by testing convergent validity (AVE). Furthermore, the structural model (inner model) was analyzed by testing the path coefficient and significance using the bootstrapping method. Hypothesis testing was carried out with the h_o rejection criterion if the p-value was < 0.05 and the t-statistic > 1.96. The results of the study show that deep learning and problem based learning have a significant effect on active and independent learning, both directly and through the mediation of self-regulated learning. All study variables met the criteria for validity and reliability, as indicated by AVE and Cronbach's alpha values above 0.5 and 0.7. The model fit index (SRMR = 0.089, and NFI = 0.931) confirms the fit of the proposed model. The results show that deep learning and problem based learning significantly affect active and independent learning through self-regulated learning strategies and are capable of enhancing students' active involvement and independence in learning process.

Keywords: Collaborative learning strategies, learning motivation, student engagement

Abstrak: Penelitian ini bertujuan untuk menganalisis pengaruh deep learning (DL) dan problem based learning (PBL) terhadap pembelajaran aktif dan mandiri siswa dengan variabel mediasi self-regulated learning (SRL) di SMA Surakarta. Metode penelitian yang digunakan adalah pendekatan kuantitatif eksplanasi dengan pendataan melalui kuesioner tertutup yang disebarkan kepada 157 siswa kelas X dan XI. Data dianalisis menggunakan pendekatan structural equation modeling (SEM) perangkat lunak SmartPLS 4.0. Tahap analisis meliputi evaluasi model pengukuran (model luar) dengan menguji validitas konvergen (AVE). Selanjutnya, model struktural (model dalam) dianalisis dengan menguji koefisien jalur dan signifikansi menggunakan metode bootstrapping. Pengujian hipotesis dilakukan dengan kriteria penolakan h_o jika nilai p < 0,05 dan statistik-t > 1,96. Hasil penelitian menunjukkan bahwa deep learning dan problem based learning memiliki pengaruh yang signifikan terhadap pembelajaran aktif dan mandiri, baik secara langsung maupun melalui mediasi self-regulated learning. Semua variabel penelitian memenuhi kriteria validitas dan keandalan, seperti yang ditunjukkan oleh nilai AVE dan cronbach's alpha di atas 0,5 dan 0,7. Indeks kesesuaian model (SRMR = 0,089, dan NFI = 0,931) mengkonfirmasi kesesuaian model yang diusulkan. Hasil penelitian menunjukkan bahwa deep learning dan problem based learning secara signifikan mempengaruhi pembelajaran aktif dan mandiri melalui strategi pembelajaran yang diatur sendiri, mampu meningkatkan keterlibatan aktif dan kemandirian siswa dalam proses pembelajaran.

Kata kunci: Strategi pembelajaran kolaboratif, motivasi belajar, keterlibatan siswa

*Corresponding author: o100230073@student.ums.ac.id

INTRODUCTION

Learning conditions in Indonesia, especially at the high school level, are still largely dominated by conventional teacher-centered learning models. This leads to low active student participation in the learning process. According to the records of the ministry of education and culture shows that in 2023, only 45% of high school students are actively involved in the learning process, while students' independent learning ability is also still low with a percentage of 38% of all high school students in Indonesia (Nisa et al., 2023). There are around 78% of schools in Indonesia that have adopted technology-based learning models, but only 35% have integrated the concept of deep learning (DL) in the merdeka curriculum (Sa'diyah et al., 2023). One of the approaches that has begun to be applied to the development of technology is deep learning (DL) and problem based learning (PBL), which is expected to be able to increase the effectiveness of teaching, especially in Islamic religious education (Osman et al., 2020).

In the modern era of education, the active and independent learning approach is the main highlight in efforts to improve the quality of learning. However, its implementation still faces various challenges. Active learning, which emphasizes students' active participation through discussions, problem-solving, and collaborative activities, has been shown to be effective in improving learning outcomes (Nasir et al., 2024; Setyantoko et al., 2023). However, the adoption of this method is often hampered by the limited time and resources available to teachers (Eickholt, 2018). Meanwhile, independent learning requires students to organize, monitor, and evaluate their own learning process, which requires a high level of motivation and discipline (Santoso et al., 2022). Learning challenges emerge when students are less accustomed to autonomy in learning, coupled with limited support from a learning environment that is not conducive to fostering student independence and activeness (Putra & Budiningsih, 2023).

The relationship between active and independent learning and deep learning is the main focus in developing effective learning strategies. Deep learning refers to a process of profound and meaningful learning, in which students not only memorize information, but also understand, connect, and apply knowledge critically (Weng et al., 2023). The active learning approach can encourage a deep learning approach by engaging students in activities that demand high-level thinking and reflection. Meanwhile, independent learning allows students to explore material independently, develop critical thinking skills, and apply knowledge in a real-world context. The active deep learner experience approach is effective in building student learning independence in elementary school, which in turn supports the deep learning process (Dita, et al., 2023; Kontesa et al., 2023). Thus, the integration between active and independent learning can be an effective strategy to encourage deep learning in the context of education.

Problem-based learning is a learning approach that puts students at the center of the learning process through complex real problem solving. Problem-based learning encourages students to actively seek information, analyze data, and formulate solutions, which directly involves them in the active learning process (Sogen et al., 2018; Zannah et al., 2022). In addition, problem-based learning requires students to learn independently, set learning strategies, and evaluate their own understanding, which is the essence of independent learning (Ghani et al., 2021). The application of problem-based learning in biology learning improves critical thinking skills, science literacy, and student learning

independence (Ramadhan & Mardin, 2023). Thus, the integration of problem-based learning in the curriculum can strengthen students' active and independent learning practices simultaneously.

Self-regulated learning is a process in which students actively set learning goals, monitor progress, and develop strategies to achieve their desired learning outcomes. Self-regulated learning has an important role in supporting active learning, as students who are able to self-regulated tend to be more proactive in participating, taking initiative, and engaging in challenging learning activities. In addition, self-regulated learning also strengthens independent learning, as students learn to take responsibility for their own learning processes and outcomes (Sukowati et al., 2020). Self-regulated learning is effective in increasing students' motivation and learning independence. Student learning motivation increased by 15.2 points, while the control class experienced an increase in motivation of 48.27% equivalent to 13.54 points. Self-learning independence also increased significantly in both classes, with an increase of around 52%, demonstrating the important role of self-regulated learning in developing students' self-learning abilities (Zakiyah, 2022).

Self-regulated learning not only strengthens active and independent learning, but also becomes an important foundation in achieving deep learning (DL) and supporting the effectiveness of PBL (Baptista, 2025; LeCun et al., 2015). Self-regulated learning allows students to set learning goals, monitor progress, and adjust their learning strategies which is a key aspect of deep learning, which is a deep and meaningful learning process (Alzahrani & Alnufaie, 2024). Problem-based learning (PBL) can improve students' self-regulated skills, by creating a challenging learning environment and encouraging students to take responsibility for their own learning process (Temel, 2013). Thus, the development of self-regulated learning in students not only strengthens active and independent learning practices, but is also the key to achieving deep learning and increasing the effectiveness of problem-based learning in the context of today's education. Therefore, if related, the deep learning and problem-based learning methods are interrelated in supporting students' active and independent learning, with self-regulated learning acting as a mediator that strengthens the relationship.

This research was carried out because until now there has been no research that directly examines how deep learning and problem-based learning relate to active and independent learning through self-regulated learning as a mediating variable. Most previous studies have only examined these variables separately, without looking at the casual relationships and mediations that influence each other among these variables in a single complete research model. In fact, in the context of modern learning that requires students to be active, independent, and able to manage their own learning process, understanding this relay is very important to be able to manage their own learning process, understanding this relationship is very important to design an effective learning strategy. Therefore, this research is needed to fill the literature gap and make an empirical contribution in the field of education, especially in the development of a learning model based on the concept of self-regulated learning.

The urgency of this research is based on the increasing demands of the world of education to produce students who are not only active in the learning process, but also have high learning independence and the ability to manage and manage the learning process optimally. In the fast-paced and competitive digital era, the ability to be active and

independent learning and self-regulated learning are essential competencies for students to be able to adapt to various academic and professional challenges. The results of this research are expected to provide strategic recommendations for students, educational institutions, and curriculum development in designing learning methods that not only focus on content, but also on the development of students' independent learning skills and self-regulation.

The researcher seeks to explore how the deep learning approach, characterized by deep conceptual understanding, interacts with problem-based learning in promoting student independence in learning. It also investigates the mediating role of self-regulated learning in these relationships. The study conceptual framework presented in Figure 1. that illustrates how the variables are interconnected and influence one another in a systematic manner, deep learning and problem-based learning are positioned as independent variables that are expected to enhance both active and independent learning directly, as well as indirectly through the mediation of self-regulated learning. These additions are in line with academic writing conventions and help readers anticipate the existence and function of your conceptual outline diagram in the article.

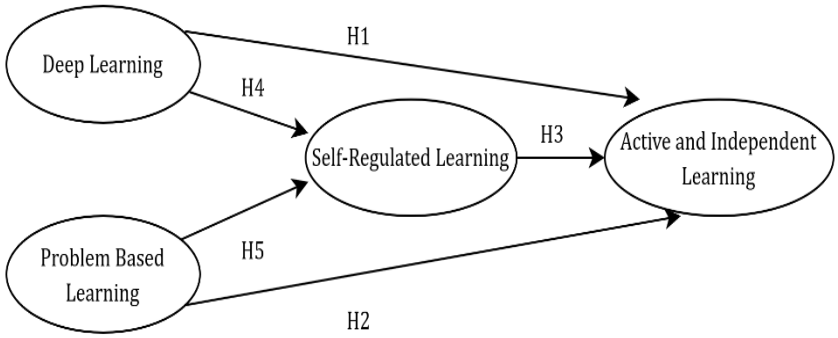

Fig. 1. Frame of mind

METHOD

This research method uses an explanatory quantitative approach with a type of field research that aims to test the relationship between dependent variables and independent variables (Sugiyono, 2017). Data was collected directly from the research site through a structured instrument, namely a questionnaire. The research was carried out by observation, documentation, and questionnaire distribution. Data collection was carried out offline through the distribution of a 1-4 likert scale questionnaire, on March 21-23, 2025. The research population consisted of all students in grades X and XI in Surakarta senior high school.

The distribution of respondents by class is presented in Table 1, which outlines the number of participants from each grade level. It shown that the students from class X made up the largest portion of the sample, totaling 85 students (54%), while the remaining 72 students (46%) were from class XI.

Table 1. Characteristics of respondents by class

No.	Class	Sum	%
1.	X	85	54
2.	XI	72	46
Total		157	100

The distribution of respondents by gender is shown in Table 2. The sample was predominantly by male with 85 students equivalent to 54%, while the rest were women with 72 students or 46%. This proportion indicates that male respondents slightly outnumbered female respondents in this study.

Table 2. Characteristics of respondents by gender

No.	Gender	Sum	%
1.	Man	85	54
2.	Woman	72	46
Total		157	100

The sampling technique used is simple random sampling (SRS) with the following procedure: first, compiling sampling frames from the entire population; second, determine the sample size using the slovin formula, namely:

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

Notes:
n denotes the number of samples, n the total population, and e the acceptable error rate (e.g. 5% = 0.005) (Thomas, 2020).

Data was gathered using a closed questionnaire applying a 4-point Likert scale: 1) strongly disagree, 2) disagree, 3) agree, 4) strongly agree. The descriptive statistical data were analyzed using mean values. To interpret the results, a mean score ranging from 3.00 to 4.00 was categorized as high, 2.00 to 2.99 as moderate, and 1.00 to 1.99 as low. This categorization was used as a reference in describing the perception levels of the respondents toward each research variable (Sugiyono, 2017). Instrument validity was measured through outer loadings (> 0.7), while reliability was confirmed with composite reliability (> 0.7).

The first analysis in the study began with an evaluation of the measurement model was first conducted, followed by an assessment of the structural model using SmartPLS version 4.1.0. The measurement model evaluation involved four criteria: a) discriminant validity, where a variable is considered valid if the AVE value exceeds 0.50; b) composite reliability; if each variable has a value of > 0.70. c) cronbach's alpha; the correlation value is considered valid if > 0.70 in each variable. Then, d) the variable can be said to be reliable and model fit, if chi square < 3,000, SRMR < 0.05/0.06/0.08/0.10, NFI >0.90 value. Data were analyzed using the structural equation modeling (SEM) approach SmartPLS 4.0 software (Zumbo, 2005). Furthermore, the structural model (inner model) was analyzed by testing the path coefficient and significance using the bootstrapping method. The coefficient of determination (R^2) was used to assess how much of the variation in the dependent

variable is explained by the model an $r^2 \geq 0.50$ is considered high. An r^2 value of 0.67 or higher is categorized as substantial, 0.33-0.66 as moderate, and 0.19-0.32 as weak in terms of explanatory power (Chin, 1998).

RESULTS AND DISCUSSION

Utilizing a quantitative research design, this study analyzes numerical data via SmartPLS software version 4.1.0. The study's primary focus is to assess the influence of deep learning and problem-based learning on active and independent learning, with self-regulated learning acting as a mediating factor. The sample comprised 157 active senior high school students in Surakarta, with data gathered through offline distribution of questionnaires a 1-4 likert scale questionnaire, on March 21-23, 2025. The variables used in this study include deep learning, problem-based learning, active and independent learning, and self-regulated learning as mediation variables.

Table 3. Variable deep learning

No.	Item variable	Mean	Category
1.	I feel comfortable explaining abstract ideas to my friends in an easy-to-understand way.	3.197	High
2.	I am often looking for new ways to apply the concepts I have learned in real-life situations.	3.191	High
3.	I can use the knowledge I learned in class to solve problems in everyday life.	3.223	High
4.	When faced with new situations, I was able to adapt learning strategies that had proven effective before.	3.127	High
5.	I always question the information I receive before accepting it as fact.	3.382	High
6.	I find it important to evaluate various points of view before making a decision.	3.350	High
7.	I often think about how best to learn new material before starting the learning process.	3.268	High
8.	When I have difficulty understanding a concept, I try to find out the cause and plan steps to overcome it.	3.261	High

Based on the results of descriptive statistical analysis presented in Table 3, it can be seen that all items related to student's perceptions of deep learning are categorized as high, with mean values ranging from 3.127 to 3.382. This indicates that, overall, students have a positive perception of the deep learning process implemented in their learning environment. Specifically, the highest mean value is found in the statement "I always question the information I receive before accepting it as fact" with a mean score of 3.382, reflecting students' critical thingking tendencies in processing information before drawing conclusions. Similarly, the statement "I find it important to evaluate various points of view before making a decision" received a high mean score of 3.350, indicating that students are accustomed to considering different perspectives when solving problems or making decisions.

Table 4. Variable problem-based learning

No.	Item variable	Mean	Category
1.	I often look for additional information to understand the context and complexity of a problem before trying to solve it.	3.217	High
2.	I feel comfortable analyzing the problem from different angles to gain a more thorough understanding.	3.236	High
3.	In a group, I value my friends' opinions and ideas as I seek solutions together.	3.497	High
4.	I feel that teamwork is essential in solving complex problems.	3.446	High
5.	I try to find solutions that are relevant to the specific context or situation I am dealing with.	3.261	High
6.	I believe that effective solutions should be adapted to the conditions and needs of the local community.	3.338	High
7.	After implementing a solution, I always assess the results to determine if the solution is effective.	3.242	High
8.	I feel it's important to reflect on the problem-solving process to improve my skills and strategies in the future.	3.299	High

Table 4 indicates that the problem-based learning variable has a high average value, with mean values ranging from 3.217 to 3.497. This indicates that students hold positive perceptions of the problem-based learning strategies applied in their classrooms. The highest mean score is found in the statement “In a group, I value my friends' opinions and ideas as I seek solutions together” with a mean of 3.497. this reflects that students highly appreciate collaborative problem-solving and actively involve their peers’ persepectives during group discussions. Other indicators such as the tendency to look for additional information to understand the context a problem with a mean score 3.217, analyze problem from various perspective (3.236), and reflect on the problem-solving process to improve future strategies (3.299) also show high mean values. This suggests that students not only actively participate in problem-solving activities but also engage in reflection and critical evaluation of their approaches.

As presented in Table 5, all items related to active and independent learning are categorized as high, with mean values ranging from 3.025 to 3.376. This reflects that students have positive perceptions of their activeness in participating in learning activities and their independence in managing their learning processes. In question indicator 6, demonstrates the highest mean value of 3,376, therefore active and independent learning will affect self-regulated learning if the school can provide adequate facilities for learning. Other high-scoring items include “I was able to set personal learning goals that fit my interests and needs” (3.242) and “I am looking for opportunities to be involved in extracurricular projects or activities that support my learning”. These results indicate that students actively seek oppurtunities to enchance their learning experiences beyond the classroom and are capable of setting personalized learning targets aligned with their goals and interests.

Moreover, indicators such as reflecting on problem-solving processes (3.153), adjusting learning goals based on feedback (3.185) also fall into the high category. This demonstrates students’ proactive efforts to engage in critical reflection and decision-

making as part of their learning process. Furthermore, it can be inferred that active and independent learning has the potential to positively influence self-regulated learning facilities and a conducive academic environment.

Table 5. Variable active and independent learning

No.	Item variable	Mean	Category
1.	I actively participate in class discussions and share my opinions with friends.	3.057	High
2.	I am looking for opportunities to be involved in extracurricular projects or activities that support my learning.	3.146	High
3.	I was able to set personal learning goals that fit my interests and needs.	3.242	High
4.	I try to adjust my learning goals based on the feedback I receive from teachers or friends.	3.185	High
5.	I was able to manage my time well between schoolwork, extracurricular activities, and personal time.	3.025	High
6.	When faced with deadlines, I can prioritize tasks that need to be completed first.	3.376	High
7.	I often analyze situations in depth before making decisions about how to solve the problem.	3.185	High
8.	I have a habit of reflecting on my problem-solving process after finding solutions to improve my skills in the future.	3.153	High

Table 6. Variable self-regulated learning

No.	Item variable	Mean	Category
1.	I always plan my study activities by setting clear goals before starting.	3.140	High
2.	I made a list of tasks and materials that needed to be studied to make sure I didn't miss anything important.	3.057	High
3.	I write down mistakes I made in previous assignments to make sure that I don't repeat them in the future.	3.102	High
4.	I feel it's important to reflect on my learning experience and determine which areas need improvement.	3.274	High
5.	I am learning because I have a high curiosity and want to understand more about the world around me.	3.261	High
6.	I feel satisfied when I successfully complete an academic challenge, even though there are no external awards involved.	3.427	High
7.	I use study aids such as apps or software to improve my learning efficiency.	3.357	High
8.	I feel comfortable using technology and social media as an additional source of information in the learning process.	3.586	High

Based on the descriptive statistical analysis presented in Table 6, all items related to self-regulated learning are classified as high based on the descriptive statistical criteria, with mean values ranging from 3.057 to 3.586. this indicates that students generally have strong self-regulation skills in managing their learning processes. The highest mean score is recorded in the statement "I feel comfortable using technology and social media as an additional source of information in the learning process", with a value of 3,586, therefore self-regulated learning will affect active and independent learning if the school can provide adequate facilities for learning. This finding reflects students' readiness to integrate digital resources into their learning activities, highlighting the role of technology in supporting self-directed learning in the digital era.

Further explanation is provided by the values shown in Figure 2, which illustrates the structural relationships among the research variables. This figure represents the results of a statistical analysis used to test whether the collected data align with proposed measurement and structural model.

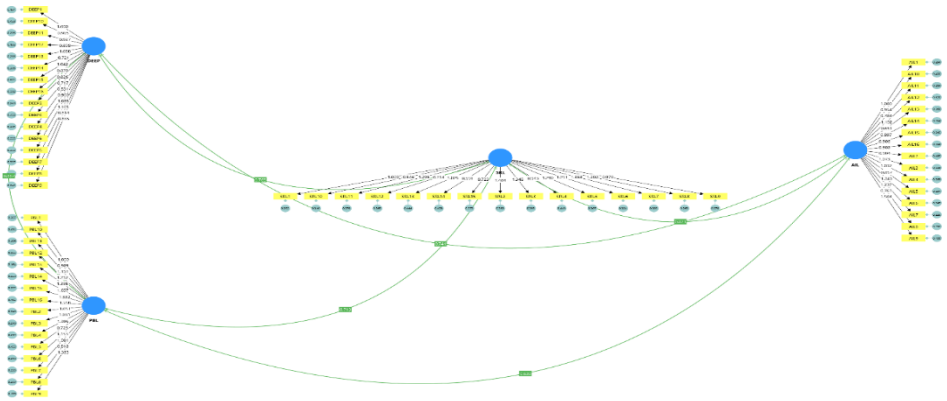

Fig. 2. Confimatory factor analysis generated model

Discriminant validity was evaluated using the average variance extracted (AVE) criterion, where a value greater than 0.5 indicates acceptable discriminant validity. As presented in Table 7, all variables in this study achieved AVE values well above the required threshold. The deep learning variable recorded the highest AVE value of 0.890, followed by problem-based learning (0.873), active and independent learning (0.777), and self-regulated learning (0.754). These results confirm that each construct possesses satisfactory discriminant validity, indicating that the indicators used in this study effectively measure their respective constructs and are distinct from other variables in the model.

Table 7. Discriminant validity results

Variabel	AVE	Information
Deep learning	0.890	Reliable
Problem based learning	0.873	Reliable
Active and independent learning	0.777	Reliable
Self-regulated learning	0.754	Reliable

The reliability of each construct in this study was assessed using composite reliability (CR), where a value greater than 0.7 is considered acceptable to confirm internal

consistency reliability. As presented in Table 8, all variables in this study demonstrated composite reliability values exceeding the minimum required threshold. The deep learning construct achieved the highest CR value of 0.885, indicating a strong level of reliability among its indicators. This was followed by problem-based learning > 0.7 is 0.875, the active and independent learning variable > 0.7 is 0.873, and the self-regulated learning variable > 0.7 is 0.859, all of which also showed reliable and consistent internal measurements.

Table 8. Composite reliability results

Construct reliability and validity	Composite reliability	Information
Deep learning	0.885	Reliable
Problem based learning	0.875	Reliable
Active and independent learning	0.873	Reliable
Self regulated learning	0.859	Reliable

Cronbach's alpha was employed to complement the reliability test conducted using composite reliability. A variable is deemed reliable if its cronbach's alpha value exceeds 0.7. As displayed in Table 9, the variables in this study demonstrated cronbach's alpha values above the acceptable threshold, confirming the internal consistency of the measurement items. Specifically, the deep learning variable obtained the highest cronbach's alpha value of 0.886, followed by problem-based learning (0.860), active and independent learning (0.875), and self-regulated learning (0.852). These findings indicate that each set of indicators consistently measures its respective construct.

Table 9. Cronbach's alpha results

Construct reliability and validity	Composite reliability	Information
Deep learning	0.886	Reliable
Problem based learning	0.860	Reliable
Active and independent learning	0.875	Reliable
Self regulated learning	0.852	Reliable

The model fit evaluation presented in Table 10 indicates that proposed model meets the recommended fit criteria. The chi square value obtained was 2832.611, which is below the recommended threshold of < 3000, suggesting an acceptable model fit. Furthermore, the standardized root mean square residual (SRMR) values was 0.089, falling within the acceptable range of < 0.10, which indicates a good fit between the observed data and the hypothesized model. Additionally, the normal fit index (NFI) achieved a value of 0.931, exceeding the minimum recommended value of 0.90, further supporting the model's goodness of fit.

Table 10. Model fit generated model results

Estimated model		Information
Chi square	2832.611	Good Fit
SRMR	0.089	Good Fit
NFI	0.931	Goot Fit

Figure 3 illustrates the relationship among the research variables, demonstrating how deep learning and problem-based learning influence active and independent learning, both directly and through the mediating role of self-regulated learning. The figure shows the path coefficients and the r^2 values for each endogenous variable, indicating the strength of influence between the constructs. The r^2 value for self-regulated learning is 0.519, meaning that 51.9% of the variance in self-regulated learning is explained by deep learning and problem-based learning. Meanwhile, the r^2 value for active and independent learning is 0.646, indicating that 64,6% of its variance is explained by deep learning, problem based learning, and self-regulated learning combined. The model visualization confirms the hypothesized relationships and the mediating effect of self-regulated learning in strengthening and independence in learning activities.

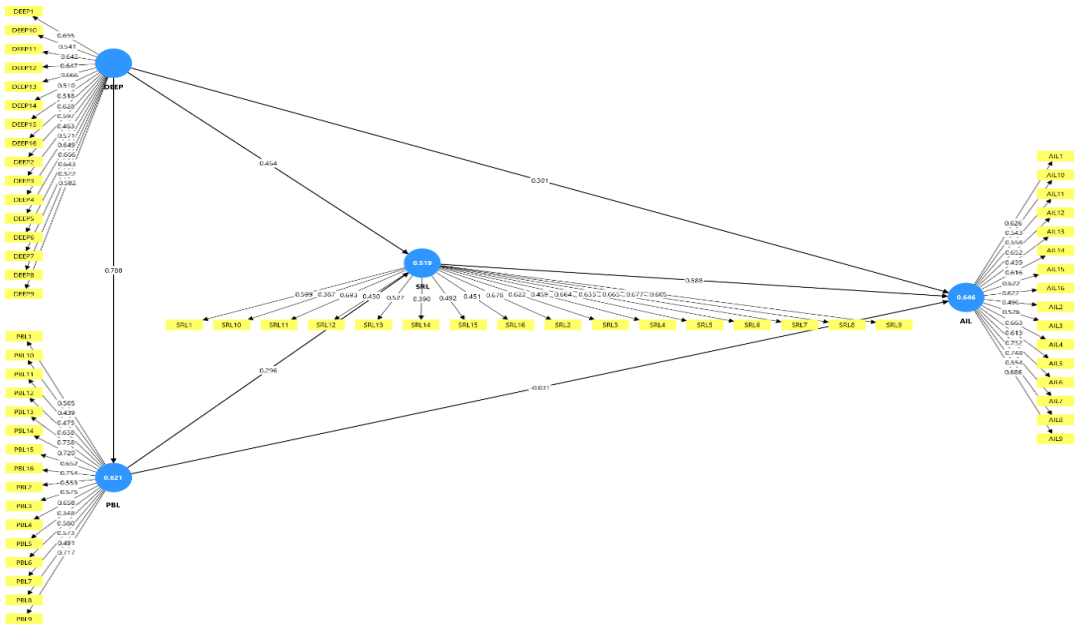

Fig. 1. Partial least squares model scheme

The convergent validity of the measurement model indicators was assessed by examining the outer loading for each item, where a value greater than 0.70 indicates that the indicator has a strong correlation with its respective latent variable. As presented in Table 11, all indicators included in this analysis achieved outer loading values exceeding the 0.70 threshold, confirming good convergent validity for each item. Specifically, for the active and independent learning variable, the indicator AIL6 and AIL7 recorded outer loading values of 0.732 and 0.748, respectively. Meanwhile, the problem-based learning variable showed high convergent validity with indicators PBL13 (0.738), PBL14 (0.720), PBL16 (0.754), and PBL9 (0.717). the results confirm that all selected indicators reliably measure their respective constructs and contribute positively to the overall measurement model validity, ensuring that the constructs are appropriately represented by their observed indicators.

Table 11. Outer loading results

Variable	Indicator	Outer loading
Active and independent learning	AIL6	0.732
Active and independent learning	AIL7	0.748
Problem based learning	PBL13	0.738
Problem based learning	PBL14	0.720
Problem based learning	PBL16	0.754
Problem based learning	PBL9	0.717

The goodness-of-fit of the structural model was assessed through the r-square (r^2) values, which indicate the proportion of variance in the dependent variables that can be explained by the independent variables. As presented in Table 12, the active and independent learning variable obtained an r^2 value of 0.646, indicating 64.6% of the variance in active and independent learning can be explained by deep learning, problem-based learning, and self-regulated learning. This falls within the moderate to substantial category, suggesting that the research model has a good predictive capability for this variable. Meanwhile, the self-regulated learning variable achieved an r^2 value of 0.519 meaning that 51.9% of its variance is explained by deep learning and problem-based learning. This also falls within the moderate category, indicating that the independent variable moderately predict the development of students' self-regulated learning abilities.

Table 12. R square results

Variable	R square	R square adjusted
Active and independent learning	0.646	0.639
Self-regulated learning	0.519	0.513

The results of this study show that deep learning and problem-based learning have a positive and significant effect on active and independent learning, both directly and through the mediation of self-regulated learners. This can be seen from the average score of all deep learning indicators that are in the high category, with the highest indicator being the ability of students to evaluate various points of view before the decision (mean = 3.382). These findings prove that the application of deep learning encourages students to think critically, reflectively, and be able to apply the concepts learned in a real context, thereby directly increasing their learning activity and independence. Deep learning involves deep understanding, critical analysis, and the application of concepts to real-world situations, thus encouraging active and independent learning activities (Entwistle, 1983).

In addition, problem-based learning has also been proven to have a significant effect on active and independent learning. All problem-based learning indicators showed a mean value above 3.00 with the highest indicator on students' ability to appreciate the opinions of friends in group discussions of 3.497. These results reinforce the notion that problem-based learning encourages students to participate more actively in learning, increase collaboration, and foster a sense of responsibility for learning processes and outcomes. Problem based learning promotes collaborative learning, critical thinking, and responsibility in the learning process (Hmelo-Silver, 2004). The integration of problem-based learning and deep learning has been shown to enchance self-regulated learning as

well as active and independent learning (Zakaria et al., 2025). A problem-based learning approach combined with deep understanding can increase students' engagement and learning independence, particularly when supported by strong self-regulation skills (Temel, 2013).

Furthermore, the results of the analysis show that self-regulated learning (SRL) plays a significant mediating variable in strengthening the relationship between deep learning and problem-based learning to active and independent learning. The highest mean value of self-regulated learning was found in the indicator of students' ability to utilize technology and social media as additional sources of information in learning (mean = 3.586), which shows the readiness of students in the digital era in managing their learning process independently. Zimmerman's theory highlights the crucial role of self-regulation as a mediating factor that enhances students' engagement, intiative, and independence in the process of active and independent learning (Zimmerman, 2008).

Based on the results of the model test using SEM SmartPLS version 4.1.0, the r^2 square value for active and independent learning is 0.646 which shows that there is a 64.5% variation in active and independent learning that can be explained by the variables of deep learning, problem-based learning, active and independent learning, and self-regulated learning. Meanwhile, the r square value for self-regulated learning of 0.519 indicates that 51.9% of self-regulated learning variations are influenced by deep learning and problem-based learning. The model also meets the criteria of a fit model, with SRMR values = 0.089 and NFI = 0.931, indicating a good model fit. Thus, the main findings of this study confirm that the integration of deep learning and problem- based learning, supported by optimal self-regulated learning capabilities, is able to encourage the creation of active and independent students in the learning process, especially in the secondary education environment.

The uniqueness of this research lies in the complete mediation model that has not been widely researched in the context of Indonesian secondary education. The effect of problem-based learning on direct learning outcomes has been examined, while the mediating role of self-regulated learning has not yet been comprehensively explored (Masliah et al., 2023). This study successfully proves the significant mediating role of self-regulated learning that strengthens these relationships. Therefore, this research makes a new scientific contribution to the development of active learning strategies in the digital era.

Contextually, the high score of self-regulated learning in the technology use indicator (mean = 3.586) shows the great potential of students in this digital era at Surakarta high school to optimize technology to support the independent learning process. This is an opportunity for schools to implement a curriculum based on deep learning and problem-based learning that is integrated with digital platforms. The finding supports the framework proposed by Pintrich (2000), who advocated the integration of self-regulated learning as a mediator to optimize the effectiveness of active learning strategies in contemporary education.

The partical implications highlight that integrating digital technology in self-regulated learning can enhance learning motivation and independence (Schunk & Zimmerman, 2012). Social support and learning environment play crucial roles in developing students' autonomous learning behaviors (Bandura, 2001). The practical

implication of these results is the importance of developing teacher training programs on the implementation of deep learning and problem-based learning based on self-regulated learning, so that teachers can design learning activities that not only encourage active student participation, but also improve students' learning abilities. This study suggests the development of an interactive technology-based learning model that can support self-regulated learning, as well as examining other factors such as intrinsic motivation, student social support, and students' digital skills in increasing the effectiveness of active and independent learning.

CONCLUSION

Deep learning significantly influences active and independent learning. Similarly, problem-based learning also has a significant impact on active and independent learning. Moreover, self-regulated learning plays an important role in shaping active and independent learning among students in Surakarta senior high school. For future research, it is recommended to include additional independent variables to further enrich the study. such as intrinsic motivational factors, social support, or technology use, in order to enrich understanding of the phenomenon being studied. In subsequent research, different research methods can be used, for example by using a quantitative approach through the smart AMOS tool. Similar research can be carried out over various time periods and trends from time to time so that it can be analyzed properly. Managerial implications for schools or colleges to be able to increase interactive activities between teachers and students to encourage improved teacher performance and student academic achievement. Teachers and students also need to improve their digital skills so that they can more easily access comprehensive learning information.

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