

Development of a Diagnostic Assessment Model based on the EWS (Early Warning System) Approach to Support Student Academic Performance in Elementary School

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Abstract

This research was conducted to produce a diagnostic assessment instrument using an EWS (Early Warning System) approach that is able to detect early learning problems in students accurately and comprehensively and to assess their impact on the academic performance of elementary school students. The research method used is research and development (R&D) using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model. The research subjects were fifth-grade students in three elementary schools in *Bima City*. Data were collected using cognitive and non-cognitive diagnostic assessment instruments based on an EWS approach as well as student academic performance assessment instruments. Research data analysis was carried out by testing the validity of the diagnostic assessment model using descriptive statistics and multiple regression tests to determine the effect of the assessment model with the help of Jamovi software. The results of the validity test showed that the EWS-based diagnostic assessment model was found to be very feasible based on the analysis by two validators (learning evaluation experts and elementary education experts) with the characteristics of the assessment model, namely comprehensive, preventive, and solution-oriented. The implementation of this assessment facilitates teachers in making informed decisions regarding learning strategies and specific interventions needed by students based on the results of cognitive and non-cognitive diagnoses. Statistical test results showed a significance value (p -value) < 0.001 , indicating a significant effect of the EWS-based diagnostic assessment model on student academic performance, with an effect size (R^2) of 63.7% of the variation in student academic performance scores.

Keywords: Assessment Model, Diagnostic, Early Warning System, Academic Performance

Abstrak

Penelitian ini dilakukan untuk menghasilkan instrumen asesmen diagnostik melalui pendekatan EWS (Early Warning System) yang mampu mendeteksi dini permasalahan belajar siswa secara akurat dan komprehensif serta melihat pengaruhnya dalam kinerja akademik siswa sekolah dasar. Metode penelitian yang digunakan adalah penelitian pengembangan (R&D) dengan menggunakan model ADDIE (Analysis, Design, Development, Implementation, Evaluation). Subjek penelitian dilakukan pada siswa kelas V pada tiga sekolah dasar yang ada di Kota Bima. Data dikumpulkan dengan menggunakan instrumen asesmen diagnostik kognitif dan non-kognitif berbasis EWS serta instrumen penilaian kinerja akademik siswa. Analisis data penelitian dilakukan dengan uji validitas model asesmen diagnostik menggunakan statistik deskriptif dan uji regresi berganda untuk mengetahui pengaruh model asesmen dengan bantuan software Jamovi. Hasil uji validitas menunjukkan bahwa

model asesmen diagnostik berbasis EWS memiliki kategori sangat layak berdasarkan analisis oleh dua orang validator (ahli evaluasi pembelajaran dan ahli pendidikan dasar) dengan karakteristik model asesmen yakni komperhensif, preventif, dan solutif. Penerapan asesmen ini memudahkan guru dalam mengambil keputusan yang tepat mengenai strategi pembelajaran maupun intervensi khusus yang dibutuhkan siswa berdasarkan hasil diagnosa dari segi kognitif maupun non-kognitif. Hasil uji statistik menunjukkan nilai signifikansi (p value) $< 0,001$ yang menandakan adanya pengaruh signifikan antara model asesmen diagnostik berbasis EWS terhadap kinerja akademik siswa dengan besaran pengaruh (R^2) sebesar 63,7% variasi dalam nilai kinerja akademik siswa.

Kata Kunci: Model Asesmen, Diagnostik, Early Warning System, Prestasi Akademik

INTRODUCTION

Education plays a strategic role in developing superior human resources. Improving the quality of human resources in school positions student academic performance as a key indicator of learning success (Fika & Zohriah, 2024; Siregar et al., 2025; Sumual et al., 2024). Student academic performance can be measured by their reading, mathematics, and science skills during the learning process (Rădulescu et al., 2022; Z. Zhang & Peng, 2023). However, in practice, many students experience academic difficulties, which result in low learning outcomes. This condition is reflected in the 2022 Indonesian PISA data, which showed a downward trend in average results compared to 2018 in mathematics, reading, and science skills. PISA data from 2018 to 2022 also showed that the gap between the highest-scoring 10% and the lowest-scoring 10% is narrowing in mathematics, while the gap remained unchanged in reading and science (Bilad et al., 2024; De Bortoli et al., 2023; Niza et al., 2023).

In this context, a more systematic approach is needed to detect students' academic problems early so that appropriate interventions can be provided to improve their learning process through diagnostic assessments (Kong & Pan, 2023; Tang & Zhan, 2021). In practice, the integration of diagnostic assessments aims to analyze students' initial abilities, identify learning difficulties, and provide an overview of students' academic needs at school (Iskandar et al., 2021). The development of assessment instruments is intended to encourage improvements in students' academic performance in the cognitive, psychomotor, and affective aspects in the learning process at school (Lestari & Harjono, 2021; Purwaningrat et al., 2021). Various international studies emphasize the importance of diagnostic assessments as a tool to identify conceptual weaknesses, misconceptions, and learning barriers from the beginning of the learning process. T. Fan et al. showed that diagnostic assessments are able to provide a detailed overview of students' academic profiles in the cognitive aspect (Fan et al., 2021). Similar findings were presented by Davison, who emphasized that diagnostic assessment plays a crucial role in designing evidence-based differentiated learning strategies (Davison et al., 2023). Furthermore, some researchers reported that diagnostic assessment also supports teachers in understanding learning preferences and potential affective and behavioral issues that hinder academic performance (Sujinah et al., 2024). However, the implementation of diagnostic assessment is still less than optimal, as most teachers still focus on summative assessments that only evaluate final results without providing sufficient information for learning interventions. Therefore, to address this problem, an innovative approach is needed, by integrating an Early Warning System (EWS) approach into diagnostic assessment.

Early Warning System (EWS) is an early warning system that enables teachers and schools to detect students at risk of learning difficulties based on data on academic, social-emotional, and learning behaviors. A research demonstrated that machine learning-based EWS can detect patterns of learning failure early through data on grades, behavior, and attendance indicators (Ma et al., 2024). A study by Cano & Leonard corroborated these findings by demonstrating that academic prediction models significantly improved the accuracy of identifying at-risk students compared to conventional

methods (Cano & Leonard, 2019). Skittou et al. also emphasized that the development of advanced EWS increasingly utilizes learning analytics and classification algorithms to provide data-driven intervention recommendations (Skittou et al., 2024).

Previous research indicates that diagnostic assessment and EWS have developed as two distinct research domains. A bibliometric mapping of Scopus articles over the past five years using VOSviewer reveals that diagnostic assessment research still predominantly focuses on identifying cognitive abilities and misconceptions, while EWS emphasizes learning analytics-based academic failure prediction. However, there is limited research integrating these two approaches into a single, holistic assessment model, especially at the elementary school level. This integration has the potential to produce a more comprehensive academic risk identification system, combining conceptual weakness diagnosis with longitudinal data-based learning performance prediction. This research gap served as the basis for this study.

The novelty of this research focuses on the development of a diagnostic assessment model specifically integrated with the EWS for elementary school students. The diagnostic assessment model developed in this study is designed to detect academic risk in elementary school students, including cognitive, affective, and behavioral aspects, based on data, and is able to provide recommendations for interventions to improve learning. Another strength of this research is the use of learning analytics within the EWS system to detect student academic patterns. Therefore, research into the development of EWS-based diagnostic assessments is highly relevant to efforts to improve the quality of education in Indonesia, particularly in facing the challenges of an increasingly dynamic curriculum. The use of this system can help schools adapt learning strategies to student needs more flexibly and responsively, particularly in the context of data-driven decision-making.

Research on the development of diagnostic assessment model instruments is expected to contribute to teachers in schools in creating inclusive learning environments and formulating more targeted education policies. This research emphasizes the formulation of research questions, including what are the characteristics of an EWS-based diagnostic assessment model in supporting the academic performance of elementary school students?; and What is the impact of implementing an EWS-based diagnostic assessment model on improving student academic performance? The final projection of the development of the EWS-based diagnostic assessment model is also expected to help schools in detecting and addressing student learning difficulties and supporting the improvement of student learning outcomes in elementary school.

METHOD

This research used the Research & Development (R&D) method. The purpose of this R&D method is to develop a specific product or model, test its effects, and refine it for application in real-world settings. Research & Development research is intended to integrate scientific research approaches with product development to produce innovative and applicable solutions (Richey & Klein, 2014). In this context, the Research & Development aims to develop a diagnostic assessment instrument model based on the Early Warning System (EWS) approach and test the effect of the EWS-based diagnostic assessment model in supporting student academic performance in elementary schools in Bima City. Model used by researchers is ADDIE (Analysis, Design, Development, Implementation, and Evaluation) (Inda, 2020).

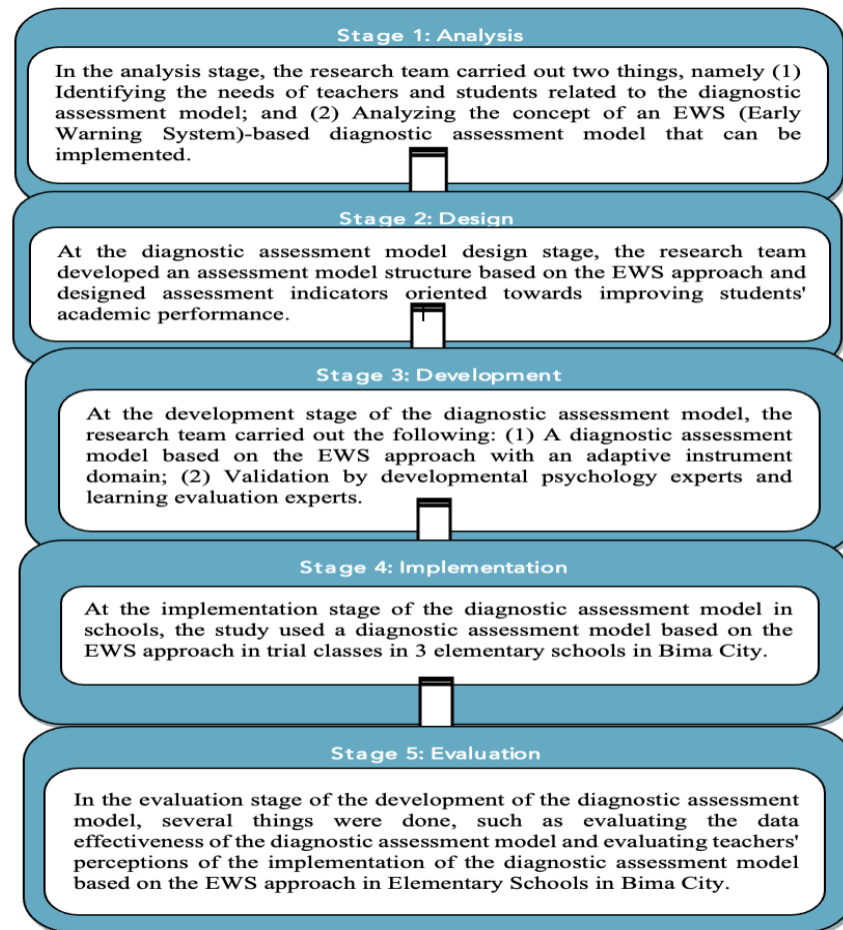


Figure 1. Stages and Procedures of ADDIE Model Research

The research was conducted on three research subjects, namely SDN 33 Lampe, SDN 22 Jatibaru, and SDN 29 Tanjung. These three schools were selected as research locations based on the results of initial observations, showing that students were identified experiencing learning difficulties, and the student academic performance was not optimal. The data were collected using diagnostic test instruments, questionnaires, and students' academic performance tests. Research data analysis was carried out by testing the validity of diagnostic assessments and testing the effectiveness of diagnostic assessment models by analyzing their influence on student academic performance using multiple linear regression analysis assisted by Jamovi software. Instrument validity was categorized into five categories: very valid (81%-100%), valid (61%-80%), quite valid (41%-60%), less valid (21%-40%), and invalid (<20%). Questionnaire response data were analyzed to determine responses related to the use of diagnostic assessment models by elementary school teachers. The indicators of success in this study are (1) the increase in student academic performance after using the EWS-based diagnostic assessment model, (2) the level of acceptance and implementation of the EWS-based diagnostic assessment model by school teachers and students.

RESULT AND DISCUSSION

The Analysis phase of the ADDIE R&D model research resulted in a needs mapping that revealed a significant gap between conventional assessment practices in elementary schools and the need for an early detection system to identify students at risk of learning difficulties. Through needs

studies, classroom observations, and interviews with teachers and principals, it was discovered that the current assessment process still focused on final assessments without ongoing monitoring mechanisms, often missing early signs of declining academic performance. Analysis of learning outcome documents revealed irregular patterns in student achievement that were not systematically addressed because teachers lacked tools capable of processing grades, behavior, and attendance data in an integrated manner. Furthermore, the characteristics of elementary school students in Bima City demonstrated diverse learning support needs due to their varied backgrounds, while teachers' readiness to utilize a variety of assessment methods was still limited. These findings then formed the basis for formulating initial specifications for an EWS-based diagnostic assessment model relevant to the context of elementary schools in Bima City for data-driven decision-making.

The next phase was Design. The design phase aimed to formulate a conceptual framework and technical design for the diagnostic assessment model, which served as the basis for developing the EWS-based diagnostic assessment model. At this stage, researchers developed a model structure that maps the assessment flow from student data input, analysis mechanisms, to outputs in the form of academic risk categories accompanied by recommended actions for classroom learning. A series of diagnostic indicators was also formulated based on the cognitive, affective, social, and behavioral dimensions of learning found in the analysis stage, then detailed into assessment items ready to be tested by the validator. The results of this design stage were in the form of a complete blueprint that includes the instrument structure, assessment indicators, analysis flow design, and data processing technical schemes that can be realized in the development stage.

The next step is the Development stage. The development stage focused on transforming the design into a usable and validated instrument prototype. At this stage, researchers developed assessment instruments and teacher response questionnaires tailored to the previously designed indicators. The resulting model was then validated by experts in elementary education and educational psychology to assess the suitability of the content, clarity of the indicators, and feasibility of the design. The validation results served as the basis for revising and refining the model to obtain a prototype that is suitable for testing. This stage ensured that the developed model is not only conceptually valid but also content-valid and ready for implementation in the field.


7. Setiap ada permasalahan, warga Kelurahan Jatibaru selalu berkumpul untuk melakukan musyawarah. Kegiatan tersebut menunjukkan...

A. Kegiatan keagamaan B. Perselisihan antarwarga
C. Interaksi sosial di masyarakat D. Kegiatan keagamaan

8. Jika banyak sampah menumpuk di sungai sekitar rumah, apa akibat yang akan terjadi?

A. Air menjadi jernih B. Terjadi banjir
C. Ikan menjadi banyak D. Warga senang bermain di sungai

9. Perhatikan gambar di bawah ini!



Apa yang terjadi pada air dalam panci yang sedang dipanaskan di atas kompor?

A. Air menguap B. Air berubah warna
C. Air membeku D. Air menjadi dingin

10. Berikut ini adalah tabel hasil panen padi di Kota Bima:

Tahun	Jumlah
2019	25,708 ton
2020	28,427 ton

ASESMEN DIAGNOSTIG NON-KOGNITIF

Petunjuk Pengisian : Bacalah setiap pernyataan dengan baik. Beri tanda centang (✓) pada kolom sesuai dengan pilihan jawaban kamu !

No.	Indikator	Ya	Tidak
A. Karakter dan Sikap			
1.	Saya lebih suka belajar sambil mendengarkan penjelasan guru.		
2.	Saya lebih mudah mengerti jika belajar menggunakan gambar atau video.		
3.	Saya suka belajar dalam kelompok bersama teman-teman.		
4.	Saya suka bertanya kepada teman atau guru ketika mendapatkan kesulitan saat belajar		
5.	Saya bertanggung jawab atas tugas yang diberikan.		
B. Hubungan Sosial (Keluarga, Teman, Lingkungan)			
6.	Orang tua saya mendukung saya untuk belajar.		
7.	Saya merasa nyaman di rumah bersama keluarga.		
8.	Saya bisa bermain dengan siapa saja.		
9.	Saya memiliki sahabat akrab di sekolah		

Figure 2. EWS-based Diagnostic Assessment Design

The Early Warning System (EWS)-based diagnostic assessment model, which has undergone development, has a key characteristic: the ability to detect potential student learning difficulties early before the problem develops further. This characteristic is supported by three core dimensions: (1)

comprehensive, encompassing academic aspects, behavior, and student engagement in the learning process; (2) preventative-oriented, providing early warnings before academic and non-academic problems develop further through diagnostic results; and (3) solution-oriented, providing practical follow-up recommendations that provide teachers with strategies, models, or approaches for follow-up classroom learning according to outcome categories (remedial, enrichment, or emotional support). Thus, this model is more than just a measuring tool; it is a system integrated with the classroom learning decision-making cycle.

The uniqueness of this model lies in the integration of cognitive and non-cognitive components and EWS mechanisms, which are rarely used simultaneously in diagnostic assessments for elementary school students. Not only does this model serve as a measuring tool, it also provides practical follow-up recommendations, such as remedial measures, enrichment programs, or emotional support, based on the resulting risk categories, providing teachers with immediate intervention guidance. The model's preventive orientation enables schools to identify potential academic and non-academic problems early on before they become more serious and degrade student performance. The combination of features of the EWS-based diagnostic assessment model creates an applicable, relevant, and valuable instrument for assessment practices in elementary schools.

EWS Diagnostic Assessment Feasibility Validation Test Results

Cognitive Diagnostic Assessment

Expert validation results for the EWS-based cognitive diagnostic assessment indicate that the instrument is highly valid, with an average feasibility percentage of 95.45%. This achievement aligns with Suharsimi's (2012) assertion that a learning instrument is valid if it measures what it is supposed to measure with high consistency. This percentage confirms that this assessment meets both content validity and construct validity standards.

Table 1. Cognitive Assessment Validation Results

No	Rated aspect	Validator		Total
		A	B	
1.	Material	11	12	23
2.	Question Construction	11	12	23
3.	Language	7	7	14
4.	Appearance	8	8	16
Validation Test Results		93.18%	97.73%	95.45%

In terms of material, the validator's assessment indicated that the developed questions aligned with the core competencies and targeted learning indicators. This supported the theory which stated that the quality of a learning instrument is largely determined by the appropriateness of the test items to the measurement objectives (Brookhart & Nitko, 2019). This instrument is also considered capable of providing a comprehensive overview of students' literacy, numeracy, social literacy, and science skills, while also serving as an early warning tool to identify students' learning weaknesses early on. Each assessment item is structured based on a clear framework and linked to competencies C1 through C4, making it easier for teachers to map students' abilities in a targeted manner. Regarding question construction, validation results showed that the instructions are clear, the answer options function optimally, and the question wording is unambiguous. This aligns with Popham's question construction criteria, which emphasize that each item must be technically correct to minimize student misinterpretation (Popham, 2020). However, it was noted that some items could be enriched with local context to further align with the characteristics of elementary school students' daily experiences.

The linguistic aspect also received a high score, indicating that the language used was communicative and appropriate for the cognitive development of elementary school-aged children.

These findings are relevant to a theory that clarity of language in the instrument will affect the validity of students' answers, as difficult-to-understand questions can measure language ability rather than the intended competency (Bolkan, 2017). However, simplifying certain terms is still recommended to optimize readability. Meanwhile, the display aspect received the maximum score from the validator. An attractive visual display, appropriate font choice, and a neat layout were deemed capable of increasing student motivation in completing the instrument. This finding aligns with Mayer's theory regarding the principles of multimodal instructional design, which states that well-managed visual elements can improve student focus and understanding in learning and assessment (Mayer, 2009).

Non-Cognitive Diagnostic Assessment

The results of the validation test conducted by two validators indicated that the non-cognitive diagnostic assessment instrument achieved a 95% feasibility percentage. This figure confirms that the instrument is categorized as highly valid for use as an assessment tool in elementary schools. High ratings across all measured aspects (material, item construction, language, and presentation) indicate that the instrument is not only content-valid but also appropriate for the characteristics of elementary school students, the primary respondents in this diagnostic assessment model.

Table 2. Non-Cognitive Assessment Validation Results

No	Rated aspect	Validator		Total
		A	B	
1	Material	8	8	16
2	Question Construction	11	11	22
3	Language	11	11	22
4	Appearance	8	8	16
Validation Test Results		95.00%	95.00%	95.00%

In terms of material, the instrument received a maximum score (8 out of 8). This indicates that the statement items align with the indicators to be measured and cover important non-cognitive dimensions such as character, social relationships, and emotional well-being. Furthermore, the instrument serves as an early warning system to identify student strengths and weaknesses, in line with the primary function of diagnostic assessment (Brookhart & Nitko, 2019). This instrument not only maps student performance but also provides recommendations for follow-up actions for teachers in teaching. In terms of construction, the instrument received a score of 11 out of 11, indicating that the instructions for completion were clear and the statements were structured systematically. The statement items were also deemed effective in measuring non-cognitive indicators without creating ambiguity. This aligns with Popham's criteria for instrument development, which states that a good instrument should present items with simple, focused, and consistent wording. This allows students to provide answers that reflect their actual conditions, rather than simply interpreting ambiguous sentences (Popham, 2020).

In terms of language, the instrument received a score of 11 out of 11. The validator assessed that the statements used language appropriate to the cognitive development level of elementary school children, were structured with positive sentences, and followed Indonesian language rules. This is in line with a view that language aspects determine the readability of an instrument and directly influence the validity of respondents' answers (Y. Zhang & Aryadoust, 2022). By using simple, clear, and communicative sentences, this instrument is able to minimize linguistic bias. The display aspect also received a maximum score (8 out of 8). The validator assessed that the type and size of the font were easy to read, and the use of colors and images was quite attractive to students. In accordance with Mayer's theory on the principles of multimodal instructional design, attractive visual displays can increase student motivation to participate in the assessment, resulting in more authentic results

(Mayer, 2009). Thus, this instrument is not only technically superior but also able to support student emotional engagement.

The implementation phase was conducted to test the impact of the EWS-based diagnostic assessment model in elementary schools. Field trials were conducted in three schools in Bima City, representing diverse contexts. Teachers were trained to use the assessment model to collect and analyze student data, and the EWS system was then used to identify students at risk of low or declining academic performance. During implementation, researchers monitored the appropriateness of the procedures, the ease of use of the model by teachers, and the accuracy of the system's detection results. The data obtained were used to assess the model's impact on improving student academic performance and to inform revisions to identified weaknesses. At this stage, the student academic performance data based on PTS (Mid-Semester Assessment) scores were also collected. The resulting data analysis from the implementation phase is presented below.

The Impact of the EWS-Based Diagnostic Assessment Model on Improving Student Academic Performance

In this study, the level of influence of the EWS-based diagnostic assessment model on improving student academic performance was analyzed and statistically tested using multiple regression analysis using Jamovi software, as follows.

Multiple Regression Test Results

Based on the normality test, a prerequisite for the distribution of research data, the p-value was >0.05 based on the Shapiro-Wilk normality analysis, indicating that the data were normally distributed. The results of the normality test are depicted in a Q-Q plot.

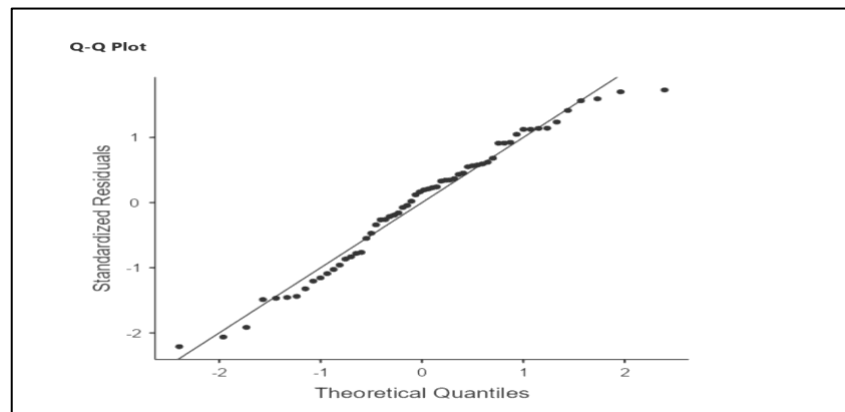


Figure 3. Q-Q Plot Graph of Data Normality Test Result

The Q-Q Plot graph presented in Figure 3 showed that most of the residual points are located around the diagonal line, with relatively small deviations at the ends of the distribution. This condition indicated that the residual distribution is close to a normal distribution. The pattern of points that follow the diagonal line indicated that the assumption of normality is met. Furthermore, the results of the Homogeneity of Variance test are presented through residual plots graphs. They showed that the residual points are distributed relatively randomly around the zero line without forming a specific pattern. There was no symptom of a "funnel effect". This random distribution of residuals indicated that the assumption of homoscedasticity is met. In addition, the distribution of residuals for each predictor variable (reading literacy, numeracy, social literacy, scientific literacy, learning character, social relationships, emotional well-being, and learning motivation) also showed a relatively even distribution. This further strengthens the fact that the error variance between data groups was homogeneous, as presented in Figure 4 below.

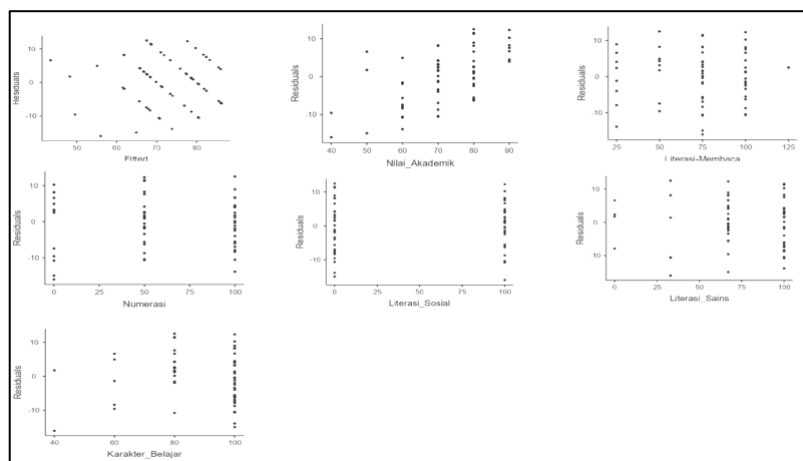


Figure 4. Residual Plots of Data Homogeneity Test Results

The statistical test used multiple regression analysis to determine the effect of diagnostic assessments covering cognitive and non-cognitive aspects on student academic performance, as measured by Mid-Semester Assessment (PTS) scores, as follows.

Model Fit Measures

Model	R	R ²	Overall Model Test			
			F	df1	df2	p
1	0.798	0.637	8.599	10	49	< .001

Figure 5. Multiple Regression Data Analysis Result

The data analysis results indicated that the EWS-based diagnostic assessment model has a strong and significant contribution to student academic performance, as reflected by the $R = 0.798$ and $R^2 = 0.637$ values, indicating that 63.7% of the variation in academic performance can be explained by the indicators in the model. This was supported by the $F(10,49) = 8.599$ and $p < 0.001$ test results, confirming the overall fit and significance of the regression model. This finding is consistent with the literature confirming that early warning systems are effective in predicting and explaining academic achievement through the integration of multidimensional indicators, including cognitive and non-cognitive aspects. Bowers and Zhou demonstrated that EWS is able to identify key academic factors that directly contribute to student academic performance (Bowers & Zhou, 2019), while a meta-analysis by Gutiérrez-de-Rozas et al. demonstrated that the combination of literacy, numeracy, and personal factors in students is a strong predictor of academic success (Gutiérrez-de-Rozas et al., 2022). Furthermore, research by Veerasamy and Kumar confirmed that structured initial assessments can improve the accuracy of academic risk prediction, consistent with the finding that the EWS-based diagnostic assessment in this study explained a significant proportion of the variation in learning outcomes (Veerasamy et al., 2020).

Interpretation of Predictor Coefficient

The multivariable analysis of predictor coefficients for cognitive and non-cognitive abilities is presented in Figure 6 below.

Model Coefficients - Nilai_Akademik

Predictor	Estimate	SE	t	p	Stand. Estimate
Intercept ^a	13.479	9.680	1.392	0.170	
Literasi-Membaca	0.088	0.046	1.913	0.062	0.190
Numerasi	0.085	0.030	2.895	0.006	0.274
Literasi_Sosial	0.078	0.023	3.386	0.001	0.330
Literasi_Sains	0.082	0.038	2.178	0.034	0.201
Karakter_Belajar	0.192	0.077	2.508	0.016	0.253
Hubungan_Sosial	0.150	0.060	2.515	0.015	0.264
Kesejahteraan_Emosional	0.079	0.095	0.829	0.411	0.092
Motivasi_Belajar	-0.006	0.068	-0.091	0.928	-0.010
Nama_Sekolah:					
SDN 33 LAMPE – SDN 23 JATIBARU	2.225	2.876	0.774	0.443	0.185
SDN 29 TANJUNG – SDN 23 JATIBARU	-0.090	3.066	-0.029	0.977	-0.007

^a Represents reference level**Figure 6.** Predictor Coefficient Analysis Results

The data analysis presented in Figure 6 showed that several variables significantly influence academic grades. Numeracy ($\beta = 0.274$; $p = 0.006$), social literacy ($\beta = 0.330$; $p = 0.001$), scientific literacy ($\beta = 0.201$; $p = 0.034$), learning character ($\beta = 0.253$; $p = 0.016$), and social relationships ($\beta = 0.264$; $p = 0.015$) were shown to contribute positively and significantly to improving students' academic performance. In other words, the higher a student's achievement in these indicators, the greater the likelihood of achieving better academic grades. Conversely, the reading literacy indicator only approached significance ($\beta = 0.190$; $p = 0.062$), so although it tends to have a positive effect, its influence was not statistically strong enough.

Theoretically, the literature on early warning systems showed that predictors based on basic academic abilities such as numeracy and literacy are the strongest indicators in predicting the possibility of learning lag in elementary school students (Bowers et al., 2019). The results of this study are in line with this view, especially because the aspects of numeracy ($\beta = 0.274$) and scientific literacy ($\beta = 0.201$) emerged as significant predictors. Both are domains that have direct cognitive transfer to problem-solving and reasoning abilities, which are consistently seen as key predictors of learning success in school (OECD, 2023). The significant influence of social literacy ($\beta = 0.330$) and social relationships ($\beta = 0.264$) indicates that students' social competence plays a role in academic performance. In elementary school students, emotional factors tend to have a greater influence on long-term learning engagement. This is because social relationships in the classroom, including the quality of interactions with peers and teachers, play an early role in shaping a sense of security, interest, and sustained participation before they are reflected in academic performance (Cappella et al., 2013). The finding that learning character ($\beta = 0.253$) is a significant predictor is consistent with Zimmerman's self-regulated learning theory, which emphasized the role of persistence, discipline, and self-management in determining learning performance (Zimmerman & Schunk, 2013).

The significant but insignificant effect of learning character on learning motivation warrants further investigation. Several meta-analyses indicate that motivation has a more fluctuating relationship with achievement, particularly at the elementary school level, because learning motivation at this age is more influenced by external contexts such as teachers, family, and learning dynamics (Howard et al., 2021). Therefore, the insignificant effect of learning motivation ($\beta = -0.010$) may indicate that at this developmental stage, observable learning behaviors (e.g., persistence and task-related habits) are more stable predictors than internal affective aspects. Meanwhile, the insignificant effect of emotional well-being ($\beta = 0.092$; $p = 0.411$) aligns with the findings of a research which found that emotional well-being does not directly influence academic achievement, as its impact is only apparent when students are encouraged to engage in learning (Schnell et al., 2025).

CONCLUSION

Based on the research findings presented, it can be concluded that the development of an Early Warning System (EWS)-based diagnostic assessment model has proven effective and relevant in supporting the improvement of elementary school students' academic performance. This model is comprehensive, preventative, and solution-oriented, encompassing both cognitive and non-cognitive aspects. Expert validation indicates that the developed instrument received a "highly valid" rating for both cognitive and non-cognitive assessments. This instrument serves not only as a measuring tool but also as an early detection system capable of identifying student weaknesses early on, while also providing applicable intervention recommendations for teachers, including remedial, enrichment, and emotional support. Therefore, EWS-based diagnostic assessment can make a significant contribution to shifting the assessment paradigm from merely evaluating outcomes to predictive and interventional assessment. Research findings through multiple regression analysis indicated that the EWS-based diagnostic assessment model has a significant effect on improving student academic performance, accounting for 63.7% of the variation in academic achievement. Significant contributing factors include numeracy skills, social literacy, scientific literacy, learning character, and social relationships. While indicators of reading literacy, learning motivation, and emotional well-being, while pedagogically important, have not been proven to be direct determinants. These results confirmed that EWS-based diagnostic assessments can provide a comprehensive picture of student conditions, enabling teachers to design more targeted, responsive, and data-driven learning strategies.

Conditions that require attention as input for future research primarily concern the accuracy of manual data input, necessitating consideration of digital systems in the assessment process. The regression results, which showed a predictor contribution of 63.7%, indicate that there are still other variables, such as family factors, learning quality, or the school environment, that have not been accommodated in this assessment model and therefore can be further developed for inclusion in research variables.

REFERENCES

- Bilad, M. R., Zubaidah, S., & Prayogi, S. (2024). Addressing the PISA 2022 Results: A Call for Reinvigorating Indonesia's Education System. *International Journal of Essential Competencies in Education*, 3(1), 1–12. <https://doi.org/10.36312/ijece.v3i1.1935>
- Bolkan, S. (2017). Development and validation of the clarity indicators scale. *Communication Education*, 66(1), 19–36. <https://doi.org/10.1080/03634523.2016.1202994>
- Bowers, A. J., & Zhou, X. (2019). Receiver Operating Characteristic (ROC) Area Under the Curve (AUC): A Diagnostic Measure for Evaluating the Accuracy of Predictors of Education Outcomes. *Journal of Education for Students Placed at Risk (JESPAR)*, 24(1), 20–46. <https://doi.org/10.1080/10824669.2018.1523734>
- Brookhart, S. M., & Nitko, A. J. (2019). *Educational assessment of students* (Eighth edition). Pearson.
- Cano, A., & Leonard, J. (2019). Interpretable Multiview Early Warning System Adapted to Underrepresented Student Populations. 12, 198–211. <https://10.1109/TLT.2019.2911079>.
- Cappella, E., Kim, H. Y., Neal, J. W., & Jackson, D. R. (2013). Classroom Peer Relationships and Behavioral Engagement in Elementary School: The Role of Social Network Equity. *American Journal of Community Psychology*, 52(3), 367–379. <https://doi.org/10.1007/s10464-013-9603-5>

- Davison, M. L., Weiss, D. J., DeWeese, J. N., Ersan, O., Biancarosa, G., & Kennedy, P. C. (2023). A Diagnostic Tree Model for Adaptive Assessment of Complex Cognitive Processes Using Multidimensional Response Options. *Journal of Educational and Behavioral Statistics*, 48(6), 914–941. <https://doi.org/10.3102/10769986231158301>
- De Bortoli, L., Underwood, C., & Thomson, S. (2023). PISA in Brief 2022: Student performance and equity in education. OECD Programme for International Student Assessment (PISA) Australia. <https://doi.org/10.37517/978-1-74286-727-4>
- Fan, T., Song, J., & Guan, Z. (2021). Integrating diagnostic assessment into curriculum: A theoretical framework and teaching practices. *Language Testing in Asia*, 11(1), 2. <https://doi.org/10.1186/s40468-020-00117-y>
- Fika, N., & Zohriah, A. (2024). Manajemen Sumber Daya Manusia Dalam Lembaga Pendidikan. *Jambura Journal of Educational Management*, 248–257. <https://doi.org/10.37411/jjem.v5i1.2745>
- Gutiérrez-de-Rozas, E, L.-M., & E, C. M. (2022). Determinants of academic achievement: Systematic review of 25 years of meta-analyses. *Revista de Educación*. 398, 37–80. <https://doi.10.4438/1988-592X-RE-2022-398-552>
- Howard, J. L., Bureau, J., Guay, F., Chong, J. X. Y., & Ryan, R. M. (2021). Student Motivation and Associated Outcomes: A Meta-Analysis From Self-Determination Theory. 16(3), 460–481. <https://doi.org/10.1177/17456916209667>
- Inda, E. (2020). Teaching Material Development of Educational Research Methodology with ADDIE Models. *Proceedings of the The 3rd International Conference Community Research and Service Engagements, IC2RSE 2019, 4th December 2019, North Sumatra, Indonesia*. <https://doi.org/10.4108/EAI.4-12-2019.2293793>
- Iskandar, R., Ms, Z., & Fahrurrozi, F. (2021). Menstimulasi Peserta Didik yang Mengalami Kesulitan Belajar Membaca Permulaan di Sekolah Dasar. *MIMBAR PGSD Undiksha*, 9(2), 330–336. <https://doi.org/10.23887/jjpgsd.v9i2.34362>
- Kong, J., & Pan, M. (2023). The role of diagnostic writing assessment in promoting Chinese EFL students' learning autonomy: An action research study. *Language Teaching Research*, 13621688231178465. <https://doi.org/10.1177/13621688231178465>
- Lestari, N. F., & Harjono, N. (2021). Pengembangan Instrumen Penilaian Karakter PPK Aspek Kemandirian Pembelajaran Tematik Terpadu Siswa SD Kelas 4. *MIMBAR PGSD Undiksha*, 9(1), 19–29. <https://doi.org/10.23887/jjpgsd.v9i1.33379>
- Ma, H., Zhao, W., Thang, Y., Zhu, H., Thang, W., & Li, K. (2024). Personalized Early Warning of Learning Performance for College Students: A Multilevel Approach via Cognitive Ability and Learning State Modeling. 17, 1440–1453. <https://10.1109/TLT.2024.3382217>.
- Mayer, R. E. (2009). *Multimedia Learning* (2nd ed.). Cambridge University Press.
- Niza, N., Suyanto, S., Mustofa, W. Z. W., & Nurdin. (2023). Determining the position of indonesian literacy, science and mathematics among PISA participating countries using Multidimensional Scaling Analysis. 3(1). <https://doi.org/10.33292/meter.v3i1.195>
- OECD. (2023). PISA 2022 Results Factsheets Indonesia. Organization for Economic Co-operation and Development.
- Popham, W. J. (2020). *Classroom assessment: What teachers need to know* (Ninth edition). Pearson.
- Purwaningrat, K. W., Antara, P. A., & Suarjana, I. M. (2021). Instrumen Penilaian Perseptual Motorik Siswa Pada Mata Pelajaran SBdP SD. *MIMBAR PGSD Undiksha*, 9(1), 128–138. <https://doi.org/10.23887/jjpgsd.v9i2.33225>

- Rădulescu, C. V., Angheluță, S. P., Burlacu, S., & Troacă, V. A. (2022, February 18). Basic Skills of Students: Reading, Mathematics and Science. International Management Conference. <https://doi.org/10.24818/IMC/2021/02.14>
- Richey, R. C., & Klein, J. D. (2014). Design and Development Research. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology* (pp. 141–150). Springer. https://doi.org/10.1007/978-1-4614-3185-5_12
- Schnell, J., Saxer, K., Mori, J., & Hascher, T. (2025). Feeling well and doing well. The mediating role of school engagement in the relationship between student well-being and academic achievement. *European Journal of Psychology of Education*, 40(1), 48. <https://doi.org/10.1007/s10212-025-00947-5>
- Siregar, N., Sahrul, Abdullah, Jamaludin, J., & Lele, D. M. (2025). Schools as Transformation Centers: The Role of Schools in Shaping the Golden Generation. 3(1). <https://doi.org/10.61942/msj.v3i1.287>
- Skittou, M., Merrouchi, M., & Gadi, T. (2024). Development of an Early Warning System to Support Educational Planning Process by Identifying At-Risk Students. 12. <https://10.1109/ACCESS.2023.3348091>.
- Sujinah, Isnah, E. S., Jalis, F. M. M., & Kharis, M. (2024). Utilizing Cognitive Diagnostic Assessments to Identify and Address Student Needs in Differentiated Classrooms. *Journal of Higher Education Theory and Practice*, 24(1). <https://doi.org/10.33423/jhetp.v24i1.6763>
- Sumual, T., Lumapow, H., & Rotty, V. (2024). The Role of Human Capital Investment in Improving the Quality of Human Resources (HR) in Education in the Digital Era. <https://10.46799/ajesh.v3i11.449>.
- Tang, F., & Zhan, P. (2021). Does Diagnostic Feedback Promote Learning? Evidence From a Longitudinal Cognitive Diagnostic Assessment. *AERA Open*, 7, 23328584211060804. <https://doi.org/10.1177/23328584211060804>
- Veerasamy, A., D'Souza, D., Apiola, M.-V., Laakso, M.-J., & Salakoski, T. (2020). Using early assessment performance as early warning signs to identify at-risk students in programming courses. https://research-repository.rmit.edu.au/articles/conference_contribution/Using_early_assessment_performance_as_early_warning_signs_to_identify_at-risk_students_in_programming_courses/27588648/1
- Zhang, Y., & Aryadoust, V. (2022). A Systematic Review of the Validity of Questionnaires in Second Language Research. *Education Sciences*, 12(10), 723. <https://doi.org/10.3390/educsci12100723>
- Zhang, Z., & Peng, P. (2023). Co-development among reading, math, science, and verbal working memory in the elementary stage. *Child Development*, 94(6), e328–e343. <https://doi.org/10.1111/cdev.13962>
- Zimmerman, B. J., & Schunk, D. H. (2013). *Self-Regulated Learning and Academic Achievement: Theoretical Perspectives*. Routledge.