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Theoretical Model of Intelligence Integration to Improve Self-Directed Learning in Mathematics in the 21st Century

Ainul Marhamah Hasibuan[1], Syahrina Anisa Pulungan[2], Ramadhani[3]
[1,2]Sekolah Tinggi Keguruan dan Ilmu Pendidikan Amal Bakti, Medan, Indonesia
[3]Universitas Muslim Nusantara Al-Washliyah, Medan, Indonesia

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ABSTRACT

This study examines the effectiveness of the Theoretical Model of Intelligence Integration in improving students' self-directed learning in 21st-century mathematics education. The research addresses the problem that many students remain dependent on teacher guidance and have limited ability to regulate their own learning processes. Therefore, this study aims to evaluate whether integrating intellectual, emotional, and spiritual intelligence can strengthen students' self-directed learning in mathematics. A quantitative approach using a true experimental posttest-only control group design was applied, involving 120 eighth-grade students divided equally into experimental and control groups through cluster random sampling. The experimental group received instruction based on the integration of multiple intelligences through stages of contextual problem orientation, self-awareness reflection, strategic problem solving, collaborative discussion, and reflective evaluation, while the control group received conventional instruction. Data were collected using a validated self-directed learning questionnaire measuring awareness, learning strategies, learning activities, evaluation, and interpersonal skills. Hypothesis testing used descriptive statistics, regression, and correlation analysis. The results show a substantial difference between groups and a strong regression effect ($R^2 = 0.823$), indicating that the model significantly improves students' learning autonomy and provides a holistic framework for strengthening self-regulation in mathematics learning.

Corresponding Author:

Ainul Marhamah Hasibuan
Sekolah Tinggi Keguruan dan Ilmu Pendidikan Amal Bakti, Medan, Indonesia
Email: ainulmarhamahhsb@gmail.com

1. INTRODUCTION

Mathematics learning in the 21st Century requires a transformation in students' roles from passive recipients of information to active learners who are capable of managing their own thinking processes. Increasingly complex numeracy literacy can only be mastered when students possess metacognitive awareness and the initiative to regulate their own learning

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strategies [1]. Global challenges also demand flexible thinking skills to solve unstructured and contextual mathematical problems [2]. Self-directed learning becomes a determining factor for long-term academic success because students are expected to plan, monitor, and evaluate their learning processes independently [3]. Therefore, developing students' ability to learn independently is increasingly recognized as a fundamental goal of contemporary mathematics education.

Evidence from one junior high school indicates that students' levels of self-directed learning still need significant improvement. Empirical data show that 65% of students remain fully dependent on teacher instructions when solving mathematical logic problems [4]. When confronted with challenging tasks, many students struggle to regulate their emotions and maintain motivation, causing their thinking processes to stagnate [5]. This condition reveals a gap between curriculum demands that emphasize independence and the students' actual capacity in the classroom [6]. This situation illustrates a critical research problem: despite curriculum reforms that emphasize student autonomy, many learners still lack the internal capacities needed to regulate their learning processes effectively.

Previous studies have attempted to enhance learning independence; however, most have focused on a single dimension of intelligence. Technology-based approaches have been shown to increase student engagement, yet they have not deeply addressed the development of emotional intelligence [7]. Other studies emphasize logical-mathematical intelligence as the primary factor of academic success without considering the role of intrapersonal intelligence in regulating motivation and self-reflection [8]. Such partial interventions have not produced sustainable long-term impacts because they fail to accommodate the full complexity of students' characteristics [9]. These studies indicate that research on learning independence has largely been fragmented, focusing only on cognitive or technological aspects while neglecting the integration of emotional and spiritual dimensions of intelligence. Consequently, a theoretical gap remains regarding how multiple forms of intelligence can be systematically integrated to strengthen self-directed learning in mathematics.

From a theoretical perspective, the concept of self-directed learning refers to learners' ability to initiate, plan, implement, and evaluate their own learning activities independently. In mathematics education, this ability is closely related to metacognitive regulation, motivation, and emotional control during problem-solving processes. Meanwhile, theories of intelligence development emphasize that learning outcomes are influenced not only by intellectual intelligence but also by emotional and spiritual intelligence that shape students' attitudes, persistence, and meaning-making in learning activities. Therefore, integrating these dimensions of intelligence may create a more holistic learning framework capable of supporting students' cognitive and personal development simultaneously.

This study proposes the development of a theoretical model that systematically integrates intellectual, emotional, and spiritual intelligence within a unified framework. Such integration is expected to balance cognitive competence with students' mental resilience in facing challenges in mathematics learning [10]. Students are guided to recognize their personal strengths, set meaningful learning goals, and build internal commitment toward the learning process [11]. The implementation of integrated intelligence within the mathematics curriculum also creates opportunities for a more adaptive and inclusive learning environment aligned with twenty-first-century characteristics [12]. Through this approach, the model aims to provide a conceptual strategy for improving students' self-directed learning by strengthening both cognitive abilities and self-regulation capacities.

Based on these considerations, the objective of this study is to develop a theoretical model of intelligence integration that can support the improvement of self-directed learning in mathematics education in the 21st Century. The model is expected to serve as a conceptual framework that guides educators in designing learning environments that foster students' independence, emotional resilience, and reflective thinking in solving mathematical problems.

The novelty of this research lies in the construction of a theoretical model specifically tailored to the characteristics of twenty-first-century mathematics learning. The model combines principles of educational psychology with the technical demands of mathematics pedagogy to establish a sustainable self-directed learning pathway. Its development is grounded in recent literature analysis and in-depth empirical observations of the interaction among students' intelligences in classroom contexts. The findings are expected to provide a new conceptual reference for curriculum development that positions students as active subjects in the learning process. Furthermore, this study is expected to contribute theoretically by bridging the gap between multiple intelligence theories and the practical implementation of self-directed learning in mathematics education, while also providing practical benefits for teachers in designing more holistic and student-centered mathematics learning environments.

2. METHOD

This study employed a quantitative approach using a true experimental design, specifically a posttest-only control group design, to examine the effectiveness of the theoretical intelligence integration model in enhancing students' self-directed learning. The research was conducted at the junior high school level, involving eighth-grade students as the primary participants. The population of this study consisted of all eighth-grade students in the selected junior high school. A total of 120 students were selected as research participants through a cluster random sampling technique, in which intact classes were randomly chosen to represent the sample. The participants were divided into two groups, namely an experimental class and a control class, each consisting of 60 students, resulting in a total sample of 120 students. The assignment of groups was conducted randomly by selecting two comparable classes and randomly designating one class as the experimental group and the other as the control group in order to minimize selection bias. The experimental group received the intelligence integration model intervention, while the control group participated in conventional instruction. The true experimental design enabled rigorous control of extraneous variables, allowing changes in students' self-directed learning to be directly attributed to the intervention provided [13].

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Table 1. Posttest-only control group design

Group	Treatment	Post-test
Experiment	X	O_1
Control	-	O_2

Table 1 presents a posttest-only control group design involving two groups, namely the experimental and control groups. The experimental group received the treatment (X), while the control group did not receive any treatment. Outcome measurement was conducted once after the intervention through a post-test, recorded as O1 for the experimental group and O2 for the control group. The comparison between O1 and O2 was used to determine the effect of the treatment on the measured variable without administering a pre-test.

The intervention implemented in the experimental group was based on the intelligence integration model that combines intellectual, emotional, and spiritual intelligence in mathematics learning activities. The learning process was conducted through several structured stages. First, the orientation stage introduced contextual mathematical problems to stimulate students' intellectual engagement. Second, the self-awareness stage encouraged students to reflect on their prior knowledge, emotions, and learning goals related to the mathematical task. Third, the strategic learning stage guided students to plan problem-solving strategies collaboratively while regulating their emotions and motivation. Fourth, the reflection and evaluation stage required students to evaluate their learning strategies and outcomes through discussion and self-assessment. Finally, the interpersonal interaction stage emphasized collaborative dialogue and peer feedback to strengthen interpersonal skills during mathematical problem solving. These stages were designed to foster students' self-directed learning by integrating cognitive processes with emotional regulation and reflective thinking.

Post-test data were collected using a self-directed learning questionnaire consisting of 30 items measuring five main dimensions according to Williamson (2007): (a) awareness; (b) learning strategies; (c) learning activities; (d) evaluation; and (e) interpersonal skills [14]. Prior to its use in the main study, the questionnaire underwent a validation process consisting of expert review and pilot testing. The expert validation involved three specialists in mathematics education and educational psychology who evaluated the relevance, clarity, and representativeness of the items. Their feedback was used to revise several statements to improve content validity. Subsequently, a pilot test was conducted with 30 students outside the research sample to examine the readability and preliminary reliability of the instrument. The pilot testing results indicated that the questionnaire items were understandable and suitable for measuring students' self-directed learning characteristics. The rating scale used in the self-directed learning questionnaire is presented in Table 2.

Table 2. Self-directed learning assessment scale

Criteria	Score
Never	1
Rarely	2
Sometimes	3
Often	4
Always	5

Data analysis was conducted through three stages of statistical testing to comprehensively address the research hypotheses. The first stage involved Confirmatory Factor Analysis (CFA) to examine the adequacy of the measurement model and to ensure the validity and reliability of the self-directed learning dimensions. The analysis employed the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach using SmartPLS 4.0 software. The evaluation of the measurement model focused on assessing convergent validity, discriminant validity, and construct reliability. Convergent validity was determined based on outer loadings greater than 0.70 and an Average Variance Extracted (AVE) greater than 0.50. Discriminant validity was examined using the Fornell–Larcker criterion and HTMT values below 0.90, indicating adequate construct distinctiveness. Construct reliability was evaluated using Composite Reliability (CR) and Cronbach's Alpha (CA), with values above 0.70 considered indicative of good internal consistency [15].

Table 3. Convergent validity and construct reliability

Dimension	Item	Outer Loadings	AVE	CR	CA
Awareness	S1	0,806	0,593	0,861	0,896
	S2	0,778			
	S3	0,728			
	S4	0,631			
	S5	0,811			
	S6	0,847			
Learning Strategies	S7	0,792	0,629	0,882	0,910
	S8	0,781			
	S9	0,782			
	S10	0,768			
	S11	0,826			
	S12	0,809			
Learning Activities	S13	0,735	0,563	0,844	0,885
	S14	0,796			
	S15	0,687			
	S16	0,767			
	S17	0,730			
	S18	0,783			
Evaluation	S19	0,855	0,607	0,870	0,902
	S20	0,751			
	S21	0,726			
	S22	0,778			
	S23	0,783			
	S24	0,775			
Interpersonal Skills	S25	0,776	0,548	0,830	0,877
	S26	0,810			
	S27	0,516			
	S28	0,829			
	S29	0,675			
	S30	0,789			

Table 3 shows that the analysis results indicate that the majority of items have met the outer loading criterion above 0.70, although a few items remain below the ideal threshold. The AVE values for all constructs exceed 0.50, indicating that convergent validity has been achieved. Internal consistency is also considered good, as the Composite Reliability and Cronbach's Alpha values are above 0.70. These findings confirm that the measurement model is appropriate for proceeding to the structural analysis stage.

Table 4. Discriminant validity

Dimension	Fornell-Larcker	HTMT
Learning Strategies → Awareness	0,478	0,544
Learning Strategies → Learning Activities	0,532	0,610
Learning Strategies → Evaluation	0,510	0,581
Learning Strategies → Interpersonal Skills	0,510	0,589
Learning Activities → Awareness	0,407	0,469
Learning Activities → Evaluation	0,414	0,477
Learning Activities → Interpersonal Skills	0,499	0,577
Evaluation → Awareness	0,489	0,562
Interpersonal Skills → Awareness	0,383	0,450
Interpersonal Skills → Evaluation	0,455	0,531

Table 4 indicates that the Fornell-Larcker values for all construct pairs are lower than the square root of their respective AVE values, thereby satisfying the discriminant validity criterion. The HTMT values are also below the 0.90 threshold, indicating the absence of excessive construct overlap. The relationships among dimensions fall within a moderate range, reflecting reasonable conceptual associations. These findings confirm that the model meets the requirements of discriminant validity and is appropriate for further analysis.

The next stage applied a regression analysis to examine the simultaneous effect of the independent variables on the dependent variable. The final stage employed a correlation test to identify the strength of the relationship between the implementation of the intelligence integration model and students' self-directed learning in the 21st Century [16]. All analytical procedures were conducted in accordance with relevant methodological foundations to ensure the scientific validity and academic acceptability of the research findings.

3. RESULTS AND DISCUSSION

3.1. Results

Descriptive statistical analysis was conducted to provide an overview of the distribution of post-test scores in both research groups after the treatment was administered. Information regarding the number of participants, score range, mean, and standard deviation is presented concisely to illustrate the quantitative tendencies of the data. This presentation serves as an initial basis for identifying differences in learning outcome characteristics between the experimental and control groups before proceeding to inferential analysis. A summary of the descriptive statistical results is presented in Table 5.

Table 5. Descriptive statistics analysis

Group	N	Minimum	Maximum	Mean	Std. Deviation
Experiment	60	73.00	89.00	82.13	3.929
Control	60	54.00	75.00	64.98	4.085

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The results of the descriptive analysis indicate a noticeable difference in score tendencies between the two groups after the treatment was administered. The mean score of the experimental group was around 82, whereas the control group was approximately 65, resulting in a mean difference of more than 17 points, which suggests a practically meaningful treatment effect. The data distribution in both groups was relatively homogeneous, with standard deviations ranging from 3 to 4, indicating that the variability among individual scores was not excessively wide and that the distribution pattern appeared stable. The score range in the experimental group also tended to fall within a higher category compared to the control group, further reinforcing the indication of differences in post-test performance. From a practical perspective, a mean difference of more than 17 points indicates a substantial improvement in students' self-directed learning performance in the experimental group compared with the control group, suggesting that the intervention may have a strong educational impact. These descriptive findings were subsequently strengthened through regression analysis, summarized in Table 6.

Table 6. Model summary of regression analysis

Model	R	R^2	Adjusted R^2	SD Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
1	.907[a]	.823	.822	4.008	.823	549.177	1	118	.000

The summary of the regression model indicates that the model demonstrates a very strong relationship, with an R value of 0.907 and an explained variance reaching 82.3%, meaning that most of the variation in the dependent variable can be accounted for by the tested model. This R^2 value represents a very large effect size, indicating that the intelligence integration model accounts for a substantial proportion of the variability in students' self-directed learning outcomes. In educational research, an explained variance above 0.50 is generally considered strong, the value of 0.823 indicates a highly meaningful practical contribution of the intervention. A significance value of 0.000 indicates that the constructed regression model is statistically feasible and significant, while the standard error of the estimate of 4.008 reflects a relatively small prediction error. These findings confirm that the model makes a substantial contribution to explaining data variability before being examined in greater detail through the coefficient parameters. A further explanation regarding the direction of the effect, the magnitude of the coefficients, and the level of significance of each predictor variable can be observed in Table 7.

Table 7. Coefficients[a] of regression analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	99.283	1.157		85.802	.000
	Theoretical Model of Intelligence Integration	-17.150	.735	-.907	-23.435	.000

The regression analysis results indicate that the model has a very strong significance with a p-value of 0.000, demonstrating that the theoretical model of intelligence integration statistically affects post-test scores. The negative regression coefficient should not be interpreted as a decrease in learning outcomes, but rather as a consequence of the coding scheme used in the analysis. In this study, the intelligence integration model variable was coded as 1 for the experimental group (receiving the intervention) and 2 for the control group (receiving conventional instruction). Therefore, the negative coefficient indicates that lower coded values (experimental group) are associated with higher post-test scores compared to higher coded values (control group).

This coding structure explains why the coefficient appears negative while the descriptive statistics clearly show higher scores in the experimental group. Thus, the regression results actually confirm that students who experienced the intelligence integration model achieved significantly higher self-directed learning outcomes than those in the control group. The large absolute t-value further reinforces that the contribution of the independent variable to the dependent variable is not due to chance. The strength and direction of this relationship are consistent with the correlation test results presented in Table 8.

Table 8. Correlations analysis

Model		Post-test scores	Theoretical Model of Intelligence Integration
Post-test scores	Pearson Correlation	1	-907**
	Sig. (2-tailed)		.000
	N	120	120
Theoretical Model of Intelligence Integration	Pearson Correlation	-907**	1
	Sig. (2-tailed)	.000	
	N	120	120

The correlation analysis results confirm a very strong relationship between the implementation of the theoretical model of intelligence integration and students' post-test scores. The correlation coefficient, approaching 1 with a significance level of 0.000, indicates that the relationship is significant at < 0.01 with a sample size of 120 respondents. Similar to the regression results, the negative direction of the correlation coefficient is influenced by the coding of the independent variable, where the experimental group was assigned a lower numerical code than the control group. Consequently, the negative correlation reflects that students exposed to the intelligence integration model tended to achieve higher post-test scores.

In terms of practical significance, the magnitude of the correlation (|r| = 0.907) indicates an exceptionally strong relationship, suggesting that the intelligence integration model plays a major role in improving students' self-directed learning performance in mathematics. This strong association provides empirical support for the effectiveness of the proposed instructional model in the context of 21st-century mathematics education. These findings reinforce the notion that the applied model has a significant contribution to improving students' self-directed learning, providing a solid basis for concluding the subsequent stage of analysis.

3.2. Discussion

The research findings indicate that the implementation of the Theoretical Model of Intelligence Integration has a significant impact on improving students' self-directed learning in 21st-century mathematics education. The mean score of the experimental group, 82.13, which exceeded the control group's mean score of 64.98, suggests that the integration of multiple dimensions of intelligence is capable of stimulating self-directed learning in a more measurable manner. The learning model designed to promote self-regulation has been proven to enhance students' ability to plan, monitor, and evaluate their learning processes independently [17]. These findings indicate that when students are supported through a learning environment that simultaneously develops cognitive understanding, emotional awareness, and personal meaning in learning, they are more capable of managing their learning processes autonomously.

The effectiveness of this model can be explained through the integration of three complementary dimensions of intelligence: intellectual, emotional, and spiritual intelligence. Intellectual intelligence enables students to analyze mathematical problems logically and apply appropriate problem-solving strategies. Emotional intelligence supports students in regulating anxiety, maintaining motivation, and sustaining persistence when facing complex mathematical tasks. Meanwhile, spiritual intelligence helps students develop meaning, purpose, and internal commitment toward learning activities. The synergy among these dimensions strengthens metacognitive awareness and internal motivation, which are essential foundations of self-directed learning.

The integrative approach in mathematics instruction demonstrates effectiveness in connecting abstract concepts with real-world problem-solving contexts relevant to students' lives [18]. The strengthening of self-directed learning aligns with the demands of mathematical literacy, which emphasize reflective and constructive thinking in developing deep conceptual understanding [19]. The regression analysis result, with an R^2 value of 0.823, indicates that the intelligence integration model contributes substantially to the variance in students' learning outcomes. A learning environment that accommodates diverse cognitive potentials has been shown to significantly predict academic success [20]. This evidence suggests that mathematics instruction should not focus solely on cognitive performance but should also integrate emotional resilience and reflective learning processes that support students in becoming autonomous learners.

An instructional model that adapts to the development of digital technology helps students manage their learning pace and strategies more autonomously [21]. Self-management skills in mathematics learning become a crucial determinant in addressing the complexity of 21st-century numeracy challenges [22]. A flexible curriculum structure that is responsive to individual intelligence profiles plays an important role in strengthening the effectiveness of the model's implementation [23]. Within this context, the intelligence integration model also aligns with contemporary educational paradigms that emphasize learner-centered instruction, personalized learning pathways, and the development of higher-order thinking skills in mathematics education.

The negative correlation coefficient of -0.907 indicates a very strong relationship between the implementation of the model and the dynamics of post-test scores in this study.

The systematic application of the model is capable of reducing barriers to independent learning, thereby improving the overall quality of the learning process [24]. A structured and supportive learning model has been shown to enhance students' self-efficacy in solving mathematical problems with greater confidence [25]. The transformation of the teacher's role into a facilitator encourages the creation of a more student-centered and participatory learning environment [26]. In this situation, teachers function not only as knowledge transmitters but also as mentors who guide students to develop reflective thinking, emotional awareness, and independent learning strategies.

The integration of technology in instructional design supports the provision of immediate feedback that strengthens students' reflection and self-evaluation processes [27]. The reinforcement of self-directed learning provides a strong foundation for the development of lifelong learners who are adaptive to change [28]. The implementation of innovative models that accommodate multiple intelligences becomes a strategic necessity in modern mathematics education [29]. The future success of education is highly dependent on institutions' ability to integrate cognitive and emotional dimensions into a holistic instructional framework [30].

From a theoretical perspective, this study contributes to the development of mathematics education theory by proposing a conceptual framework that integrates multiple dimensions of intelligence as a foundation for self-directed learning. Previous studies often examined cognitive intelligence or technological interventions separately; however, the present model demonstrates that effective mathematics learning requires a holistic interaction between cognitive competence, emotional regulation, and personal meaning-making. Therefore, the proposed model provides a theoretical bridge between multiple intelligence theory, self-regulated learning theory, and contemporary mathematics pedagogy.

Despite these promising findings, several limitations should be acknowledged. First, the study was conducted in a single educational setting involving only eighth-grade students, which may limit the generalizability of the findings to broader educational contexts. Second, the intervention period was relatively limited, so the long-term impact of the intelligence integration model on students' learning development could not be fully observed. Third, the measurement of self-directed learning relied primarily on questionnaire data, which students' self-perception may influence. Future studies are therefore recommended to involve larger and more diverse samples, apply longitudinal research designs, and incorporate additional data sources such as classroom observations and performance-based assessments to strengthen the validity of the findings.

The implementation of the Theoretical Model of Intelligence Integration has been proven effective in enhancing students' self-directed learning through the strengthening of self-regulation, learning management, and self-efficacy in mathematics instruction. The integration of multiple dimensions of intelligence is capable of creating an adaptive and contextual learning environment that is relevant to the demands of 21st-century literacy and numeracy. Overall, the results of this study suggest that integrating intellectual, emotional, and spiritual intelligence within mathematics instruction represents a promising strategy for developing autonomous learners who are capable of critical thinking, reflective learning, and adaptive problem solving in the rapidly evolving educational landscape.

4. CONCLUSION

This study confirms that the Theoretical Model of Intelligence Integration supports the development of students' self-directed learning in 21st-century mathematics education. The integration of intellectual, emotional, and spiritual intelligence strengthens students' ability to regulate their learning, sustain motivation, and think reflectively when solving mathematical problems, thereby promoting more autonomous and resilient learners. These findings imply that mathematics instruction should adopt more holistic and student-centered approaches that combine cognitive development with emotional and meaningful learning experiences. However, the study is limited by the restricted research setting and sample size, which may limit the generalizability of the findings. Future research is recommended to involve larger and more diverse samples and explore longitudinal or technology-integrated implementations to further examine the model's long-term effectiveness and broader educational impact.

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