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Original Article

Enactive and Iconic Representations in Student Intellectual Development in Mathematics: The Mediating Role of Cognitive Flexibility

Imma Tessie Donne D. Llemit

Author Information:

Holy Cross of Davao College, Davao City, Philippines

Correspondence:
immatessiedonne.llemit@deped.gov.ph

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Abstract. Low intellectual development in mathematics persists globally, with many students struggling to progress from concrete to abstract reasoning. While prior research has focused on mathematical performance, few studies have explored the instructional and cognitive barriers underlying this issue. Addressing this gap, the present study examines cognitive flexibility as a mediator between enactive and iconic representations and students' intellectual development in mathematics. A quantitative, correlational design with mediation analysis was employed, and data were collected from 250 Grade 11 Technical–Vocational–Livelihood students. Grounded in Bruner's Theory of Representation, the findings reveal that both enactive and iconic representations have significant direct and indirect effects on students' intellectual development through cognitive flexibility. Mediation analysis showed that cognitive flexibility accounted for 16.80% and 54.78% of the effects of enactive and iconic representations, respectively, highlighting the role of adaptive reasoning in enhancing the benefits of hands-on and visual learning. These findings emphasize the instructional value of integrating multiple representations with cognitive flexibility in mathematics education. Further studies may explore additional mediating variables to explain the remaining variance in the relationships between enactive and iconic representations and intellectual development that is not accounted for by cognitive flexibility. Potential mediators may be identified from a qualitative study.

Keywords: *Enactive and iconic representations; Cognitive flexibility; Mathematics; Mediating role; Student intellectual development.*

Low intellectual development in mathematics is a persistent global concern. Many students worldwide struggle to demonstrate the intellectual abilities required for mathematical growth, leading to failure to reach higher levels of mathematical thinking, reflecting the widespread difficulties in achieving deeper mathematical understanding (Mullis et al., 2022; OECD, 2023). This issue is also evident across international contexts. International studies have consistently reported that students often fail to progress from concrete to abstract reasoning and exhibit low levels of intellectual development in mathematics (Makondo & Makondo, 2021; Durongkaveroj, 2023). In the Philippines, the same trend is observed at the local level. International and national assessments highlight the country's low standing and weak intellectual performance in mathematics (Schleicher, 2019; Bernardo, 2020). Supporting these local studies by Galabo et al. (2018), Quezada (2020), and Rellon (2025) revealed that students in the Davao Region and Mindanao continued to struggle in mathematics, indicating low intellectual development.

Despite numerous studies describing student performance in mathematics, only a few explore the underlying factors that hinder the students' intellectual development in mathematics. The persistence of low intellectual development across global, international, national, and regional levels prevented learners from advancing beyond concrete to abstract thinking. As noted by Coles and Sinclair (2019), Bernardo et al. (2022), and Rellon (2025), this gap left students with weak foundations in algebra and functions, unprepared for higher mathematics and future learning. Thus, this study sought to address and understand these situations. By examining the mediating role of cognitive flexibility in mathematics learning, the study would enhance students' intellectual development and problem-solving skills in the Philippine context. It supports the vision, mission, and goals of Holy Cross of Davao College in providing quality, value-oriented education, while aligning with the United Nations Sustainable Development Goal 4: Quality Education, which promotes inclusive and equitable learning for all.

Jerome Bruner's Theory of Representation (1966) underpinned this study, where learning and intellectual development progress through enactive, iconic, and symbolic modes, moving from concrete action to visual representation and ultimately to abstract reasoning (Sperry & Smith, 2001). In this study, the enactive representation in learning reflects engagement in learning activities, conceptual understanding, and the application of knowledge. These indicators corresponded to the enactive stage described in Bruner's Theory of Representation. Moreover, the iconic representation in learning - characterized by visual engagement, conceptual clarity, and knowledge retention and application – reflects the iconic stage of the theory. Cognitive flexibility, indicated by strategy shifting, format adaptation, and knowledge transfer, represented the symbolic stage. Lastly, intellectual development, as reflected in indicators of absolute, transitional, independent, and contextual stages, mirrored the progression of learning and intellectual development described in theory.

Generally, this research aimed to determine the significance of the mediating effect of cognitive flexibility on the relationship between enactive and iconic representations and students' intellectual development in mathematics. Specifically, it sought to determine the levels of students' intellectual development in terms of cognitive skills, reasoning ability, and knowledge application; the levels of students' engagement with enactive representations in terms of engagement in learning activities, conceptual understanding, and application of knowledge; the levels of students' engagement with iconic representations in terms of visual engagement, concept clarity, and knowledge retention and application; and the levels of students' cognitive flexibility in terms of strategy shifting, format adaptation, and knowledge transfer. Furthermore, the study aimed to examine the significance of the relationship between enactive and iconic representations and students' intellectual development in mathematics, the direct effects of enactive and iconic representations while controlling for intellectual development, the indirect effects through cognitive flexibility, and the total effects of enactive and iconic representations on students' intellectual development in mathematics.

Methodology

Research Design

This study employed a quantitative-correlational design with mediation analysis to examine the mediating role of cognitive flexibility in the relationship between enactive and iconic representations and students' intellectual development. The correlational design aimed to determine the relationships among the study variables without experimental manipulation. Moreover, mediation analysis was conducted to assess the effects of the learning representations on students' intellectual development through the lens of cognitive flexibility.

Respondents and Sampling Technique

The study was conducted in four selected public Senior High Schools in Digos City offering the Technical-Vocational-Livelihood (TVL) track, including both rural and urban schools. Digos City, the capital of Davao del Sur, serves as an important educational center in the province, providing diverse learning opportunities for senior high school students and supporting the development of practical and academic skills aligned with local community needs.

The study involved 250 Grade 11 students enrolled in the Technical-Vocational-Livelihood (TVL) track taking General Mathematics in public Senior High Schools during the 2025–2026 school year. These students had previously completed the General Mathematics subject. Moreover, students who are not enrolled in the Grade 11 TVL track were excluded from this study.

The sample of 250 students was determined using the Raosoft technique, which calculates a statistically representative sample based on population size, confidence level, and margin of error (Raosoft, 2025). Stratified random sampling, a probability sampling method in which the population is divided into subgroups or strata, and random samples are drawn from each to ensure representation, was applied to ensure proportional inclusion of all relevant subgroups (Better Evaluation, 2026).

Research Instrument

This study used four sets of survey questionnaires to measure enactive learning representation, iconic learning representation, cognitive flexibility, and intellectual development in mathematics. The first instrument was a researcher-developed Enactive Representation survey comprising 15 items that assessed students' engagement in hands-on and action-based learning (Sivakumar & Sharma, 2022; Rovira & Sta. Maria, 2021; Ji et al., 2024). The second instrument was an adapted Iconic Representation questionnaire with 15 items that evaluated learning through visual aids. Cognitive flexibility was measured using a revised version of Martin and Rubin's (1995) scale adapted for mathematics, comprising nine items. Finally, Intellectual Development in Mathematics was assessed using a modified MINDS scale (Mandeville et al., 2018), which comprises 12 items measuring processing ability, reasoning skills, and knowledge application.

The survey questionnaire underwent expert validation and pilot testing to ensure its accuracy and effectiveness. The pilot sample consisted of 30 Grade 11 students enrolled in the TVL track, drawn from a different school than the main study participant. Validity referred to the extent to which an instrument measures what it is intended to measure (Creswell & Creswell, 2018). The data obtained from the pilot test were subjected to reliability analysis using Cronbach's alpha to assess the internal consistency of the items (Wong et al. 2023). The results indicated good and acceptable reliability coefficients: Enactive Representation ($\alpha = 0.759$), Iconic Representation ($\alpha = 0.710$), Cognitive Flexibility ($\alpha = 0.737$), and Intellectual Development in Mathematics ($\alpha = 0.755$). No items were deleted, as they all met the acceptable reliability standards.

Data Gathering Procedure

The study collected data using a research-made survey questionnaire on enactive and adapted iconic representations, cognitive flexibility, and intellectual development, rated on a 4-Point Likert scale. Approval was secured from the Holy Cross of Davao College – Society for Moral Integrity and Legal Ethics (HCDC-SMILE), endorsed by the Graduate School Dean, and then submitted to the Schools Division Superintendent of DepEd Digos City. Permission letters were sent to school heads to facilitate the administration of the survey.

Questionnaires were distributed online via Google Forms. The researcher explained the study, obtained informed consent from participants and their guardians, and ensured respondents completed the survey at their own pace. The data collection was conducted over two weeks. All data was securely stored to maintain confidentiality. Collected responses were organized and statistically analyzed. Findings were interpreted to address the study objectives, and conclusions and recommendations were derived from the results.

Data Analysis Procedure

The procedure involved data retrieval, verification, classification, and tabulation to prepare the information for statistical analysis. To address the research objectives, the following statistical tools and analyses were employed using JAMOVI software. Specifically, descriptive statistics, such as the mean and standard deviation, were used to assess the levels of the four variables: enactive and iconic representations, cognitive flexibility, and students' intellectual development in mathematics. The Pearson Product–Moment Correlation was employed to test the significance and strength of the relationships between the predictive and criterion variables. Furthermore, the data were checked to ensure that basic regression assumptions were met before conducting the mediation analysis. Normality, linearity, and homoscedasticity were examined, while independence of errors was assessed with the Durbin-Watson statistic. Afterward, the mediation analysis was conducted to assess the significance of the effects of the predictive variables, particularly the direct and indirect (mediated) effects on students' intellectual development in mathematics.

Ethical Considerations

The study adhered to strict ethical standards. The researcher coordinated with the students' mathematics teachers, who served as respondents in the study. Such teachers explained the purpose of the study to their students and informed them of their right to participate voluntarily and withdraw at any time without any consequences. Likewise, informed consent was obtained from the parents or guardians, and assent was secured from students. Confidentiality was maintained by anonymizing responses and safeguarding data. Permission to conduct the study was secured from the Department of Education. Finally, the research proposal was approved by the Society of Moral Integrity and Legal Ethics (SMILE), manifesting full compliance with ethical, legal, and moral principles.

Results and Discussion

Descriptive Statistics of the Study Variables

Table 1 presents the descriptive statistics of the study variables, namely: enactive representation in learning, iconic representation in learning, cognitive flexibility, and intellectual development of students in mathematics with their respective indicators. It also includes the sample size, computed means, standard deviations, and the corresponding descriptive interpretations.

Table 1. *Descriptive analysis results (n = 250)*

Variables	SD	$\underline{x}$	Interpretation
Enactive Representation in Learning	**0.39**	**2.97**	**High**
Application of Physical Learning	0.45	2.96	High
Conceptual Understanding Through Action	0.43	2.98	High
Physical Engagement	0.43	2.98	High
Iconic Representation in Learning	**0.40**	**2.98**	**High**
Application of Visual Learning	0.45	2.94	High
Conceptual Understanding Through Visuals	0.42	3.01	High
Visual Engagement	0.46	2.99	High
Cognitive Flexibility	**0.29**	**2.97**	**High**
Strategy Shifting	0.49	2.92	High
Format Adaptation	0.48	3.00	High
Knowledge Transfer	0.00	3.00	High
Intellectual Development of Students in Mathematics	**0.42**	**2.99**	**High**
Absolute Stage (Confidence in Certainty)	0.48	2.97	High
Transitional Stage (Embracing Duality)	0.48	3.01	High
Independent Stage (Active Construction)	0.48	3.03	High
Contextual Stage (Critical Mastery and Growth)	0.55	2.95	High

Specifically, Table 1 shows that enactive representation in learning (*M* = 2.97 and *SD* = 0.39), indicating that TVL students are good at engaging in hands-on learning activities. On the other hand, iconic representation in learning (visual learning) (*M* = 2.98, SD = 0.40) indicates High, implying that students are good at using visual or pictorial representations to understand concepts. Moreover, cognitive flexibility (*M* = 2.97, SD = 0.29) is described as high, indicating that TVL students are good at adapting strategies and shifting their thinking when solving problems. The intellectual development of students in mathematics (M = 2.99, SD = 0.42) was described as high, with highly consistent responses among respondents. It indicates that TVL students are good at demonstrating understanding, application, or analysis of concepts. Overall, the results indicate that integrating multiple representations and fostering cognitive flexibility positively contribute to the mathematical intellectual development of TVL students.

Correlation Analysis Results

Table 2 shows a correlation table. It contained the variables involved in the study and showed the relationships among enactive representation, iconic representation, and cognitive flexibility with TVL students' intellectual development in Mathematics. It also included the r-value, p-value, decision on Ho, and its corresponding interpretation.

Table 2. *Correlation analysis results*

	Intellectual Development of Students in Mathematics			
Variables	r-value	p-value	Decision on Ho	Interpretation
Enactive Representation in Learning	.775	.000	Reject Ho	High and Significant Correlation
Iconic Representation in Learning	.803	.000	Reject Ho	High and Significant Correlation
Cognitive Flexibility	.802	.000	Reject Ho	High and Significant Correlation

Specifically, the enactive representation showed high and significant correlation with intellectual development ($p < .001$, $r = .775$), indicating that as students frequently engage in hands-on or action-based activities, their intellectual growth in Mathematics increases. The iconic representation exhibited the highest positive correlation (p < .001, r = .803), indicating that students who often use diagrams, graphs, and models demonstrate stronger conceptual understanding and analytical ability. Similarly, cognitive flexibility revealed a high and significant correlation with intellectual development ($p < .001$, $r = .802$), suggesting that learners who adapt strategies and shift thinking when solving problems achieve higher intellectual performance.

This reveals that enactive representation, iconic representation, and cognitive flexibility are all significantly correlated with students' intellectual development in mathematics. Among these variables, iconic representation shows a slightly stronger correlation compared to enactive representation and cognitive flexibility. These results indicate that different forms of representation and cognitive skills collectively enhance students' mathematical understanding and intellectual growth.

The study found that enactive and iconic representations are significantly correlated with students' intellectual development in mathematics. These findings support recent evidence that multiple representations enhance students' mathematical understanding and intellectual growth. Studies show that engaging learners through both physical and visual models strengthens conceptual connections and reasoning (Tana, Clivaz, & Sakamoto, 2023; Haque, 2024), aligning with Polo Blanco et al. (2025), who reported that translating among representations improves generalization and problem-solving. At the same time, the idea that cognitive overload may occur with poorly designed representations (Rexigel et al., 2025) is denied.

Mediation Analysis Results

Table 3 presents the mediation analysis examining the indirect, direct, and total effects of the variables. The table includes the type of effect, the estimate, the beta value, the z-score, the p-value, the decision on the hypothesis, and the corresponding interpretation. Furthermore, the path model illustrates how Cognitive Flexibility (CF) functions as a significant mediating variable linking learning representations—Enactive (ER) and Iconic (IR)—to students' Intellectual Development (ID) in mathematics.

Table 3. *Mediation analysis results*

Type	Effect	Estimate	SE	B	Z	P	Decision on Ho	Interpretation
Indirect	ER ⇒ CF ⇒ ID	0.062	0.030	0.058	2.04	.041	Reject Ho	Significant
	IR ⇒ CF ⇒ ID	0.298	0.050	0.281	5.97	< .001	Reject Ho	Significant
Component	ER ⇒ CF	0.106	0.050	0.142	2.13	.033	Reject Ho	Significant
	CF ⇒ ID	0.583	0.080	0.407	7.31	< .001	Reject Ho	Significant
	IR ⇒ CF	0.511	0.049	0.691	10.34	< .001	Reject Ho	Significant
Direct	ER ⇒ ID	0.307	0.063	0.289	4.87	< .001	Reject Ho	Significant
	IR ⇒ ID	0.246	0.075	0.232	3.30	< .001	Reject Ho	Significant
Total	ER ⇒ ID	0.369	0.069	0.347	5.34	< .001	Reject Ho	Significant
	IR ⇒ ID	0.544	0.069	0.513	7.91	< .001	Reject Ho	Significant

Percent of Mediation of CF: (a) For ER and ID = 16.80%, (b) For IR and ID = 54.78%

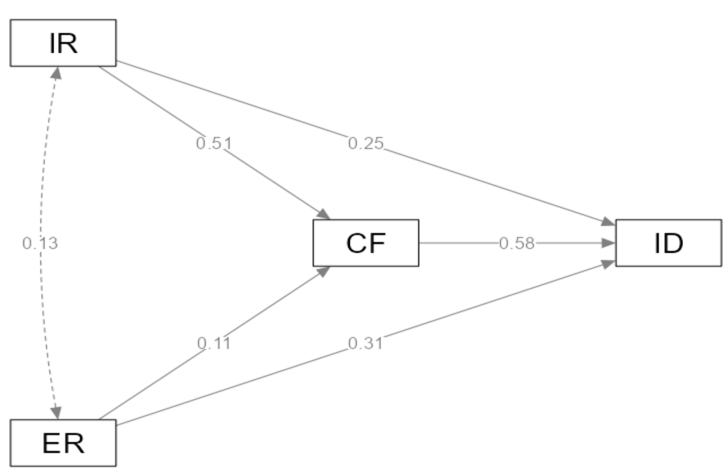

Figure 1. *Path Model Showing the Mediation of Cognitive Flexibility (CF) Towards Enactive (ER) and Iconic (IR) Representations with Intellectual Development (ID) in Mathematics*

Specifically, Table 3 shows that, while controlling for cognitive flexibility, the direct effects of enactive and iconic representations on intellectual development were statistically significant, with p-values of .001 and .001, respectively, both below the p-value of .05; hence, the null hypothesis is rejected. It indicates that the direct effect of enactive and iconic representations is significant for intellectual development, while controlling for cognitive flexibility. Moreover, it shows that the indirect effects of enactive and iconic representations on intellectual development, via cognitive flexibility, have p-values of .041 and .001, respectively, both below the .05 threshold; hence, the null hypothesis is rejected. It indicates that the indirect effect of enactive and iconic representation is significant on intellectual development through cognitive flexibility.

Since both the indirect and direct effects are significant, the mediation is partial. Thus, cognitive flexibility has a weak mediation effect (16.80%) on the correlation between enactive representation and intellectual development. In contrast, it has a strong mediation effect (54.78%) on the correlation between iconic representation and intellectual development. The results indicate that both the direct and indirect effects of enactive and iconic representations on intellectual development are significant when controlling for cognitive flexibility. This confirms that cognitive flexibility partially mediates the relationship, highlighting its role in enhancing the impact of these representations on students' intellectual development.

The study also found that enactive and iconic representations have a significant total effect on students' intellectual development in mathematics. These findings support recent studies of Prahmana et al. (2023) and Haque (2024), which demonstrate that combining multiple representations produces cumulative learning gains and stronger conceptual understanding. It also affirms the study of Polo Blanco et al. (2025), which found that coordinated representations strengthen students' ability to generalize concepts. While Bley et al. (2024) reported mixed outcomes depending on context, this study found a significant total effect, highlighting the importance of integrating enactive and iconic representations alongside cognitive flexibility.

Conclusion

The findings indicate that enactive and iconic representations are significantly correlated with students' intellectual development in mathematics and exert both significant direct and indirect effects through cognitive flexibility. This suggests that learning representations enhances intellectual development not only through hands-on and visual support but also through their ability to adapt thinking during problem-solving. Cognitive flexibility serves as a partial mediator, indicating that flexible thinking enhances both enactive and iconic representations of the mathematical learning outcomes. Although these representations directly contribute to intellectual development, their impact is strengthened when students demonstrate their ability to shift strategies and adjust reasoning. Anchored on the Theory of Representation, the results highlight the importance of integrating multiple representations with cognitive flexibility in mathematics instruction. Further studies may examine additional influencing factors and employ qualitative approaches to deepen the understanding of students' learning processes.

Contributions of Authors

Author: conceptualization, methodology, writing, reviewing, editing, data collection, supervision, data analysis

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Conflict of Interests

No conflict of interest.

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