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Research Article

Exploratory Path Analysis of Mathematics Ability Among At-Risk Students

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Abstract
Persistent mathematics underachievement among at-risk students remains a pressing educational concern because weak performance in mathematics can constrain later academic progression and learners' ability to cope with more advanced school tasks. This study examined mathematics ability among at-risk students through an exploratory path analysis linking school-related, teacher-related, and student-related factors. Using a quantitative, cross-sectional, explanatory design, the study focused on students identified as at risk in mathematics through a TIMSS-like screening assessment. The respondents were 450 Grade 9 students from public and private junior high schools in Northwestern Mindanao, Philippines. There were 370 classified as at risk, and 368 cases were retained for the inferential analyses. Data were drawn from a mathematics ability test, a mathematics anxiety questionnaire, an attitude toward mathematics questionnaire, and a mathematics teaching strategy questionnaire. Analysis proceeded through descriptive statistics, regression-based screening, and exploratory path analysis using observed variables only. The final parsimonious model showed a good fit to the data. Appraisal and confidence emerged as the most immediate positive predictors of mathematics ability, while negative attitude showed a smaller negative role in the preliminary screening model. Teacher-related and school-related variables were linked to mathematics ability mainly through instructional and affective pathways. Reflective strategy showed positive direct and indirect associations through appraisal and confidence, whereas discussion showed negative indirect associations through the same mediators. The type of school also retained a small but significant direct contribution to mathematics ability, suggesting that broader school conditions remained relevant even after proximal affective and instructional factors were considered. The findings indicate that mathematics ability among at-risk students is best understood as a layered outcome shaped by school context, instructional processes, and students' evaluative and competence-related responses to mathematics.

Keywords: Appraisal, At-Risk Student, Confidence, Exploratory Path Analysis, Mathematics Ability, Reflective Strategy

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1. INTRODUCTION

Mathematics underachievement remains a persistent educational problem, particularly in systems where large numbers of students struggle to attain even minimum proficiency. International evidence has consistently shown that mathematics performance is shaped not only by cognitive skill but also by broader contextual conditions, including students' confidence, valuing of mathematics, instructional clarity, and school support (Mullis et al., 2020). For learners already performing at the lower end of the achievement distribution, this problem becomes even more urgent because difficulty in mathematics is rarely a matter of content knowledge alone; it is often entangled with how students experience mathematics in school, how capable they believe themselves to be, and how classroom and school conditions support or constrain their engagement.

In the Philippine context, this issue is especially pressing. In PISA 2022, Filipino 15-year-olds obtained an average mathematics score of 355, far below the OECD average of 472, and only 16% attained at least Level 2 proficiency, compared with the OECD average of 69% (OECD, 2023b). These figures indicate that mathematics difficulty in the Philippines is not confined to a small subgroup of extremely low performers, but reflects a broader system-level concern. They also point to contextual constraints in schools, including staff shortages and other conditions that may affect learning. Mathematics underachievement in the Philippines, therefore, cannot be interpreted as a narrow learner deficit alone; rather, it is embedded in instructional and school environments that shape how students encounter and respond to mathematics.

The concern becomes more critical when attention is directed to students already identified as low-performing. Bernardo et al. (2022) showed that more than half of Filipino students performed below the lowest proficiency level in mathematics and that low-performing students in public and private schools exhibited different profiles of associated motivational, family, and school-related factors. Their findings imply that mathematically at-risk learners should not be treated as a single homogeneous group. Instead, they should be understood as students whose mathematics outcomes may reflect different combinations of affective, instructional, and contextual conditions. For studies that aim to inform intervention, this distinction matters because the explanatory structure of mathematics ability among at-risk learners may differ from the pattern found in broader student populations.

A substantial body of research also indicates that mathematics performance is closely tied to affective variables. Barroso et al. (2021) reported a significant negative relationship between mathematics anxiety and mathematics achievement. Similarly, Wen and Dubé (2022) posited that attitudes toward mathematics are multidimensional and include value, confidence, self-concept, enjoyment, and anxiety, among others. These findings suggest that mathematics-related affective factors should not be reduced to a single broad label. For students already at risk, more specific evaluative and self-belief variables may therefore be more informative than global attitude or anxiety measures alone.

Instructional processes and school context also matter, but their roles are often indirect and layered rather than simple or uniform. Some studies have emphasized that classroom conditions can either support or hinder students' access to mathematical understanding. Christopher and William (2026), for example, showed that language-supportive pedagogy can reduce barriers in mathematical word problems, while Deaño et al. (2023) highlighted that mathematical performance depends on processes of translation, integration, planning, and execution rather than on final answers alone. These studies reinforce the idea that teacher-related variables may influence mathematics outcomes not only directly, but also through the classroom experiences that shape students' engagement, confidence, and appraisal of mathematics.

Despite the growing literature on mathematics performance, a clear empirical gap remains. Much of the existing research examines students' affective factors, instructional practices, and school context as separate influences, rather than as interrelated factors that may operate through direct and indirect pathways. The affective domain is also conceptually crowded, with overlapping constructs such as anxiety, confidence, self-efficacy, attitude, and value, making construct specification especially important. This limitation is more consequential in studies of at-risk learners, whose mathematics performance may be shaped by a different configuration of relationships than those observed in general student populations. In the Philippine setting, locally grounded evidence on how student-, teacher-, and school-linked factors jointly explain mathematics ability within a screened at-risk subgroup remains limited.

The present study addresses this gap by examining mathematics ability among at-risk students through an exploratory path-analysis framework. Rather than assuming that mathematics ability is explained by a single class of predictors, the study considers how student-related affective variables, teacher-related instructional variables, and school-linked contextual variables may operate together. Particular attention is given to whether mathematics ability is more immediately associated with student affective factors such as appraisal and confidence, and whether teacher and school conditions are linked to mathematics ability through these more proximal student processes. In doing so, the study offers a locally grounded account of mathematics ability among students already vulnerable to low performance and provides an empirical basis for designing more responsive support for learners who continue to struggle in mathematics.

1.1. Literature Review

1.1.1. Mathematics Underachievement and At-Risk Learners

Mathematics underachievement is commonly defined as performance below expected levels given a student's cognitive potential or ability (Geary, 2011). It is associated with a combination of cognitive, motivational, emotional, and contextual factors that place learners at risk of persistent low achievement (Capuno et al., 2019; Saha et al., 2024). Underachievement may occur across ability levels, including among high-ability students whose motivation and valuing of mathematics are low (Jordan et al., 2009; Svraka & Ádám, 2022). Recent studies, however, no longer treat mathematics underachievement as a narrow problem of weak computational skill. Mathematics achievement is linked not only to prior knowledge and cognitive ability (Banerjee & Gautam, 2024) but also to self-concept (Devries et al., 2021), self-regulation (Özcan, 2015; Tee et al., 2021), and executive functions (Svraka & Ádám, 2022). Mathematics underachievement, therefore, is better understood as a multidimensional condition produced by interacting cognitive, motivational, and regulatory processes rather than by a single learner deficit.

Lau et al. (2024) explain that mathematics anxiety is not merely an emotional consequence of poor performance; it also contributes to underachievement by reducing processing efficiency and increasing avoidance of mathematical activity. Thus, learners become underachieving not only because they know less mathematics, but also because they engage with it less confidently (Numajiri & Kosaka, 2025), less persistently, and often less frequently (Verplanken & Orbell, 2022). Underachievement must therefore be framed not only as low attainment, but also as a process shaped by both competence and participation.

In the Philippine context, this argument becomes more urgent where weak mathematics performance is not confined to a small subgroup. In PISA 2022, 15-year-old students in the Philippines scored 355 points in mathematics compared with the OECD average of 472, and only 16% attained at least level 2 proficiency (OECD, 2023b). The earlier PISA 2018 Philippine National Report already revealed a similarly serious pattern: the national mean in mathematical literacy was 353, only 19.7% of Filipino students reached at least level 2 proficiency, 54.4% performed below level 1, and students in private schools (395) substantially outperformed those in public schools (343) (DepEd, 2019). These figures show that mathematics underachievement in the Philippines is situated within a broader system-level pattern of weak mathematical performance.

Bernardo et al. (2022) identified contrasting profiles of low-performing mathematics students in public and private schools, pointing to varying combinations of motivation, socioeconomic resources, school climate, and learning experiences rather than a single explanation for low performance. Similarly, Lapinid et al. (2022) argued that explanations of poor performance must go beyond curricular and instructional factors, as social and psychological experiences in school are also important markers of poor-performing students. These studies suggest that mathematically at-risk learners should not be treated as a homogeneous group, but as a subgroup whose outcomes reflect interacting affective, instructional, and contextual conditions.

Early evidence further suggests that mathematics underachievement in the Philippines begins well before secondary school. Cheung et al. (2021) found that numeracy interest and numeracy competence among young Filipino children were associated with parental attitudes, home numeracy practices, socioeconomic status, age, gender, and literacy skills. Relatedly, Cheung et al. (2018) showed that parents' education and the home numeracy environment were directly related to children's numeracy skills in low- to middle-income Filipino families. These studies indicate that later underachievement in school mathematics is not merely a secondary-school problem. It is partly rooted in unequal early numeracy opportunities and family support structures that shape children's readiness long before formal mathematics becomes more demanding (King & Purpura, 2021).

As learners move into later schooling, self-regulatory, dispositional, and affective mechanisms help explain why some Filipino students remain low performing. Capuno et al. (2019) reported that attitudes and study habits are associated with junior high school mathematics performance. Santos et al. (2022) likewise found that stronger time management is positively related to performance, whereas academic procrastination is negatively related during online science and mathematics classes. Bernardo (2021) further showed that a growth mindset has a positive but limited association with learning in mathematics and science, and that its benefits are more evident among higher-socioeconomic-status students. Capinding

(2022) adds that even when students report motivation and generally positive attitudes under modular distance learning, substantial mathematics anxiety remains and is negatively associated with achievement. This body of work suggests that Filipino mathematics underachievement cannot be explained by motivation alone. Self-regulation and affect matter, but they operate within structural inequalities that shape whether adaptive beliefs can translate into achievement.

Philippine studies also point to underachievement as an instructional and opportunity-to-learn issue. Balagtas et al. (2019) found uneven alignment between the Philippine K to 12 curriculum and the TIMSS 2015 assessment framework, indicating that national performance problems are partly tied to curriculum and implementation conditions. Jaudinez (2019) similarly documented difficulties in teaching senior high school mathematics related to curriculum content, instructional strategies, learning resources, and assessment. At the classroom level, Santos and Boyon (2020) showed that inquiry-based lessons improved Grade 11 STEM students' competencies in limits and continuity. The more persuasive interpretation, therefore, is that mathematics underachievement in the Philippines should not be framed solely as a weakness of learners. It is also linked to the quality, alignment, and form of instruction made available to them.

What remains insufficiently developed in the Philippine literature is an integrated account of Filipino underachievers in mathematics as a specifically screened at-risk group. Existing studies have identified important dimensions of the problem. The national low performance, heterogeneous low-performing profiles, early numeracy disadvantage, weak study regulation, anxiety, and instructional misalignment, but these strands are often examined separately or within broad mixed-ability samples. A stronger direction is to study Filipino mathematically at-risk learners as a subgroup whose mathematics ability is shaped by interacting student, family, teacher, and school factors.

1.1.2. Affective Factors in Mathematics Learning

Students' affective factors in mathematics learning refer to the beliefs, emotions, and motivational evaluations that shape how they engage with mathematical tasks. Recent evidence indicates that mathematics achievement is associated not only with prior knowledge and cognitive ability, but also with learner characteristics such as mathematics self-concept, self-regulation, metacognition, and executive functions (Breit et al., 2025). This broader view is consistent with control-value theory, which explains that students' achievement emotions arise from how much control they feel over learning and how much value they attach to the task; these emotions, in turn, influence engagement, persistence, and performance (Pekrun, 2024). Affective factors in mathematics, therefore, should be treated as integral to learning rather than as mere by-products of achievement.

Among these factors, self-efficacy and related competence beliefs occupy a central place because they shape how students respond to challenge, effort, and persistence. Students who believe they can succeed in mathematics are more likely to engage productively and attain stronger outcomes, whereas weak competence beliefs can reduce effort and reinforce disengagement. Longitudinal evidence further suggests that these relations are reciprocal: mathematics achievement and mathematics self-efficacy strengthen one another over time, and prior achievement also contributes to later interest in mathematics (Du et al., 2021). In this sense, affect in mathematics learning is not static; it develops through repeated interactions between performance and self-belief.

Mathematics anxiety remains one of the most consequential negative affective factors because it both reflects and intensifies learning difficulty. Recent reviews show that the relation between mathematics anxiety and achievement is reciprocal: poor performance can heighten anxiety, and anxiety can subsequently impair performance through cognitive interference and avoidance of mathematical activity (Lau et al., 2024; Li et al., 2021; Wahyuni et al., 2024). Large-scale cross-national evidence likewise indicates that mathematics anxiety has both individual and contextual dimensions, meaning it is shaped not only by personal dispositions but also by the broader environment in which students learn mathematics (Jenifer et al., 2022; Lau et al., 2022). Anxiety, therefore, is not merely an emotional response to failure; it is part of the mechanism through which underperformance can become persistent.

Positive affective factors such as interest, enjoyment, and confidence are equally important, but they do not operate in isolation from beliefs and context. Du et al. (2021) found that prior anxiety and self-efficacy predict later mathematics interest, showing that interest is partly built through earlier emotional and competence experiences. Recent work on achievement emotions also indicates that students' enjoyment, anxiety, boredom, and related emotions vary across learning environments and across performance levels, suggesting that affective experiences in mathematics are shaped by both individual and instructional conditions (Sydänmaanlakka et al., 2024; Pekrun, 2024). Thus, positive affect in mathematics is better understood as something cultivated through successful, meaningful, and emotionally supportive learning experiences.

The literature likewise shows that classroom relationships and instructional support are central to the development of students' affective experiences in mathematics. Perceived teacher support has been found to improve mathematics achievement directly and in combination with mathematics self-efficacy, while supportive teacher–student relationships can also reduce mathematics anxiety by strengthening students' self-efficacy (Wang et al., 2024; Zhu et al., 2024). The literature therefore suggests that students' affective factors in mathematics learning are not peripheral variables but key mechanisms through which learners interpret mathematical difficulty, sustain engagement, and convert learning opportunities into achievement.

For the present study, this literature supports focusing on student affective variables as the most proximal explanatory layer in the model. It also supports distinguishing among affective dimensions rather than treating anxiety or attitude as broad, undifferentiated constructs. This is especially important in this context, where appraisal and confidence emerged as more informative than a single global affective label.

1.1.3. Instructional and School Context in Mathematics Learning

Instructional and school context in mathematics learning refers to the ways teaching approaches, classroom processes, curriculum opportunities, and school conditions jointly shape students' mathematical engagement and achievement. Recent literature shows a sustained move away from purely teacher-centered transmission toward student-centered and context-rich approaches. Syntheses indicate that problem-based learning, inquiry-oriented teaching, collaborative work, and technology-supported instruction are commonly associated with stronger conceptual understanding, engagement, and problem solving when they are implemented coherently rather than as isolated activities (Ayari et al., 2025; Hidayat & Firmanti, 2024; Mediana et al., 2025). This suggests that effective mathematics instruction is not defined by novelty alone, but by how well learning tasks are organized around meaningful problems, active participation, and guided conceptual development.

At the same time, the literature shows that instructional effects are mediated by school conditions. Student-centered pedagogies are more likely to work when teachers are adequately prepared, learning materials are available, and classroom routines are orderly enough to sustain discussion, inquiry, and feedback (Martinsone et al., 2023). In this sense, school context is not a background variable separate from pedagogy; it shapes whether sound instructional designs can be carried out consistently. International large-scale assessment evidence likewise indicates that school resources, staffing, and the quality of the classroom environment remain closely tied to opportunities to learn mathematics well.

This interaction between instruction and context is especially important in the Philippines, where weak mathematics performance has persisted across large-scale assessments. OECD reporting for PISA 2022 shows that only 16% of Filipino students reached at least level 2 proficiency in mathematics, while many students studied in schools affected by teacher shortages, inadequate staffing, and an unfavorable disciplinary climate in mathematics lessons (OECD, 2023a). Philippine evidence also indicates that school type is not merely an administrative distinction. Bernardo et al. (2022) found that low-performing students in public and private schools show different profiles, with combinations of personal, family, instructional, and school-related factors distinguishing those left behind in mathematics. The implication is that mathematics underperformance in the Philippines cannot be explained adequately by learner characteristics alone; it must also be read through differences in school environments and instructional experiences.

Philippine studies on curriculum and classroom practice reinforce this point. Balagtas et al. (2019) found uneven alignment between the Philippine K to 12 mathematics curriculum and the TIMSS 2015 framework, with stronger alignment in Grade 4 than in Grade 8, suggesting that the opportunity to learn may already vary within the formal curriculum itself. At the implementation level, Jaudinez (2019) documented recurring issues in senior high school mathematics related to curriculum content, teaching strategies, instructional resources, assessment, and teacher preparation. Yet Philippine classroom-based work also shows that stronger pedagogies can make a difference. Santos and Boyon (2020) reported that inquiry-based lesson exemplars improved Grade 11 STEM students' competencies in limits and continuity, suggesting that better-designed instruction can address specific areas of weakness even within challenging conditions. These studies indicate that mathematics learning in the Philippine context is shaped not only by what is taught, but by how it is taught and by the school conditions that support or constrain that teaching.

What remains insufficiently developed in the literature is an integrated account of how instructional practices and school context jointly shape mathematics learning among Filipino at-risk learners. Existing studies have identified important elements of the problem, such as curriculum misalignment, resource constraints, sector differences, and the promise of inquiry-oriented teaching—but these are often examined separately. A stronger direction is to analyze mathematics learning as the product of interacting instructional and contextual conditions, especially for learners already vulnerable to underachievement.

1.1.4. Gap in the Literature and Direction of the Present Study

The literature points to a layered explanation of mathematics performance. Mathematics underachievement is associated with cognitive, motivational, and contextual conditions; affective variables such as anxiety, confidence, and self-belief function as proximal learner-level mechanisms; and instructional and school contexts shape the learning conditions within which those affective processes develop. What remains underdeveloped, however, is an integrated model that examines these strands together among Filipino students already identified as at risk in mathematics.

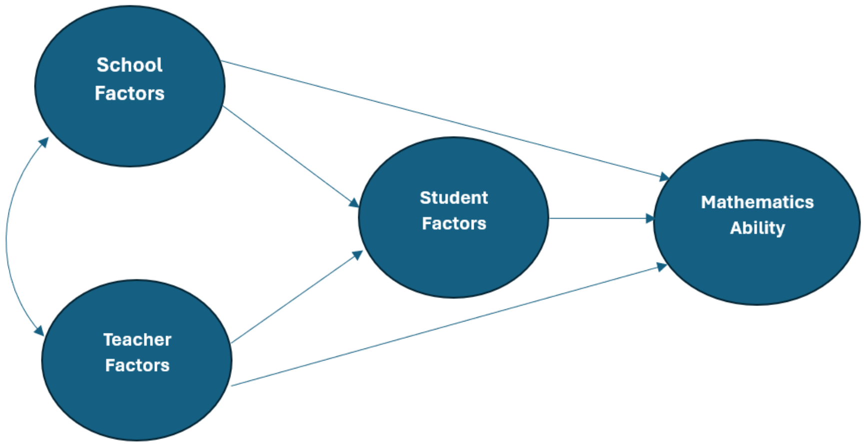

Figure 1. Hypothesized Mathematics Ability Model of At-Risk Students

Three specific gaps follow from this synthesis. First, many studies examine mathematics anxiety, confidence, attitude, teacher practice, or school context separately, even though mathematics performance may arise from their combined action. Second, the affective domain remains conceptually crowded, with overlapping constructs such as anxiety, confidence, self-efficacy, and value, making it necessary to identify which affective dimensions are most relevant in a given empirical setting. Third, there is still limited locally grounded research in the Philippine context that models how student-, teacher-, and school-linked variables jointly explain mathematics ability within a screened at-risk junior high school subgroup.

The present study addresses this gap through an exploratory path-analytic framework anchored primarily in Control-Value Theory (Pekrun, 2024) and a layered contextual-process logic. The Control-Value Theory explains how students' evaluative and control-related beliefs shape achievement emotions and, in turn, engagement and performance. In the context of the present study, student-related affective variables such as appraisal and confidence are treated as the most proximal learner-level mechanisms linking learning conditions to mathematics ability. Teacher-related instructional variables are positioned as classroom-level processes that may shape these affective responses, while school-linked variables are treated as broader contextual conditions that structure instructional opportunities and constraints. Figure 1 operationalizes this theoretical logic by positioning school context as a distal layer, teacher-related instructional variables as intermediate classroom mechanisms, and student-related affective variables as the most immediate pathways to mathematics ability.

2. METHODOLOGY

2.1. Research Design

This study employed a quantitative, cross-sectional, explanatory design using exploratory path analysis to examine the factors associated with mathematics ability among at-risk Grade 9 junior high school students. It was explanatory because it aimed to determine how selected student-related, teacher-related, and school-related variables were associated with mathematics ability and to identify the most parsimonious set of direct and indirect pathways among them. It was exploratory because the final path model was developed through theoretically informed screening and model refinement rather than from a fully fixed confirmatory model (Kline, 2016; Shipley, 1997).

The study focused on students identified as at risk in mathematics based on their performance in a TIMSS-like mathematics ability assessment. Within this subgroup, the analysis examined whether mathematics ability was more closely associated with student affective variables, such as appraisal, confidence, and attitudes toward mathematics, and whether teacher- and school-linked contextual variables contributed directly or indirectly through these student factors. In line with this purpose, the analytic procedure began with descriptive statistics and regression-based screening models, followed by the estimation of a final parsimonious path model that retained only the most substantively and statistically meaningful pathways.

Exploratory path analysis was appropriate for three reasons. First, the study modeled relationships among observed variables rather than latent constructs, making path analysis more suitable than full covariance-based structural equation modeling. Second, the study examined not only direct associations with mathematics ability but also mediated pathways linking school and teacher context to student outcomes. Third, the final model was interpreted as an exploratory student-level path model because teacher- and school-related variables were linked to students through repeated contextual values rather than estimated as independent higher-level effects. Accordingly, the retained pathways were interpreted as explanatory student-level associations rather than multilevel causal effects of teachers or schools.

2.2. Respondents

The respondents of the study were Grade 9 junior high school students from public and private schools in Northwestern Mindanao, Philippines. The study began with a screening sample of 450 students, all of whom took the TIMSS-like Mathematics Ability Test. Using the study's screening rule, students who scored below 50% of the total test score were classified as at risk in mathematics. This process yielded 370 at-risk students, who constituted the descriptive sample used for the profile and summary statistics reported in the Results section. For the inferential analyses, two cases with incomplete or extreme values were excluded from the working dataset, resulting in an analytic sample of 368 students for the regression screening and final path analysis. This explains the difference between the descriptive sample size and the inferential sample size reported in the manuscript.

The at-risk sample ranged from 14 to 17 years old, with most respondents being 15 years old (62.4%), followed by those aged 16 years old (28.4%), 17 years old (6.5%), and 14 years old (2.7%). The sample was nearly balanced by sex, consisting of 188 females (50.8%) and 182 males (49.2%). In terms of ethnicity, most respondents were Cebuano/Bisaya (96.2%), while 3.8% were Maranao. The students were also linked to varying instructional and school contexts. Slightly more than half were taught by teachers whose field of specialization was Mathematics Education (53.5%), while the rest were taught by teachers with General Education specialization (46.5%). In terms of school characteristics, 73.5% of the students were enrolled in public schools and 26.5% in private schools, while the distribution across urban (49.5%) and rural (50.5%) school locations was nearly even. The respondents were likewise distributed across four school mathematics NAT-performance contexts: 43.9%, 50.1%, 57.7%, and 65.7%.

The student was treated as the unit of analysis throughout the study. Accordingly, teacher-related and school-related variables were attached to each student record based on the mathematics teacher handling the student and the school in which the student was enrolled. Thus, the frequencies reported for teacher- and school-linked variables refer to the number of students associated with those contextual characteristics rather than to independent counts of teachers or schools. In the same way, the mathematics NAT-performance values correspond to the school-level ratings of the participating schools and were repeated across students within the same school context.

The use of an at-risk subgroup was central to the purpose of the study. Rather than modeling mathematics ability in a general student population, the study focused specifically on learners already identified as vulnerable to low mathematics performance. This sampling focus made it possible to examine more closely how contextual, instructional, and affective factors were associated with mathematics ability within a population for whom mathematics difficulty was already an immediate educational concern. The resulting respondent structure is therefore appropriate for the study's exploratory path-analysis objective, while also requiring caution in generalizing the findings beyond similarly screened at-risk junior high school learners.

2.3. Research Instruments

Four researcher-developed and validated instruments were used in the study: the Mathematics Ability Test (MAT), Mathematics Anxiety Survey (MAS), Attitude Toward Mathematics Instrument (ATMI), and Mathematics Teaching Strategy Inventory (MTSI). The item pools were generated from literature review, released assessment items, established mathematics affective-scale traditions, and commonly used teaching-strategy domains. The instruments were contextualized for Grade 9 at-risk learners in the local Philippine setting and underwent expert review, content validation, item analysis or revalidation, and reliability testing before use in the descriptive, regression, and exploratory path analyses.

The MAT was a TIMSS-like paper-and-pencil test consisting of 120 items, with 40 items each for conceptual understanding, procedural knowledge, and logical skills. The items covered are number, algebra, geometry, measurement, patterns, probability, and problem solving. Item construction was patterned from released TIMSS Grade 8 mathematics items and TIMSS-style assessment tasks (National Center for Education Statistics [NCES], 2013), and the competencies were aligned with the Grade 9 mathematics table of specifications. Scores from the MAT were used both to screen the respondents and to construct the mathematics-ability variables used in the descriptive, regression, and path analyses. Each domain had a maximum score of 40, while the total test had a maximum score of 120. Students scoring below 50% of the total score were classified as at risk in mathematics. Before administration, the test items were reviewed by three subject matter experts in mathematics, all with postgraduate preparation in the field and more than 15 years of teaching experience. The test was then subjected to item analysis and its internal consistency using the KR-21 coefficient was .735, indicating acceptable reliability.

The MAS was a 15-item five-point Likert-type instrument ranging from 1 (strongly disagree) to 5 (strongly agree). Its item pool drew from mathematics affective-scale traditions, particularly items on mathematics confidence, usefulness, value, and anxiety-related responses (Caviola et al., 2017; Doepken et al., 1993; Fennema & Sherman, 1976; Kul et al., 2024). In this study, the MAS was represented through two derived dimensions: appraisal and confidence. Rasch validation showed that the appraisal dimension retained nine items with item reliability = .96, person reliability = .91, and Cronbach's alpha = .90. The confidence dimension retained four items with item reliability = .89, person reliability = .83, and Cronbach's alpha = .78. Two items were excluded from the final analysis because they did not meet acceptable fit criteria. Higher scores indicated stronger endorsement of the items comprising each subscale.

The ATMI was a 25-item five-point Likert-type instrument designed to measure students' positive and negative orientations toward mathematics. Its item pool was informed by established mathematics attitude-scale literature on positive and negative affective responses toward mathematics (Aiken & Dreger, 1961; Dewanti et al., 2020; Szczygieł, 2022; Turanlı et al., 2008). Rasch validation yielded two dimensions: positive attitude and negative attitude. The positive attitude dimension retained 12 items with item reliability = .81, person reliability = .81, and Cronbach's alpha = .80. The negative attitude dimension retained 11 items with item reliability = .89, person reliability = .84, and Cronbach's alpha = .81. Two items were removed after validation because they did not satisfy the acceptable fit range. In the study dataset, these dimensions were used together with an overall composite score in the descriptive and screening analyses.

The MTSI was originally an 80-item five-point Likert-type instrument administered to the mathematics teachers. Its item pool was developed from common instructional strategy domains in mathematics teaching: lecture, reflective, collaborative, discovery, integrative, experiential, inquiry, and discussion. These domains are consistent with learner-centered pedagogical approaches emphasized in the K to 12 curriculum, particularly constructivist, collaborative, inquiry-based, reflective, integrative, and experiential approaches (SEAMEO INNOTECH, 2022). After pilot testing, two items from the experiential teaching-strategy domain were removed to improve reliability, resulting in a final 78-item version. Internal consistency estimates showed acceptable to high reliability across the domains, with Cronbach's alpha values ranging from .852 to .965.

The Likert-type instruments for mathematics anxiety, attitude toward mathematics, and teaching strategies were reviewed by five experts and subjected to item content validity index (I-CVI) and scale content validity index (S-CVI) procedures, consistent with established content-validity practices (Lynn, 1986; Polit et al., 2007). The resulting indices ranged from .81 to .94, indicating acceptable to high content validity. These instruments provided the observed-variable basis for the study's exploratory path-analysis framework.

2.4. Procedures

Data collection was conducted in person using printed test and survey instruments. First, the researchers administered the TIMSS-like Mathematics Ability Test to 450 Grade 9 students for screening purposes. The test consisted of three domains: conceptual understanding, procedural knowledge, and logical skills. To reduce test fatigue, the three domains were administered separately during regular mathematics classes, with the approval and coordination of the classroom mathematics teacher. Each domain was allotted 45 minutes, and the full Mathematics Ability Test was completed across three successive meetings. Students who scored below 50% of the total score were classified as at risk in mathematics. This screening yielded 370 at-risk students, who formed the descriptive sample for the study.

Second, the students identified as at risk completed the Mathematics Anxiety Survey and the Attitude Toward Mathematics Instrument on separate days. No strict time limit was imposed for these instruments because they were attitudinal measures rather than cognitive tests. Students were given sufficient time to read and respond to each item honestly, with the clarification that there were no right or wrong answers. Student background information, including age, sex, and ethnicity, was also recorded as part of the analytic dataset.

Third, the Mathematics Teaching Strategy Inventory was administered in person to the mathematics teachers linked to the student respondents. No strict time limit was imposed because the instrument required teachers to report their instructional practices rather than answer test items. Teacher profile information, including field of specialization and self-reported use of mathematics teaching strategies, was gathered. These teacher data were then attached to each student record based on the mathematics teacher handling that student. In the same way, school-linked contextual information, such as the type of school, school location, and mathematics NAT performance, was attached to each student record based on the school attended. The resulting dataset was organized at the student level, with teacher-related and school-related variables represented as contextual values linked to each student case.

Fourth, the dataset was screened and prepared for analysis. The 370 at-risk cases were first used for descriptive statistics and contextual summaries. For the inferential analyses, two cases with incomplete data were treated as missing and excluded from the regression and path-analysis stages, resulting in an analytic sample of 368 students. This accounts for the difference between the descriptive and inferential sample sizes reported in the Results section.

The procedure moved from screening to subgroup identification, to student and teacher data collection, and finally to dataset integration for exploratory path analysis. This sequence was appropriate because the study aimed to explain mathematics ability specifically among students already identified as vulnerable to low mathematics performance while accounting for the instructional and school contexts linked to them.

2.5. Data Analysis

Data analysis proceeded in three stages: descriptive analysis, regression-based screening, and exploratory path analysis. All statistical analyses were conducted using Jamovi version 2.6.26. The level of statistical significance was set at $\alpha = .05$ for all inferential tests.

First, descriptive statistics were computed to summarize the profile of the at-risk student sample and the distributions of the student, teacher, and school-linked variables. Frequencies and percentages were used for categorical variables, while means, standard deviations, skewness, and kurtosis were computed for the student scale variables. For the teacher strategy variables, only means, standard deviations, and rank order were reported because the teacher sample was small. These descriptive analyses were based on the 370 at-risk students retained after the initial screening process.

Second, multiple regression screening analyses were conducted to identify the observed variables most strongly associated with mathematics ability and with the student affective variables retained for the final model. Separate regression models were estimated for: (a) student factors predicting mathematics ability, (b) school-linked factors predicting student affective variables, and (c) teacher-linked factors predicting student affective variables. In these models, mathematics ability was treated as a composite observed outcome, while the student affective variables included Appraisal, Confidence, and attitude-related dimensions. These screening analyses were used to identify candidate direct and indirect paths for the final exploratory model. Because two cases with incomplete or extreme values were excluded from the inferential dataset, regression analyses involving mathematics ability used 368 student cases, whereas some screening analyses involving contextual variables remained based on the descriptive at-risk sample of 370.

Third, exploratory path analysis was performed using observed variables only. Path analysis was selected because the study aimed to estimate direct and indirect relationships among measured variables rather than latent constructs. The final parsimonious model was developed by retaining only those pathways that were theoretically sensible and empirically supported by the screening analyses and model refinement process. The resulting model linked selected school-related factors, teacher-related instructional variables, and student affective variables to mathematics ability through a reduced set of direct and indirect paths. Model fit was evaluated using the chi-square test statistic (χ^2), degrees of freedom (*df*), standardized root mean square residual (SRMR), root mean square error of approximation (RMSEA) with its 90% confidence interval, comparative fit index (CFI), and Tucker–Lewis index (TLI). Direct and indirect effects were interpreted using unstandardized coefficients (*B*), standard errors, standardized estimates (β), confidence intervals, and p-values.

Throughout the analysis, the student remained the unit of analysis. Teacher-related and school-related predictors were linked to each student based on the mathematics teacher handling the student and the school attended. These contextual predictors were therefore repeated across student records within the same teacher or school grouping. For this reason, the retained path model was interpreted as an exploratory student-level path model rather than as a multilevel or hierarchical model of independent teacher-related or school-level effects.

3. RESULTS

3.1. Respondent Profile and Student-Linked Contextual Characteristics

Table 1 presents the profile of the at-risk junior high school students included in the descriptive phase of the analysis. The respondents were between 14 and 17 years old, with the largest proportion being 15 years old (62.4%), followed by those aged 16 years old (28.4%), 17 years old (6.5%), and 14 years old (2.7%). In terms of sex, the sample was nearly balanced, with 188 female students (50.8%) and 182 male students (49.2%). Most respondents were Cebuano/Bisaya (96.2%), whereas only 3.8% were Maranao.

Table 1. Respondent Profile and Student-Linked Contextual Characteristics (N = 370)

Variable	Category	*n*	%
Student demographics			
Age	14 years old	10	2.7
	15 years old	231	62.4
	16 years old	105	28.4
	17 years old	24	6.5
Sex	Female	188	50.8
	Male	182	49.2
Ethnicity	Cebuano/Bisaya	356	96.2
	Maranao	14	3.8
Student-linked instructional and school context			
Teacher's field of specialization	General Education	172	46.5
	Mathematics Education	198	53.5
Type of school	Public	272	73.5
	Private	98	26.5
School location	Urban	183	49.5
	Rural	187	50.5
Mathematics NAT performance (%)	43.9	98	26.5
	50.1	104	28.1
	57.7	89	24.1
	65.7	79	21.4

Note. Frequencies and percentages are based on the number of student respondents, consistent with the student as the unit of analysis. Thus, categories under teacher- and school-related variables indicate the number of students taught by teachers with those characteristics or enrolled in schools with those characteristics, rather than the number of teachers or schools themselves. The Mathematics NAT performance values correspond to the school-level ratings of the four participating schools and are repeated across students within each school.

With respect to student-linked instructional and school context, a slightly larger share of students was taught by teachers whose field of specialization was Mathematics Education (53.5%) than by teachers with General Education specialization (46.5%). Most students were enrolled in public schools (73.5%), while 26.5% came from private schools. The distribution by school location was also nearly even, with 49.5% from urban schools and 50.5% from rural schools.

In terms of school mathematics performance, the largest proportion of students came from schools with a mathematics NAT performance of 50.1% (28.1%), followed by 43.9% (26.5%), 57.7% (24.1%), and 65.7% (21.4%). These figures indicate that the respondents were distributed across four school contexts with varying levels of school mathematics performance.

It is important to note that the student was treated as the unit of analysis. Thus, the teacher- and school-related variables reported in Table 1 represent the number of students linked to those contextual characteristics rather than independent counts of teachers or schools. In particular, the mathematics NAT performance values correspond to the school-level ratings of the four participating schools and were repeated across students within each school.

This profile suggests that the at-risk student sample was demographically balanced in sex, predominantly Cebuano/Bisaya, and situated across distinct teacher- and school-linked contexts that were later examined as possible sources of variation in mathematics-related affect and ability.

3.2. Descriptive Statistics of Student and Teacher Variables

Table 2 summarizes the descriptive statistics of the student variables retained for the exploratory modeling process. For attitude toward mathematics, the students showed a mean of 3.31 for Positive Attitude and 3.12 for Negative Attitude, with an overall composite mean of 3.22. For mathematics anxiety, the mean for appraisal was 3.52, while Confidence had a mean of 3.31, yielding an overall composite mean of 3.46. In terms of mathematics ability, the highest mean score was observed in conceptual understanding (M = 21.1, SD = 6.37), followed by logical skills (M = 19.5, SD = 6.38) and procedural knowledge (M =

16.5, *SD* = 7.34). The overall mathematics ability composite mean was 57.0 (*SD* = 18.48), which is consistent with the classification of the retained respondents as at-risk students based on the study's below-threshold screening criterion. The observed skewness and kurtosis values reported in Table 2 were generally modest, suggesting no severe univariate departure from normality among the student variables used in the screening and path analyses.

Table 2. Descriptive Statistics for Students' Mathematics Attitudes, Anxiety, and Ability (*N* = 370)

Observed Variable	Subscale	M	SD	Skewness		Kurtosis	
				Skewness	SE	Kurtosis	SE
Attitude Towards Mathematics	Positive Attitude	3.31	0.62	-0.26	0.13	0.52	0.25
	Negative Attitude	3.12	0.59	-0.15	0.13	0.53	0.25
	Composite Score	**3.22**	**0.35**	**-0.24**	**0.13**	**0.80**	**0.25**
Mathematics Anxiety	Appraisal	3.52	0.58	-0.02	0.13	-0.30	0.25
	Confidence	3.31	0.68	0.13	0.13	0.34	0.25
	Composite Score	**3.46**	**0.49**	**0.25**	**0.13**	**0.57**	**0.25**
Mathematics Ability	Conceptual Understanding	21.1	6.37	-0.47	0.13	0.14	0.25
	Procedural Knowledge	16.5	7.34	-0.36	0.13	-0.72	0.25
	Logical Skills	19.5	6.38	-0.40	0.13	-0.58	0.25
	Composite Score	**57.0**	**18.48**	**-0.67**	**0.13**	**-0.34**	**0.25**

Note. Statistics are based on student data only. Attitude and anxiety scores were obtained from 5-point Likert-type scales, with higher scores indicating stronger endorsement of the measured dimension; thus, higher scores indicate stronger endorsement of the items comprising each subscale. Mathematics ability scores were based on raw scores and interpreted using the study's quartile-based descriptive guide (e.g., scores below the 3rd quartile were classified as average). These score meanings are provided only to guide interpretation and do not represent standardized normative benchmarks.

The pattern suggests that the respondents performed relatively better in conceptual understanding than in logical and procedural aspects of mathematics, while procedural knowledge emerged as the weakest of the three mathematics-ability dimensions. At the same time, the means for the affective variables indicate that the students generally expressed moderate levels of both mathematics-related attitudes and anxiety-related responses, rather than extremely favorable or unfavorable positions. These patterns justified retaining both affective and cognitive variables in the subsequent screening analyses for the final path model.

Table 3. Descriptive Statistics for Teachers' Self-Reported Use of Mathematics Teaching Strategies (*n* = 8)

Variable Observed	Subscale	Mean	SD	Rank
Teaching Strategy	Lecture	3.98	0.11	7
	Reflective	4.00	0.16	4
	Collaborative	4.16	0.21	1
	Discovery	4.07	0.14	2
	Integrative	3.99	0.09	5
	Inquiry	3.99	0.14	6
	Experiential	3.83	0.18	8
	Discussion	4.01	0.08	3

Note. Statistics are based on teachers' self-reports. Teaching strategy scores were obtained from 5-point Likert-type scales, with higher mean scores indicating more frequent use of the strategy in teaching mathematics; values near the upper end of the scale suggest that the strategy was used often to always. These score meanings are provided only to guide interpretation and do not represent standardized benchmarks.

The teacher variables are presented in revised Table 3 using mean and standard deviation only, as these provide the most useful descriptive summary for the small teacher sample. Across the seven retained strategy domains, the reported means ranged from 3.98 to 4.16, indicating that all strategies were used relatively often. Collaborative strategy had the highest mean (*M* = 4.16, *SD* = 0.21), followed by discovery (*M* = 4.07, *SD* = 0.14), discussion (*M* = 4.01, *SD* = 0.08), reflective (*M* = 4.00, *SD* = 0.16), integrative (*M* = 3.99, *SD* = 0.09), inquiry (*M* = 3.99, *SD* = 0.14), lecture (*M* = 3.98, *SD* = 0.11), and experiential (*M* = 3.83, *SD* = 0.18). These descriptive results suggest that the mathematics teachers reported frequent use of multiple instructional strategies rather than reliance on a single dominant classroom approach.

Consistent with the instrument structure used in the study, the student measures represented two attitude dimensions, two mathematics-anxiety dimensions, and three mathematics-ability dimensions, whereas the teacher block represented multiple self-reported strategy domains in mathematics instruction. These descriptive results served as the empirical starting point for the regression screening procedures and the development of the final parsimonious path model reported in the succeeding subsections.

3.3. Preliminary Regression Screening of Student, School, and Teacher Factors

To identify candidate paths for the final exploratory model, preliminary multiple regression analyses were conducted separately for student factors, school-linked factors, and teacher-linked factors. These analyses were used as screening procedures to determine which observed variables showed meaningful associations with mathematics ability and with the two student affective dimensions later considered in the path model.

Table 4. Multiple Regression Analysis of Student Factors Associated with Mathematics Ability (*N* = 368)

Predictor	B	SE	β	95% Confidence Interval		p-value
				Lower	*Upper*	
Sex (Male – Female)	-1.63	1.05	-0.04	-0.10	0.01	.123
Ethnicity (Maranao – Cebuano)	-3.30	2.68	-0.03	-0.09	0.02	.220
Positive Attitude	2.24	1.22	0.08	-0.01	0.16	.066
Negative Attitude	-2.96	1.14	-0.09	-0.16	-0.02	.010
Appraisal	18.24	1.24	0.57	0.49	0.64	<.001
Confidence	7.38	1.18	0.27	0.18	0.35	<.001

Note. Dependent variable = Mathematics Ability. Unstandardized coefficients are reported as B with corresponding standard errors (SE), and confidence intervals are shown for the standardized coefficients (β). The intercept is omitted for brevity. The overall model was significant, R = .851, R^2 = .725, adjusted R^2 = .720, RMSE = 9.68, $F(6, 361)$ = 158.00, p < .001.

The student-factor regression results are presented in Table 4. The overall model was statistically significant, $F(6, 361) = 158.00, p < .001$, explaining 72.5% of the variance in mathematics ability (R^2 = .725; adjusted R^2 = .720). This suggests that the model had strong explanatory power. Among the predictors, appraisal (B = 18.24, β = .57, p < .001), this means that students with higher appraisal scores tended to have substantially higher mathematics ability scores, holding the other student factors constant. Additionally, confidence (B = 7.38, β = .27, p < .001) showed significant positive effects, indicating that students with greater confidence in mathematics tended to demonstrate higher mathematics ability. In contrast, a negative attitude showed a significant negative effect (B = -2.96, β = - .094, p = .010). This suggests that, after accounting for the other predictors, students with stronger negative attitudes toward mathematics tended to have lower mathematics ability scores. Moreover, sex, ethnicity, and positive attitude did not significantly predict mathematics ability in the screening model. These results suggested that the most relevant student-level candidates for the final path model were not the demographic variables, but the affective dimensions of mathematics anxiety and attitude.

School-linked screening models are shown in Table 5. For mathematics anxiety, the model was significant, $F(3, 366) = 27.8, p < .001$, with R^2 = .186. In this model, the type of school had a significant negative association (B = -0.19, β = -.38, p = .032), indicating that students in private schools tended to have lower mathematics anxiety scores than those in public schools. While mathematics NAT performance also showed a significant negative association (B = -0.03, β = -.54, p < .001), suggesting that students from schools with higher NAT mathematics performance tended to report lower mathematics anxiety scores. School location was not significant. For attitude toward mathematics, the model was likewise significant, $F(3, 366) = 4.68, p = .003$, although the explained variance was much smaller (R^2 = .037). Here, the type of school was positively associated with attitude (B = 0.15, β = .43, p = .027), indicating that students in private schools tended to obtain higher attitude scores than those in public schools. School location was negatively associated with attitude (B = -0.17, β = -.47, p < .001). This implies that students in rural schools tend to have lower attitude scores than those in urban schools. While the mathematics NAT performance was not significant. These screening models indicated that school context was more strongly related to students' mathematics anxiety than to their general attitude toward mathematics.

Table 5. Regression Models of School-Related Factors Associated with Student Factors (*N* = 370)

Model	Predictor	B	SE	β	95% CI		p-value
					Lower	Upper	
Model 1: Mathematics Anxiety R = .431, R² = .186, adjusted R² = .179, RMSE = .440, F(3, 366) = 27.8, p < .001.	Type of School (Private – Public)	-0.19	0.09	-0.38	-0.74	-0.03	.032
	School Location (Rural – Urban)	0.01	0.06	0.02	-0.21	0.25	.882
	Mathematics NAT Performance	-0.03	0.00	-0.54	-0.67	-0.40	<.001
Model 2: Attitude towards Mathematics R = .192, R² = .037, adjusted R² = .029, RMSE = .346, F(3, 366) = 4.68, p = .003	Type of School (Private – Public)	0.15	0.07	0.43	0.05	0.81	.027
	School Location (Rural – Urban)	-0.17	0.04	-0.47	-0.72	-0.22	<.001
	Mathematics NAT Performance	0.00	0.00	0.03	-0.12	0.18	.718

***Note*.** Models were estimated from student-level observations (N=370), with school-related predictors linked to each student based on the school attended. Thus, school-level values were repeated across students and should be interpreted as exploratory student-level associations rather than independent school-level effects. Unstandardized coefficients are reported as B with corresponding standard errors (SE). Confidence intervals shown are for the standardized coefficients (*β*).

Table 6. Regression Models of Teacher-Related Factors Associated with Student Factors (*N* = 370)

Model	Predictor	B	SE	β	95% CI		p-value
					Lower	Upper	
Model 1: Mathematics Anxiety *R* = .466, *R*² = .217, adjusted *R*² = .200, RMSE = .431, *F*(8, 361) = 12.5, *p* < .001.	Teacher's Field of Specialization:						
	Mathematics Education – General Education	0.02	0.08	0.04	-0.28	0.36	.805
	Lecture	0.90	0.48	0.21	-0.01	0.43	.059
	Reflective	-1.82	0.49	-0.58	-0.89	-0.28	<.001
	Collaborative	-0.99	0.28	-0.42	-0.67	-0.18	<.001
	Discovery	1.86	0.76	0.54	0.10	0.97	.015
	Integrative	-1.18	1.11	-0.22	-0.63	0.19	.290
	Inquiry	-2.32	0.66	-0.64	-0.90	-0.28	<.001
	Discussion	1.97	0.70	0.31	0.09	0.53	.005
Model 2: Attitude towards Mathematics *R* = .251, *R*² = .063, adjusted *R*² = .042, RMSE = .341, *F*(8, 361) = 3.03, *p* = .003	Teacher's Field of Specialization:						
	Mathematics Education – General Education	0.02	0.06	0.04	-0.31	0.39	.811
	Lecture	0.81	0.38	0.26	0.02	0.50	.033
	Reflective	1.02	0.39	0.45	0.11	0.79	.009
	Collaborative	0.22	0.22	0.13	-0.13	0.40	.326
	Discovery	1.35	0.60	0.54	0.07	0.72	.025
	Integrative	-2.13	0.88	-0.55	-0.99	-0.10	.016
	Inquiry	-0.86	0.52	-0.33	-0.72	0.06	.101
	Discussion	-0.38	0.56	-0.08	-0.32	0.16	.499

***Note*.** Models were estimated from student-level observations (N=370), with teacher-related predictors linked to each student based on the mathematics teacher handling that student. Thus, teacher-level values were repeated across students and should be interpreted as exploratory student-level associations rather than independent teacher-level effects. Unstandardized coefficients are reported as B with corresponding standard errors (SE). Confidence intervals shown are for the standardized coefficients (*β*).

Teacher-linked screening models are presented in Table 6. For mathematics anxiety, the model was significant, $F(8, 361) = 12.5, p < .001$, with $R^2 = .217$. Significant negative predictors were reflective strategy ($B = -1.82, \beta = -.58, p < .001$), collaborative strategy ($B = -0.99, \beta = -.42, p < .001$), and inquiry strategy ($B = -2.23, \beta = -.64, p < .001$), indicating that students whose teachers reported more frequent use of these strategies tended to have lower mathematics anxiety scores. On the contrary, discovery ($B = 1.86, \beta = .54,$

p = .015) and discussion (*B* = 1.97, *β* = .31, *p* = .005) showed positive associations, suggesting that more frequent use of these strategies was associated with higher mathematics anxiety scores. The lecture was only marginal (*p* = .059), and the teacher's field of specialization was not significant. For attitude toward mathematics, the teacher-linked model was also significant, $F(8, 361) = 3.035$, $p = .003$, though with smaller explanatory power ($R^2 = .063$). In this model, lecture, reflective, and discovery strategies showed significant positive associations with attitude, indicating that students tended to show more favorable attitudes in mathematics when these strategies were more frequently used by their teachers. On the other hand, the integrative strategy showed a significant negative association, suggesting that more frequent use of this strategy was associated with less favorable attitudes. The remaining teacher variables were not significant. These results suggested that specific teaching strategies were more consistently linked to students' anxiety and attitude than was teacher field of specialization alone.

These preliminary screening analyses informed the construction of the final parsimonious path model in two ways. First, they showed that appraisal and confidence were the most prominent student-level candidates for direct links to mathematics ability. Second, they indicated that selected school- and teacher-linked variables were more plausibly connected to mathematics ability through student affective factors than through broad direct effects alone. Because teacher- and school-related predictors were linked to students through repeated contextual values, however, these screening results are interpreted cautiously as exploratory student-level associations rather than as independent teacher- or school-level effects.

3.4. Final Parsimonious Path Model of Mathematics Ability

Following the preliminary regression screening, an exploratory path analysis was conducted to identify the most parsimonious model that could explain mathematics ability among at-risk junior high school students. The retained model is shown in Figure 2, while its global fit indices are presented in Table 9. As depicted, the final model linked school-related factors, selected teacher-related strategy variables, and student affective variables to mathematics ability through a smaller and more interpretable set of direct and indirect paths.

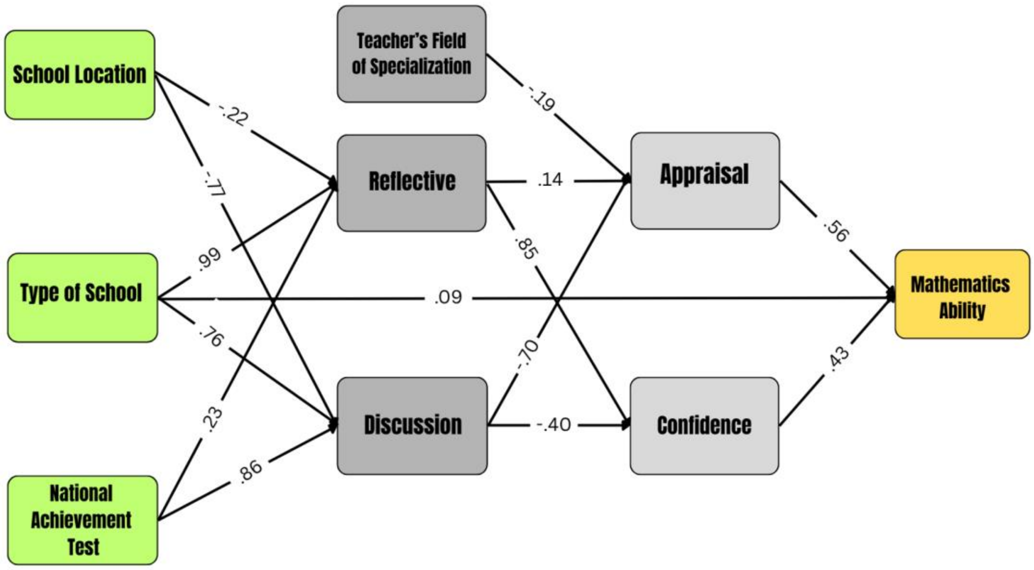

Figure 2. Final Parsimonious Mathematics Ability Model of At-Risk Students

The final parsimonious path model, as shown in Figure 2, demonstrated good overall fit to the data, with χ^2=24.2, df=16, and p=.085. The remaining fit indices also supported the adequacy of the model: SRMR = .035, RMSEA = .037, with a 90% confidence interval of [.000, .066], CFI = .996, and TLI = .993. These indices suggest that the retained model reproduced the observed covariance structure well and provided an acceptable parsimonious representation of the relationships among the retained variables.

Table 7. Global Fit Indices for the Final Parsimonious Path Model

Model	χ^2	*df*	*p*	SRMR	RMSEA	90% CI for RMSEA	CFI	TLI
Final parsimonious path model	24.2	16	.085	.035	.037	[.000, .066]	.996	.993

Note. χ^2 = chi-square test statistic; *df* = degrees of freedom; SRMR = standardized root mean square residual; RMSEA = root mean square error of approximation; CI = confidence interval; CFI = comparative fit index; TLI = Tucker-Lewis index

The structure of the final model, therefore, supports an exploratory interpretation in which mathematics ability among at-risk students is shaped through a chain of interrelated contextual, instructional, and affective influences. More specifically, the retained model suggests that school context may matter partly because it is associated with the kinds of teaching strategies students encounter, and these strategies may, in turn, relate to students' confidence and value/learning-related responses toward mathematics. Those student affective dimensions, rather than broad demographic characteristics, emerged as the most proximal predictors of mathematics ability in the final model.

Because the retained school- and teacher-related predictors were linked to students through repeated contextual values, the model should be interpreted as an exploratory student-level path model rather than as a multilevel causal model of independent teacher or school effects. Even with this caution, the model provides a coherent and well-fitting account of how selected contextual and affective factors may operate together in relation to mathematics ability among students already identified as academically at risk in mathematics.

3.5. Direct Effects on the Final Path Model

The direct effects retained in the final parsimonious path model are presented in Table 8. At the level of the outcome variable, three predictors showed statistically significant direct effects on mathematics ability. Appraisal had the strongest positive direct effect on mathematics ability (B = 18.05, β = .56, p < .001), followed by confidence (B = 11.87, β = .43, p < .001). In addition, the type of school retained a smaller but statistically significant positive direct effect (B = 3.58, β = .09, p = .025). These results indicate that, within the retained model, student affective variables were the most proximal and influential direct predictors of mathematics ability, while school type still contributed a modest contextual effect even after the intervening variables were taken into account.

Table 8. Direct Effects Retained in the Final Parsimonious Path Model of Mathematics Ability (*N* = 368)

Path (Direct Effect)	B	SE	95% CI		β	z-value	p -value
			Lower	Upper			
Type of School → Mathematics Ability	3.58	1.60	0.45	6.71	0.09	2.24	0.025
Confidence → Mathematics Ability	11.87	3.39	5.22	18.51	0.43	3.5	<.001
Appraisal → Mathematics Ability	18.05	3.66	10.87	25.23	0.56	4.93	<.001
Discussion → Confidence	-3.50	0.54	-4.57	-2.44	-0.40	-6.44	<.001
Reflective → Confidence	3.68	0.29	3.12	4.24	0.85	12.9	<.001
Teacher's Field of Specialization → Appraisal	-0.22	0.06	-0.34	-0.09	-0.19	-3.47	<.001
Discussion → Appraisal	-5.28	0.65	-6.56	-4.00	-0.70	-8.09	<.001
Reflective → Appraisal	4.18	0.31	3.57	4.80	0.14	13.3	<.001
Mathematics NAT Performance → Discussion	0.01	0.00	0.01	0.01	0.86	8.29	<.001
School Location → Discussion	-0.12	0.01	-0.13	-0.10	-0.77	-18.09	<.001
Type of School → Discussion	0.13	0.02	0.10	0.16	0.76	8.55	<.001
Mathematics NAT Performance → Reflective	0.00	0.00	0.00	0.01	0.23	3.33	<.001
School Location → Reflective	-0.38	0.01	-0.40	-0.35	-0.22	-27.94	<.001
Type of School → Reflective	0.35	0.02	0.30	0.40	0.99	14	<.001

At the level of the student affective variables, both discussion and reflective teaching strategies showed significant direct effects on confidence. Discussion had a negative direct effect on confidence (B =

-3.50, $\beta = -.40$, $p < .001$), whereas reflective strategy had a strong positive direct effect ($B = 3.68$, $\beta = .85$, $p < .001$). A similar pattern appeared for appraisal. The teacher's field of specialization had a negative direct effect ($B = -.22$, $\beta = -.19$, $p < .001$), discussion also had a negative direct effect ($B = -5.28$, $\beta = -.70$, $p < .001$), and reflective strategy had a positive direct effect ($B = 4.18$, $\beta = .14$, $p < .001$). These findings suggest that the instructional processes retained in the model were linked meaningfully to the two student affective mediators, although the directions of the effects differed across strategy types.

The model also retained significant direct paths from the school-related variables to the two teacher-strategy variables. For discussion teaching strategy in mathematics, mathematics NAT performance ($B = 0.01$, $\beta = .86$, $p < .001$) and type of school ($B = 0.13$, $\beta = .76$, $p < .001$) showed positive effects, whereas school location had a negative effect ($B = -0.12$, $\beta = -.77$, $p < .001$). For the reflective strategy, mathematics NAT performance again showed a positive effect ($B \approx 0.00$, $\beta = .23$, $p < .001$), type of school had a strong positive effect ($B = 0.35$, $\beta = .99$, $p < .001$), and school location showed a negative effect ($B = -0.38$, $\beta = -.22$, $p < .001$). These direct paths indicate that school context was linked to mathematics ability not only through a small remaining direct effect of school type, but also through its associations with the instructional strategies retained in the model.

Overall, the direct effects support the interpretation that mathematics ability among at-risk students was most immediately associated with the affective dimensions of appraisal and confidence, while school and teacher variables operated both directly and through more proximal instructional and affective pathways. In particular, the pattern of retained direct paths suggests a layered structure in which contextual conditions were associated with teacher strategy use, teacher strategy use was associated with student affective responses, and these affective responses were in turn associated with mathematics ability.

3.6. Indirect Effects in the Final Path Model

The specific indirect effects retained in the final parsimonious path model are presented in Table 9. Overall, the indirect-effect results show that the contributions of school- and teacher-related variables to mathematics ability were transmitted primarily through the mediating roles of discussion, reflective strategy, confidence, and appraisal in mathematics. This pattern reinforces the logic of the final model in which contextual and instructional factors were linked to mathematics ability mainly through more proximal student affective processes rather than through broad direct effects alone.

Among the school-related variables, Type of School showed substantial indirect effects on mathematics ability through two contrasting pathways. Through the chain type of school → discussion → confidence → mathematics ability, the indirect effect was negative ($B = -5.45$, $\beta = -.13$, $p = .003$), and through type of school → discussion → appraisal → mathematics ability, the indirect effect was also negative and larger in magnitude ($B = -12.49$, $\beta = -.30$, $p < .001$). In contrast, the reflective-strategy routes were positive: type of school → reflective → confidence → mathematics ability yielded a positive indirect effect ($B = 15.17$, $\beta = .36$, $p < .001$), while type of school → reflective → appraisal → mathematics ability showed an even stronger positive indirect effect ($B = 26.22$, $\beta = .63$, $p < .001$). These contrasting paths suggest that school type was linked to mathematics ability through different instructional channels that operated in opposite directions.

A similar pattern appeared for the teacher-strategy variables themselves. Discussion had negative indirect effects on mathematics ability through both confidence ($B = -41.58$, $\beta = -.17$, $p = .001$) and appraisal ($B = -95.28$, $\beta = -.39$, $p < .001$). By contrast, the reflective strategy had positive indirect effects through both confidence ($B = 43.67$, $\beta = .37$, $p < .001$) and appraisal ($B = 75.51$, $\beta = .63$, $p < .001$). These findings suggest that, within the retained model, the reflective strategy functioned as a beneficial instructional pathway, whereas the discussion strategy was associated with less favorable indirect pathways to mathematics ability. The teacher's field of specialization also showed a significant negative indirect effect through appraisal ($B = -3.91$, $\beta = -.11$, $p = .002$), indicating that specialization was linked to mathematics ability through this affective mediator rather than through a retained direct path.

The school mathematics context also exerted indirect effects through the same mediating chains. Mathematics NAT performance showed a negative indirect effect through the discussion routes, both via confidence ($B = -0.34$, $\beta = -.15$, $p = .002$) and through appraisal ($B = -0.78$, $\beta = -.34$, $p < .001$). However, the reflective routes were positive, with mathematics NAT performance → Reflective → confidence →

mathematics ability yielding (*B* = 0.19, *β* = .08, *p* = .016) and mathematics NAT performance → reflective → appraisal → mathematics ability yielding (*B* = 0.33, *β* = .14, *p* = .010). For school location, the pattern again differed by route: the discussion-mediated chains were positive, whereas the reflective-mediated chains were negative. Specifically, school location → discussion → confidence → mathematics ability had a positive indirect effect (*B* = 4.82, *β* = .13, *p* = .002), and school location → discussion → appraisal → mathematics ability had a larger positive effect (*B* = 11.04, *β* = .30, *p* < .001). In contrast, school location → reflective → confidence → mathematics ability showed a negative indirect effect (*B* = -16.43, *β* = -.45, *p* < .001), while school location → reflective → appraisal → mathematics ability showed the strongest negative indirect effect, as shown in the table (*B* = -28.40, *β* = -.77, p < .001).

Table 9. Indirect Effects in the Final Parsimonious Path Model of Mathematics Ability (*N* = 368)

Path Description	B	SE	CI [L, U]	β	p-value
Type of School ⇒ Discussion ⇒ Confidence ⇒ Mathematics Ability	-5.45	1.82	[-9.02, -1.89]	-0.13	.003
Type of School ⇒ Discussion ⇒ Appraisal ⇒ Mathematics Ability	-12.49	3.18	[-18.72, -6.27]	-0.30	<.001
Type of School ⇒ Reflective ⇒ Confidence ⇒ Mathematics Ability	15.17	4.44	[6.46, 23.87]	0.36	<.001
Type of School ⇒ Reflective ⇒ Appraisal ⇒ Mathematics Ability	26.22	5.83	[14.80, 37.64]	0.63	<.001
Discussion ⇒ Confidence ⇒ Mathematics Ability	-41.58	13.03	[-67.12, -16.05]	-0.17	.001
Discussion ⇒ Appraisal ⇒ Mathematics Ability	-95.28	22.11	[-138.61, -51.94]	-0.39	<.001
Reflective ⇒ Confidence ⇒ Mathematics Ability	43.67	12.45	[19.26, 68.07]	0.37	<.001
Reflective ⇒ Appraisal ⇒ Mathematics Ability	75.51	16.11	[43.94, 107.07]	0.63	<.001
Teacher's Field of Specialization ⇒ Appraisal ⇒ Mathematics Ability	-3.91	1.27	[-6.39, -1.42]	-0.11	.002
Mathematics NAT Performance ⇒ Discussion ⇒ Confidence ⇒ Mathematics Ability	-0.34	0.11	[-0.56, -0.12]	-0.15	.002
Mathematics NAT Performance ⇒ Discussion ⇒ Appraisal ⇒ Mathematics Ability	-0.78	0.19	[-1.15, -0.41]	-0.34	<.001
Mathematics NAT Performance ⇒ Reflective ⇒ Confidence ⇒ Mathematics Ability	0.19	0.08	[0.04, 0.35]	0.08	.016
Mathematics NAT Performance ⇒ Reflective ⇒ Appraisal ⇒ Mathematics Ability	0.33	0.13	[0.08, 0.59]	0.14	.010
School Location ⇒ Discussion ⇒ Confidence ⇒ Mathematics Ability	4.82	1.54	[1.80, 7.84]	0.13	.002
School Location ⇒ Discussion ⇒ Appraisal ⇒ Mathematics Ability	11.04	2.70	[5.75, 16.34]	0.30	<.001
School Location ⇒ Reflective ⇒ Confidence ⇒ Mathematics Ability	-16.43	4.72	[-25.67, -7.18	-0.45	<.001
School Location ⇒ Reflective ⇒ Appraisal ⇒ Mathematics Ability	-28.40	5.95	[-40.07, -16.73]	-0.77	<.001

Note. Estimates are based on student-level observations (N=368). Teacher- and school-related predictors were linked to each student based on the mathematics teacher handling the student and the school attended; accordingly, these effects should be interpreted as exploratory student-level associations rather than independent teacher- or school-level effects. Unstandardized indirect effects are reported as B with corresponding standard errors (SE) and 95% confidence intervals; β denotes the standardized indirect effect. Only the specific indirect effects retained in the final parsimonious model are presented.

These indirect effects indicate that the influence of school and teacher context on mathematics ability was not uniform but pathway-dependent. In particular, the final model suggests that the same contextual factor may relate to mathematics ability differently depending on whether it operates through discussion or reflective strategy and whether the more proximal student mediator is confidence or appraisal. Thus, the model highlights that the association of contextual factors with mathematics ability among at-risk students is best understood as an interconnected chain of exploratory pathways rather than as a single linear effect. Because these estimates were derived from student-level observations with repeated teacher- and school-linked values, they should be interpreted cautiously as exploratory student-level indirect associations rather than as independent teacher- or school-level causal effects.

4. DISCUSSION

This study examined mathematics ability among at-risk students through an exploratory path model linking school-related, teacher-related, and student-related factors. The final model suggests that mathematics ability in this group is best understood not as a purely demographic or school-composition outcome, but as an affectively proximal and contextually conditioned phenomenon. In the preliminary screening model, student affective variables were more salient than sex and ethnicity, with appraisal and confidence emerging as the strongest positive predictors of mathematics ability, while negative attitude showed a smaller negative effect. In the final parsimonious path model, appraisal and confidence remained the most immediate direct predictors of mathematics ability, whereas teacher- and school-related factors operated mainly through instructional and affective pathways. This pattern suggests that, among students already identified as mathematically at risk, what matters most immediately is not who they are demographically, but how they evaluate mathematics and how capable they feel in engaging with it.

Appraisal emerged as a key proximal pathway in the final model. Students' evaluative orientation toward mathematics, especially whether they see it as useful, learnable, and personally meaningful, formed an important link between broader learning conditions and mathematics performance. This interpretation is consistent with the multidimensional view of mathematics-related affect advanced by Wen and Dubé (2022), who argue that value, confidence, self-concept, and anxiety should not be collapsed into a single undifferentiated construct. It also aligns with Control-Value Theory, which explains that students' judgments of value and control shape achievement emotions, engagement, and performance (Pekrun, 2024). In this study, appraisal appears to function as a motivational and interpretive lens through which at-risk students decide whether mathematics is worth sustained effort.

The prominence of confidence reinforces this interpretation. Confidence showed a strong positive direct effect on mathematics ability, second only to appraisal, suggesting that perceived capability remains central even among students already classified as low-performing. This finding aligns with evidence that mathematics self-efficacy and achievement are reciprocally related over time, such that stronger competence beliefs support engagement and performance, while successful performance also strengthens later self-belief (Du et al., 2021). Recent evidence further shows that mathematics anxiety and mathematics confidence do not necessarily change in simple opposite directions, indicating that confidence-building should be treated as an explicit instructional target rather than as a mere by-product of reducing anxiety (Smith et al., 2025). Similarly, Granello et al. (2025) emphasized that mathematics self-efficacy and self-concept are crucial for sustaining mathematics learning in middle school and that interventions can be designed to strengthen these beliefs. Taken together, the present findings suggest that mathematics ability among at-risk learners is supported by a dual affective process: students must see mathematics as worth engaging and must also believe that they can engage it successfully.

Teacher strategy mattered mainly through student affective pathways. Reflective strategy showed positive effects on both confidence and appraisal, whereas discussion showed negative effects on the same mediators. The indirect-effect results extended this pattern: reflective strategy had positive indirect effects on mathematics ability through confidence and appraisal, whereas discussion had negative indirect effects through the same pathways. This contrast is substantively meaningful. The reflective strategy items emphasize self-analysis, revisiting prior experiences, guided reflection, and connecting lessons to students' real-life experiences. They also include reflective expression through journals, portfolios, recounting experiences, and similar activities. These features suggest that reflective teaching may provide at-risk students with structured opportunities to interpret mathematics learning in personally meaningful ways. By contrast, the discussion-related items emphasize participation in classroom discourse, debate, structured presentation of ideas, comparison of information, and drawing conclusions through interaction. Although these processes can support learning, they may also place greater verbal and cognitive demands on students who are already uncertain in mathematics. This interpretation is consistent with studies showing that access to mathematical understanding can be shaped by how classroom discourse is structured and scaffolded (Christopher & William, 2026) and that mathematical performance depends on translation, integration, planning, and execution processes rather than final answers alone (Deaño et al., 2023). For at-risk learners, reflective instructional processes may therefore offer a more supportive route for strengthening appraisal, confidence, and mathematics ability.

The school-context findings suggest that mathematics ability among at-risk students is shaped not only by proximal affective factors but also by broader school conditions that continue to matter after those pathways are considered. The direct contribution of the type of school implies that the advantage associated with private schooling was not fully explained by appraisal, confidence, or the instructional variables included in the model. At the same time, the strong association between private-school context and reflective strategy indicates that part of this advantage may lie in the instructional environment students encounter. This matters because reflective teaching was the more educationally favorable pathway in the final model, given its positive role in strengthening appraisal and confidence. In this sense, the contribution of school context is not simply that students from one school sector performed better than those from another, but that school conditions appear to become educationally meaningful when they support classroom processes that help at-risk learners view mathematics as understandable, worthwhile, and manageable. This interpretation is consistent with Bernardo et al. (2022), who showed that low-performing Filipino students in public and private schools differ not only in performance level but also in the broader combinations of personal, instructional, and school-related conditions associated with that performance. The present findings therefore suggest that school context should be understood less as a static category and more as a condition that may shape the instructional and affective pathways linked to mathematics ability.

The role of the teacher's field of specialization is likewise better understood as an indirect rather than a dominant direct influence. In the preliminary teacher-linked screening model, field of specialization did not emerge as a significant standalone predictor, yet in the final path model, it retained a significant direct effect on appraisal and a significant indirect effect on mathematics ability through that same pathway. This pattern suggests that specialization mattered less as an isolated credential marker and more through its association with how students came to evaluate mathematics as understandable, useful, and worth engaging. This interpretation is consistent with Control-Value Theory, which positions students' appraisals of value and control as proximal mechanisms linking learning conditions to achievement outcomes (Pekrun, 2024). It is also consistent with evidence that teacher-related support and classroom relationships shape mathematics-related self-beliefs and emotional responses, which in turn are associated with performance (Wang et al., 2024). In the Philippine context, this reading is further supported by work showing that the educational significance of teacher characteristics lies not only in formal preparation itself, but in how that preparation is enacted through instruction, classroom support, and learning conditions (Jaudinez, 2019). Thus, the relevance of teacher specialization in the present study lies in its linkage to students' appraisal, not in a simple specialist–non-specialist contrast.

A further implication emerges from the descriptive results on mathematics ability. The students performed relatively better in conceptual understanding than in logical skills and especially procedural knowledge, with procedural knowledge emerging as the weakest mathematics-ability dimension among Grade 9 students. This suggests that the difficulty of at-risk students may not lie only in grasping isolated concepts, but in converting understanding into systematic procedures and sustained solution processes (Hurrell, 2021). Read alongside the final model, this pattern indicates that affective orientation and instructional process may be important in helping students move from partial understanding to more organized procedural performance. Students who appraise mathematics more positively, feel more confident, and experience reflective instructional support may be better positioned to persist through procedural demands rather than disengage when solution steps become extended or cognitively demanding. This interpretation is compatible with evidence that mathematical performance depends on structured cognitive processing supported by appropriate instructional mediation (Deaño et al., 2023). It is also supported by recent work showing that perceived self-efficacy plays an important role in self-regulation during mathematical problem solving (Landa et al., 2025).

The practical implications of the model differ across stakeholders. For mathematics teachers, the findings point to the value of structured reflective activities that help at-risk learners examine errors, connect mathematical ideas with prior experience, and build confidence before moving into more demanding classroom discourse. For school heads and instructional leaders, the findings suggest the need to create classroom conditions that support reflective and confidence-building instruction, rather than relying only on test-score monitoring or broad school-sector comparisons. For curriculum developers, remediation materials for at-risk learners should combine procedural practice with guided reflection, confidence-building tasks, and activities that help students see mathematics as useful and learnable. For policymakers, the findings suggest that mathematics recovery programs should treat low performance as both an instructional and affective concern, requiring support for teacher development, school learning conditions, and learner confidence. For researchers, the model provides a basis for testing similar pathways in larger samples and with multilevel designs that can more clearly separate student-, teacher-, and school-level effects. These implications are consistent with recent intervention literature showing that mathematics self-competence beliefs can be strengthened through carefully designed instructional, collaborative, technological, and self-regulatory approaches (Granello et al., 2025).

The interpretation of these findings must remain methodologically disciplined. The final model was estimated from student-level observations, while teacher- and school-related predictors were linked to students through repeated contextual values. These associations should therefore be interpreted as exploratory student-level pathways, not as independent multilevel causal effects of teachers or schools. In addition, the transition from 450 assessed students to 370 at-risk students, and then to 368 cases in some inferential analyses, means that the model pertains specifically to a screened at-risk subgroup rather than to the full junior high school population. The value of the study lies not in claiming a universal causal structure, but in offering a coherent exploratory explanation of how contextual, instructional, and affective processes may combine in relation to mathematics ability among students already vulnerable to low performance.

The final parsimonious model, therefore, suggests that mathematics ability among at-risk students is most plausibly shaped through a layered process in which school context influences instructional pathways, instructional pathways shape student appraisal and confidence, and these affective conditions directly support or constrain mathematics ability. Among these components, appraisal and confidence emerged as the most proximal explanatory variables, with reflective strategy appearing as the most beneficial instructional route in the retained model. The central implication of the study is that improvement among at-risk mathematics learners may depend as much on how mathematics is experienced and appraised as on how it is formally taught.

5. CONCLUSION

This study examined mathematics ability among at-risk junior high school students through an exploratory path model linking school-related, teacher-related, and student-related factors. The final parsimonious model showed good fit and indicated that mathematics ability was most directly associated with two student affective variables, namely appraisal and confidence, while school and teacher factors were linked to mathematics ability mainly through indirect instructional and affective pathways. In particular, the retained model showed that appraisal had the strongest positive direct effect on mathematics ability, followed by confidence, while the type of school retained a smaller direct contribution. At the same time, reflective and discussion strategies functioned as important intervening pathways through which contextual conditions were associated with mathematics ability.

The study therefore supports the view that mathematics ability among at-risk learners is not explained only by background characteristics or school placement. Rather, it appears to be shaped through an interconnected process in which school context is associated with instructional practices, instructional practices are associated with student appraisal and confidence, and these affective conditions are, in turn, associated with mathematics ability. For this group of learners, the issue is not simply low performance in mathematics, but the broader way mathematics is experienced, interpreted, and approached in school.

These findings carry practical implications for mathematics education. Support for at-risk learners should not be limited to content remediation alone. Interventions should also strengthen students' appraisal of mathematics as useful, meaningful, and learnable, while building confidence in dealing with mathematical tasks. The model also suggests that reflective instructional processes may serve as a more supportive route for these learners than discussion-heavy pathways when the goal is to improve confidence, appraisal, and mathematics ability. In this sense, efforts to improve school mathematics performance are likely to be more effective when they address both instructional practice and student affect, not only test outcomes.

The study should also be interpreted within its limitations. First, the final model was derived from student-level observations, while teacher- and school-related predictors were linked to students through repeated contextual values; thus, the results should be interpreted as exploratory student-level associations rather than independent teacher- or school-level causal effects. Second, the study focused only on students classified as at-risk based on the TIMSS-like screening assessment, so the findings are most applicable to this subgroup rather than to all junior high school students. Third, the exploratory nature of the retained path model means that the results should be viewed as a plausible explanatory structure that requires further testing in broader and more robust samples.

Future research may build on this study by testing the model in larger and more diverse student populations, by incorporating stronger multilevel designs that can more appropriately separate student, teacher, and school effects, and by examining whether interventions focused on appraisal, confidence, and reflective mathematics instruction can improve procedural and overall mathematics performance among at-risk learners. Despite its limitations, the study offers a coherent account of how contextual, instructional, and affective factors may combine in shaping mathematics ability and provides a useful basis for designing more responsive support for students who are most vulnerable to persistent low performance in mathematics.

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Research Ethics. Informed consent was obtained from all participants prior to data collection. Ethical clearance for the conduct of the study was granted by the Research Ethics Review Committee of St. Michael's College of Iligan, Inc.

Declaration of AI Use. AI tools, specifically OpenAI's ChatGPT, were utilized in this study to support manuscript organization, enhance language clarity, and assist with grammar checking. All AI-assisted outputs were fully reviewed, supervised, and approved by the authors. The research design, data collection, and all analyses were conducted manually without the use of AI tools.

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