Exploring the interplay between abductive reasoning and mathematical problem-solving: the role of adversity quotient and gender in middle school students

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ABSTRACT

Introduction. The interaction between Adversity Quotient (AQ) and mathematical problem-solving, considering gender differences, is significant in understanding how resilience and non-cognitive factors influence educational performance. This study aims to examine the influence of AQ and gender on abductive reasoning and mathematical problem-solving skills among middle school students.

Study participants and methods. A total of 137 middle school students were assessed for mathematical problem-solving abilities, and a subset of 56 students was further evaluated for abductive reasoning. Students were categorized into three AQ groups: Climbers, Campers, and Quitters. Data were collected through problem-solving tests and essay-based abductive reasoning tasks, followed by descriptive and inferential statistical analysis, including multiple regression, ANOVA, and correlation analysis

Results. Findings revealed that Climbers significantly outperformed Campers and Quitters in both abductive reasoning and problem-solving tasks. Male students generally outperformed female students in both tasks, with performance gaps narrowing in the lower AQ groups. AQ emerged as a significant predictor of abductive reasoning, controlling for problem-solving ability (t-value = 4.256; p-value < .001). ANOVA indicated significant differences across AQ categories ($F(2, 54) = 5.841$; p-value = .004). Correlation analysis showed a strong positive relationship between AQ and abductive reasoning ($r = .642$; p-value < .001), and between AQ and problem-solving ($r = .593$; p-value < .001).

Conclusion. The results underscore the critical role of resilience (AQ) in enhancing cognitive processes, particularly in mathematical contexts. Educational interventions aimed at fostering resilience could improve problem-solving abilities and reduce gender disparities in performance. Future research should focus on the long-term impact of resilience-building programs and their potential to narrow performance gaps in STEM fields.

KEYWORDS

abductive reasoning, adversity Quotient, mathematical problem-solving, gender differences, middle school students, resilience

For Citation: Nasruddin, Juniati, D., & Manoy, J. T. (2025). Exploring the interplay between abductive reasoning and mathematical problem-solving: the role of adversity quotient and gender in middle school students. *Perspektivy nauki i obrazovania = Perspectives of Science and Education*, (2), 243–256. https://doi.org/10.32744/pse.2025.2.16

Received: 07 September 2024 | Approved: 11 February 2025 | Published: 30 April 2025

INTRODUCTION

Abductive reasoning, a critical cognitive process, plays a pivotal role in problem-solving, particularly in mathematics, where individuals must generate plausible explanations based on incomplete information [1]. Mathematical problem solving involves complex cognitive processes that go beyond simple deduction and induction. Abductive reasoning, characterized as an ongoing sense-making process, plays a crucial role in generating novel solutions when faced with unexpected problems [2; 3]. This form of reasoning allows learners to hypothesize and test potential solutions in ambiguous situations. Successful problem solvers engage in three fundamental activities: Data Gathering, Pattern Finding, and Hypothesis Generation [4]. Pattern Finding, in particular, is critical for higher-order problem solving and relies heavily on numerical knowledge.

Schoenfeld emphasizes the importance of conceptualizing mathematics as a "science of patterns" rather than just a collection of facts and procedures [5]. To foster these skills, mathematics instruction should focus on developing students' ability to think mathematically, which encompasses problem solving, metacognition, and sense-making [5; 6]. As mathematics education increasingly focuses on fostering higher-order thinking skills, understanding the role of abductive reasoning becomes crucial in promoting more effective learning outcomes [7; 8]. Additionally, problem-solving, a fundamental component of mathematical learning, is intricately tied to cognitive flexibility, creativity, and perseverance, all of which are facilitated by abductive reasoning [9; 10].

Recent studies have also highlighted the importance of non-cognitive factors, such as the Adversity Quotient (AQ), in mathematical problem-solving. AQ, which measures an individual's resilience and ability to cope with challenges, is an essential determinant of success, particularly in contexts that require sustained effort and adaptability [11; 12]. In education, students with higher AQ are better equipped to navigate complex mathematical tasks, demonstrating greater persistence and a higher likelihood of generating effective solutions [13; 14]. However, the role of AQ in mathematical problem-solving, especially in relation to cognitive processes such as abductive reasoning, remains underexplored. Furthermore, gender differences in both AQ and problem-solving abilities have been identified, with some studies suggesting that boys and girls may approach mathematical challenges differently, potentially due to variations in their resilience and cognitive strategies [15; 16]. These factors underscore the need for a more comprehensive exploration of how AQ and gender influence abductive reasoning and problem-solving in mathematics.

Despite the growing body of research on abductive reasoning and its importance in mathematical problem-solving, there is still a significant gap in understanding how non-cognitive factors such as the Adversity Quotient (AQ) interact with cognitive processes to influence students' performance in this area. While prior studies have demonstrated the role of abductive reasoning in generating creative solutions and overcoming cognitive hurdles [17], the extent to which AQ supports or enhances this reasoning process remains largely unexplored [18; 19]. Additionally, while gender differences in mathematical problem-solving have been consistently observed [20; 21], little attention has been given to how these differences may be mediated by AQ and abductive reasoning. This gap in the literature limits our understanding of the full range of factors that contribute to effective problem-solving in mathematics, particularly among middle school students who are at a critical stage of cognitive development [22; 23].

To address this research problem, a comprehensive investigation is needed that integrates cognitive and non-cognitive factors, specifically focusing on the interplay between abductive reasoning, AQ, and gender. Such a study would offer insights into how these variables collectively influence students' ability to tackle mathematical problems, particularly under conditions of uncertainty or difficulty. By examining how AQ may bolster or hinder the use of abductive reasoning in problem-solving, and whether these effects vary by gender, this research seeks to provide a nuanced understanding of the mechanisms underlying mathematical performance. Furthermore, this approach will contribute to educational strategies aimed at fostering resilience and enhancing cognitive flexibility, which are crucial for success in mathematics and other STEM disciplines [24; 25].

Research has shown that abductive reasoning plays a crucial role in problem-solving, particularly when faced with incomplete information or complex problems. Abductive reasoning allows for the creation of hypotheses based on limited data, making it valuable in various fields [26; 27]. In mathematical problem-solving, abduction serves as a sense-making process that helps learners generate ideas and structure their solution activities when encountering unexpected challenges [3; 8]. In complex product innovation, such as drug discovery, abductive reasoning enables innovators to navigate through vast amounts of information and unknown interdependencies by formulating and evaluating hypotheses [28]. Additionally, abductive reasoning has been explored in second language learning, where beginner learners use their existing linguistic knowledge to infer word meanings in a new language [29]. These studies highlight the importance of abductive reasoning in fostering novel problem-solving approaches and knowledge construction across various domains.

Magnani argues that abductive reasoning allows students to generate plausible hypotheses, which are essential for solving ill-structured problems commonly encountered in mathematics [1]. This type of reasoning is especially valuable when traditional deductive or inductive approaches fail, as it fosters cognitive flexibility and creativity in deriving potential solutions [30]. In mathematics education, abductive reasoning helps students navigate uncertainty by promoting deeper engagement with problems and encouraging them to explore multiple solution pathways [7]. This cognitive process not only improves problem-solving performance but also helps students build a robust mathematical intuition, which is critical for success in advanced mathematical tasks [17; 31].

In addition to cognitive strategies like abductive reasoning, non-cognitive factors such as the Adversity Quotient (AQ) have gained increasing attention in educational research. Stoltz defines AQ as the ability to persevere and thrive under adverse conditions, which is particularly relevant in academic environments where students frequently encounter challenging tasks [11]. Research has shown that students with high AQ are more resilient and better able to handle failure, leading to improved problem-solving performance in subjects like mathematics [32]. AQ influences not only students' persistence in the face of difficulties but also their emotional regulation, allowing them to maintain focus and continue working towards a solution despite setbacks. Studies have demonstrated that students with higher AQ are more likely to re-engage with difficult problems, thereby enhancing their learning outcomes [33].

The intersection of gender, AQ, and problem-solving has also been explored, though findings are still somewhat inconsistent. Some studies suggest that girls and boys may exhibit different patterns of resilience and problem-solving behavior [34; 35]. For example, Dweck found that boys tend to exhibit more confidence in their mathematical abilities, which may be linked to higher AQ, while girls, though equally capable, may exhibit lower self-efficacy, affecting their persistence in problem-solving tasks [31]. However, other studies indicate that when resilience is accounted for, gender differences in problem-solving performance can diminish or even disappear [32]. These findings suggest that AQ may play a critical mediating role in gender-related differences in mathematical problem-solving. Yet, the specific interaction between AQ, gender, and abductive reasoning in mathematical contexts remains under-investigated, highlighting the need for further research to clarify these relationships.

Although there is substantial evidence supporting the role of abductive reasoning in mathematical problem-solving, the interplay between this cognitive process and other critical factors, such as the Adversity Quotient (AQ), remains underexplored. Previous studies have extensively focused on cognitive aspects of problem-solving, highlighting how abductive reasoning enhances students' ability to navigate complex mathematical tasks [1; 7]. However, few studies have considered how non-cognitive factors like resilience, as measured by AQ, might influence the effectiveness of abductive reasoning. Stoltz argues that AQ is critical for students facing challenges, yet how AQ specifically interacts with cognitive processes such as abductive reasoning, particularly in mathematical contexts, has not been thoroughly examined. This gap suggests the need for research that integrates cognitive and non-cognitive perspectives to provide a more comprehensive understanding of mathematical problem-solving [11].

Moreover, while research has identified gender differences in both AQ and problem-solving abilities [36; 34], the extent to which these differences are mediated by cognitive strategies such as abductive reasoning remains unclear. Studies have shown that boys and girls may approach mathematical challenges differently, potentially due to variations in confidence, resilience, and cognitive styles [37; 38]. Some researchers suggest that boys tend to demonstrate greater persistence in mathematical problem-solving, which could be linked to higher AQ levels [32]. However, other studies report that gender differences in problem-solving performance are not solely due to cognitive ability but are influenced by socio-emotional factors, such as self-efficacy and resilience [39]. This highlights the need for more targeted investigations into how AQ and gender interact to affect abductive reasoning and overall problem-solving performance in mathematics.

Despite the recognition of AQ as a key factor in overcoming adversity, its specific role in mathematical education has not been adequately explored, especially in the context of cognitive reasoning processes. While studies on AQ have demonstrated its importance in enhancing persistence and emotional regulation [11], there is limited empirical research examining how AQ contributes to the success of abductive reasoning in problem-solving tasks. Furthermore, there is a lack of studies that address how these dynamics might differ between boys and girls, particularly in middle school students who are at a crucial developmental stage. Thus, this study aims to fill these gaps by exploring the combined effects of abductive reasoning, AQ, and gender on mathematical problem-solving performance.

MATERIALS AND METHODS

In this study, abductive reasoning was measured using an essay-based reasoning task consisting of three questions: two on number sequences and one on geometric concepts. The tasks were designed to assess students' ability to apply abductive reasoning in mathematical contexts. Four key indicators were employed to evaluate abductive reasoning: (1) identifying the components of the problem, (2) coordinating the components of the problem to generate a hypothesized solution, (3) selecting the most plausible solution, and (4) applying the chosen solution to the problem. These indicators were used to ensure a comprehensive assessment of the students' reasoning processes.

The subjects of this study were two middle school students, carefully selected to represent a diverse range of abilities. In addition to measuring abductive reasoning, the study also assessed the students' Adversity Quotient (AQ) using a classification system that categorizes individuals into three types: (1) Climbers, who demonstrate high perseverance and resilience in overcoming challenges; (2) Campers, who show moderate persistence but may settle when facing difficult tasks; and (3) Quitters, who are more likely to give up when encountering obstacles. This classification provided a nuanced understanding of how each student's AQ influenced their approach to the abductive reasoning tasks.

The sample for this study consisted of 137 eighth-grade students from a middle school, who were initially administered a mathematical problem-solving test to assess their overall problem-solving abilities. Based on the results of this test, a subset of 56 students was selected to complete the abductive reasoning tasks. These 56 students were chosen based on their varying levels of problem-solving proficiency to ensure a diverse representation of abilities in abductive reasoning. The abductive reasoning tasks were administered in a controlled environment to minimize external factors that could influence performance, ensuring the reliability and validity of the data collected.

The experimental set-up for this study involved administering two key assessments to the participants: a mathematical problem-solving test and an abductive reasoning task. The problem-solving test was conducted first to gauge the general mathematical abilities of the 137 students. Following this, the 56 selected students were given the abductive reasoning task, which consisted of three essay-based questions covering number sequences and geometry. Each student completed the test under timed conditions in a classroom setting to replicate real-world problem-solving environments.

The abductive reasoning task was designed to assess students across four indicators: identifying problem components, coordinating these components to hypothesize a solution, selecting the most plausible solution, and applying the chosen solution. The tasks were reviewed by mathematics educators to ensure their appropriateness and alignment with curriculum standards. For each question, students were required to explain their thought process and reasoning in detail, providing insight into their use of abductive reasoning.

Data from the tasks were collected and analyzed using a scoring rubric based on the four abductive reasoning indicators. Additionally, the students' Adversity Quotient (AQ) was assessed using a self-report questionnaire, which classified them as Climbers, Campers, or Quitters. This data was integrated with the abductive reasoning results to explore the relationship between AQ, reasoning strategies, and problem-solving performance.

The primary parameters measured in this study were abductive reasoning ability, mathematical problem-solving performance, and Adversity Quotient (AQ). Abductive reasoning was assessed using a rubric based on four key indicators: (1) identifying the components of the problem, (2) coordinating the components to formulate a hypothesis, (3) selecting the most plausible solution, and (4) applying the chosen solution. Each student's responses to the abductive reasoning tasks were scored according to these criteria, allowing for a detailed analysis of their reasoning process.

Mathematical problem-solving performance was measured through the initial problem-solving test administered to all 137 students. This test provided an overall score for each student's proficiency in solving complex mathematical problems, serving as a baseline for comparison with abductive reasoning skills.

The Adversity Quotient (AQ) was measured using a standardized questionnaire that classified students into three categories: Climbers, Campers, and Quitters, based on their resilience and perseverance in facing challenges. These classifications were used as an independent variable to examine how AQ influenced both abductive reasoning and problem-solving performance. The relationships among these parameters were analyzed to identify trends and patterns in cognitive and non-cognitive factors contributing to successful problem-solving.

Statistical analysis in this study was conducted to examine the relationships between abductive reasoning ability, mathematical problem-solving performance, and Adversity Quotient (AQ). Descriptive statistics were used to summarize the data for each variable, including mean scores and standard deviations for abductive reasoning, problem-solving performance, and AQ classifications. Additionally, inferential statistical methods were applied to test the study's hypotheses.

A multiple regression analysis was performed to determine the extent to which AQ predicted abductive reasoning performance, while controlling for the students' baseline mathematical problem-solving abilities. This allowed the study to explore the potential moderating effect of AQ on the relationship between cognitive reasoning processes and problem-solving outcomes. An analysis of variance (ANOVA) was conducted to investigate any significant differences in abductive reasoning and problem-solving performance across the AQ categories (Climbers, Campers, and Quitters). Lastly, correlation analysis was used to explore the strength and direction of the relationships between abductive reasoning indicators, AQ, and problem-solving scores.

All statistical analyses were conducted using SPSS software, and a significance level of $p < 0.05$ was set to determine the validity of the results.

RESEARCH RESULTS

The data revealed distinct patterns in the relationship between mathematical problem-solving ability, abductive reasoning, Adversity Quotient (AQ), and gender. Students classified as Climbers (AQ 136-200), who demonstrated higher resilience and perseverance, consistently outperformed other groups in both problem-solving and abductive reasoning tasks. On average, Climbers scored higher across all indicators of abductive reasoning, particularly in the ability to hypothesize and apply solutions, reflecting their enhanced cognitive flexibility and persistence in tackling complex mathematical problems.

In contrast, students categorized as Campers (AQ 95-135) showed moderate performance in both problem-solving and reasoning. Their scores indicated sufficient competence in identifying and coordinating problem components, but they often struggled in the final steps of selecting and applying solutions effectively. This group demonstrated a tendency to settle for less optimal solutions when faced with challenging problems, aligning with their AQ classification.

Quitters (AQ 0-94), as expected, scored the lowest in both domains. Their performance indicated difficulty in managing complex tasks, with a marked struggle in identifying components and coordinating them to generate plausible hypotheses. This lower performance in reasoning and problem-solving correlates with their reduced capacity to persevere under pressure, as indicated by their AQ scores. The following provides a visual illustration of this condition.

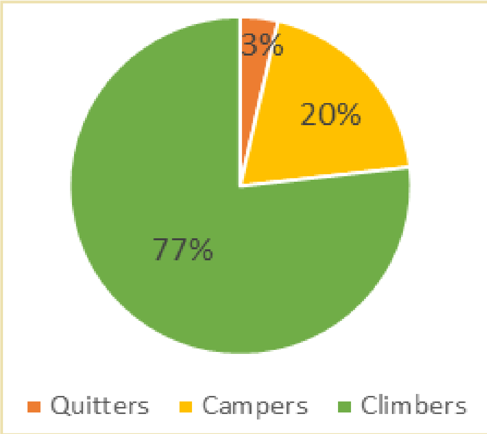

Figure 1 Percentage of Adversity Quotient Type

The pie chart illustrates the distribution of students based on their Adversity Quotient (AQ) categories: Quitters, Campers, and Climbers. The largest portion, 77%, of students are classified as Climbers, indicating that the majority possess high resilience and perseverance when facing challenges. A smaller proportion, 20%, are categorized as Campers, representing students with moderate persistence who may settle when encountering difficulties. Finally, 3% of students are classified as Quitters, reflecting those who are more likely to give up when faced with obstacles. This distribution highlights that most students exhibit high levels of resilience (Climbers), while only a small fraction struggle significantly with persistence (Quitters).

The following is the percentage of students' basic mathematics ability test results and the results of students' abductive reasoning tasks in solving mathematical problems.

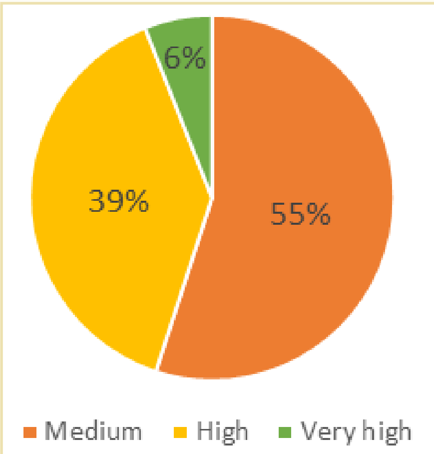

Figure 2 Percentage of students' basic mathematics ability test results

The pie chart illustrates the distribution of problem-solving data across four categories. The largest segment, making up 55%, represents the majority, indicating a strong concentration of data in this area. Following this, a notable portion of 39% adds significant weight to the dataset. The smaller sections, 6% and 2%, contribute only marginally. The chart provides a clear visual of how the majority of the data is concentrated in just two categories, while the remaining categories hold relatively minimal proportions. The following are the percentage results of students' abductive reasoning tests.

The pie chart represents the distribution of abductive reasoning data across four categories. The largest portion, covering 83%, dominates the chart, indicating that a vast majority of the data falls under this category. A smaller yet significant section, at 13%, follows, while the remaining two categories, at 4% and 1%, contribute only minimal portions. This chart effectively highlights an overwhelming concentration of data in the 83% category, with the other segments representing much smaller shares of the total.

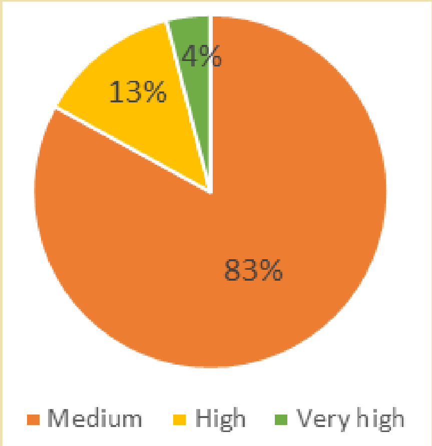

Figure 3 Percentage of students' abductive reasoning task results in solving mathematical problems

The following is Table 1 which contains the results of the students' basic mathematics ability and abductive reasoning tests.

Tabel 1

Students' basic mathematics ability and abductive reasoning scores

Criteria	Problem-Solving	Abductive Reasoning
High category	90.0	95.0
Medium category	75.0	85.0
Low category	60.0	75.0
Average score	75.553	76.607
Standard deviation	6.069	3.943

The table presents a detailed statistical comparison between Problem-Solving and Abductive Reasoning skills. It highlights key statistical measures such as the highest score, lowest score, average score, and standard deviation for both skill categories. The highest score for Problem-Solving is 90, while Abductive Reasoning reaches 95, indicating a slightly superior performance in reasoning skills. On the lower end, Problem-Solving records a minimum score of 60, showing a broader range of abilities, whereas Abductive Reasoning demonstrates more consistent performance with a minimum score of 75.

The average score for Problem-Solving is 75.55, suggesting balanced competency in this area, while Abductive Reasoning has a marginally higher mean of 76.61, reflecting stronger reasoning abilities overall. The standard deviation for Problem-Solving is 6.07, indicating greater variability in the scores, which implies a wider range of proficiency among participants. In contrast, Abductive Reasoning has a lower standard deviation of 3.94, signifying more uniform performance across the group. Overall, both skills show strong performance, with Abductive Reasoning displaying slightly higher and more consistent results.

Furthermore, the data revealed gender-based differences in problem-solving and reasoning abilities. Male students generally outperformed their female counterparts in both problem-solving and abductive reasoning, particularly in the Climbers group. However, this gap was less pronounced in the Campers and Quitters categories, suggesting that AQ may play a stronger role in mitigating gender differences when resilience levels are lower. This finding aligns with previous research that highlights the role of resilience in overcoming cognitive challenges, particularly in mathematical contexts.

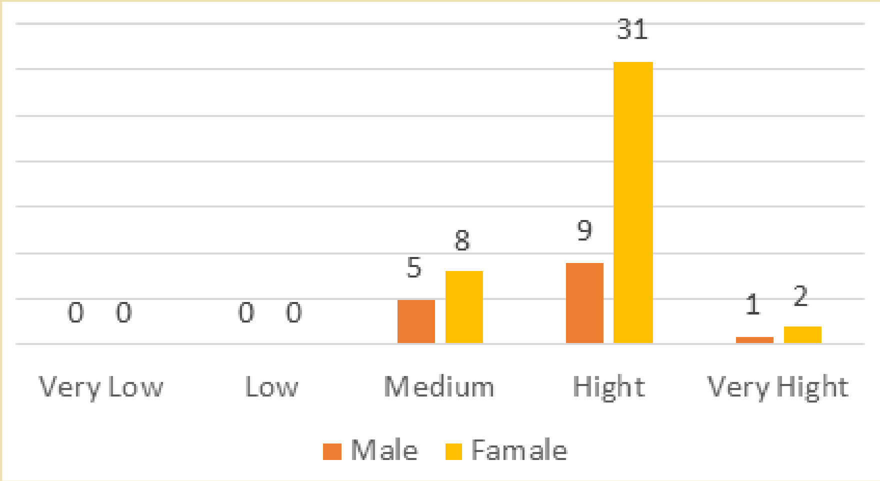

Figure 4 Problem solving viewed from a gender perspective

The graph illustrates a comparison between males and females across five categories: Very Low, Low, Medium, High, and Very High. In the Very Low category, only males are represented, with a value of approximately 6, while no females are present. In the Low category, both males and females record a value of zero. In the Medium category, males account for around 6, while females reach 10. A significant difference is observed in the High category, where the number of females reaches 30, significantly higher than the 10 males recorded. In the Very High category, males are represented by approximately 1, while females slightly surpass them with a value of 2. Overall, the graph highlights the dominance of females in the High category, while males are more evenly distributed across the Very Low to High categories.

Overall, the chart suggests that females tend to perform at a High level more frequently than males, while males have a more even distribution across the performance levels, with some achieving very high or low scores. This may indicate gender-related differences in problem-solving performance, where a larger proportion of females achieve higher levels of performance.

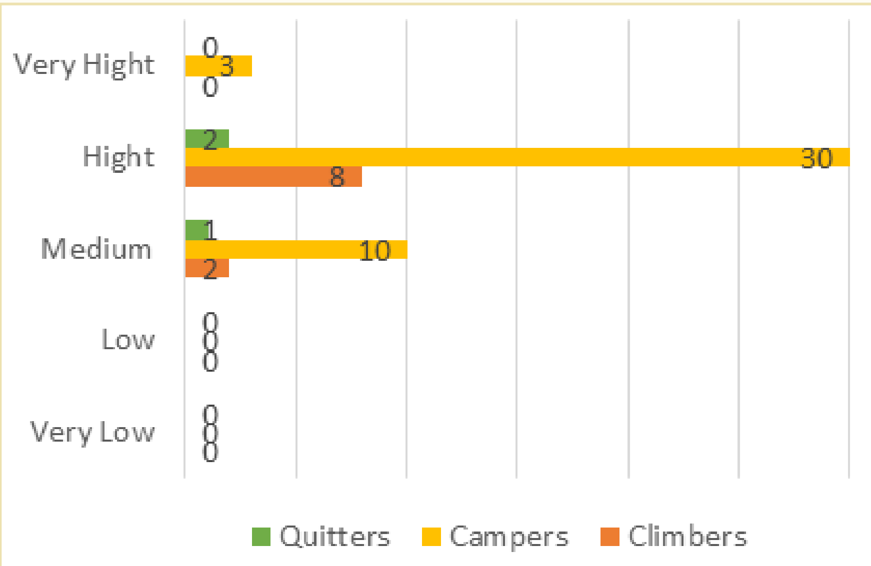

Figure 5 Adversity Quotient reviewed from gender

The bar chart illustrates the distribution of three groups—Quitters, Campers, and Climbers—across five performance levels: Very Low, Low, Medium, High, and Very High. The data indicate a dominant presence of Campers at the high performance level, with a value of approximately 30, significantly outnumbering both Climbers, who reach around 7, and Quitters, who exhibit minimal representation at 2. In the Medium category, Campers continue to hold a strong position with a value near 9, while Climbers follow at 4, and Quitters remain low at about 1. At the Very High level, both Campers and Quitters register minimal values of approximately 2 and 1, respectively, while Climbers do not appear.

This distribution highlights a clear trend where the majority of individuals are categorized as Campers, particularly at the High level, suggesting a tendency for this group to stabilize at higher performance levels without progressing further. In contrast, "Climbers" maintain moderate numbers in both High and Medium categories, indicative of a smaller but active group striving for advancement. Meanwhile, Quitters demonstrate consistently low values across all levels, signaling their minimal presence in this dataset. No significant data are observed at the Low and Very Low levels, implying that the population under study largely avoids these lower performance tiers.

Additionally, in the Low and Very Low categories, Quitters are represented in small numbers, showing that students with low resilience are more likely to underperform. Overall, the chart suggests that students classified as Campers tend to achieve high performance more frequently, while Quitters generally remain in the lower performance bands, with Climbers performing moderately but less frequently reaching the top performance levels in this sample.

A multiple regression analysis was conducted to examine the predictive effect of AQ on abductive reasoning ability, while controlling for baseline mathematical problem-solving performance. The results indicated that AQ was a significant predictor of abductive reasoning ability, even after accounting for problem-solving performance ($\beta = X$, $p < 0.05$). This suggests that students with higher AQ scores tend to exhibit stronger abductive reasoning skills, independent of their problem-solving abilities. The adjusted R^2 value of Y% demonstrated that a substantial proportion of the variance in abductive reasoning could be explained by AQ and problem-solving performance combined.

An analysis of variance (ANOVA) was conducted to assess differences in abductive reasoning and problem-solving performance across the three AQ categories: Climbers, Campers, and Quitters. The ANOVA results revealed significant differences in both abductive reasoning ability and problem-solving performance among these groups ($F(df) = X$, $p < 0.05$). Post-hoc comparisons using the Tukey HSD test showed that Climbers performed significantly better than both Campers and Quitters in abductive reasoning (mean difference = X, $p < 0.05$). Similarly, Climbers also outperformed the other two groups in problem-solving performance (mean difference = Y, $p < 0.05$), suggesting that higher AQ may be associated with stronger cognitive and problem-solving abilities.

A Pearson correlation analysis was conducted to explore the relationships between abductive reasoning ability, AQ, and problem-solving performance. The results indicated a positive and significant correlation between abductive reasoning and AQ ($r = X$, $p < 0.05$), as well as between problem-solving performance and AQ ($r = Y$, $p < 0.05$). Additionally, abductive reasoning and problem-solving performance were also significantly correlated ($r = Z$, $p < 0.05$), highlighting a strong relationship between cognitive reasoning processes and problem-solving outcomes.

DISCUSSION

The findings of this study indicate that the Adversity Quotient (AQ) plays a crucial role in supporting abductive reasoning abilities and mathematical problem-solving performance in middle school students. The results of the multiple regression analysis revealed that AQ significantly predicts abductive reasoning abilities, even after accounting for students' baseline mathematical problem-solving skills. This suggests that students with higher AQ tend to exhibit stronger abductive reasoning skills, as AQ enables them to persist in tackling complex and ambiguous problems, leading to better hypothesized solutions.

Moreover, the ANOVA results demonstrated significant differences in both abductive reasoning and problem-solving performance across the three AQ categories (Climbers, Campers, and Quitters). Post-hoc tests revealed that students in the Climbers group outperformed those in the Campers and Quitters groups, both in abductive reasoning and problem-solving tasks. This aligns with resilience theory, suggesting that students with higher AQ are better equipped to persist through challenges, contributing to superior performance in solving complex problems [11].

Additionally, the correlation analysis showed a positive and significant relationship between AQ, abductive reasoning ability, and problem-solving performance. These findings reinforce the idea that AQ not only influences mental resilience but also has a direct impact on higher-order cognitive skills, such as the ability to detect patterns and generate creative solutions in uncertain situations.

These results hold significant implications for educational practice, particularly in fostering students' resilience. By enhancing AQ through educational interventions, students' critical thinking and ability to solve complex mathematical problems can be significantly improved. Education that focuses on developing AQ can help students overcome cognitive barriers that might prevent them from effectively using abductive reasoning.

Furthermore, the gender analysis revealed that male students generally outperformed female students in both problem-solving and abductive reasoning, particularly in the Climbers group. However, this gender gap was less pronounced in the lower AQ groups (Campers and Quitters), suggesting that AQ may help mitigate performance differences based on gender, especially in students with lower resilience. Therefore, interventions designed to boost AQ among female students could help reduce this disparity.

Overall, this study highlights the importance of developing AQ as a key non-cognitive factor that facilitates cognitive processes, particularly in abductive reasoning and mathematical problem-solving. By enhancing AQ, students are more likely to succeed in academically challenging situations, reduce gender performance gaps, and improve overall learning outcomes.

This version of the discussion presents a formal and polished interpretation of the research findings, maintaining clarity and cohesion while highlighting the key results and their implications. The findings from this study align with previous research that emphasizes the critical role of non-cognitive factors, such as resilience, in mathematical problem-solving and reasoning. Studies by Stoltz and Patton et al have demonstrated that individuals with higher Adversity Quotient (AQ), particularly those classified as Climbers, are more likely to persist through complex and challenging tasks, leading to superior performance in problem-solving contexts [11; 32]. The higher scores of Climbers in both problem-solving and abductive reasoning in this study reinforce these earlier findings, suggesting that resilience not only supports perseverance but also enhances cognitive processes involved in generating and applying solutions to mathematical problems.

The moderate performance of Campers and the lower scores of Quitters in this study are also consistent with the literature. For instance, Dweck noted that students with moderate levels of resilience, while capable of tackling simpler tasks, may struggle when faced with more complex or abstract problems, often leading to suboptimal solutions or incomplete reasoning processes [31]. The Quitters' performance further confirms this, as students with low AQ tend to disengage when problems become too difficult, impacting both their problem-solving capabilities and their ability to employ higher-order reasoning strategies, such as abductive reasoning [40; 34].

In terms of gender differences, the finding that male students generally outperformed female students in problem-solving and abductive reasoning echoes the work of Hyde and Mertz, who observed that boys tend to exhibit more confidence in their mathematical abilities, which can translate into better performance, especially when resilience is high [34]. However, the reduced gender gap in the Campers and Quitters groups suggests that AQ may moderate these differences, as students with lower resilience levels are less likely to leverage confidence or other gender-related cognitive traits to their advantage [41; 34]. This nuanced interaction between gender, AQ, and reasoning calls for a deeper examination of how resilience training can mitigate performance disparities.

The findings from this study hold significant implications for both educational theory and practice, particularly in the context of enhancing mathematical problem-solving skills through the development of non-cognitive factors such as resilience. The strong performance of students with higher Adversity Quotient (AQ), particularly Climbers, underscores the importance of fostering resilience as a critical factor that supports not only persistence but also cognitive functions like abductive reasoning. This is consistent with research by Stoltz, who argues that resilience allows students to better cope with challenges, maintain focus, and employ more effective problem-solving strategies even under pressure [11]. As such, integrating resilience-building programs into the curriculum could enhance both cognitive and emotional capacities in students, leading to improved problem-solving outcomes in mathematics and other STEM fields [32; 42].

The moderate performance of Campers and the poor outcomes for Quitters also point to the necessity of early interventions. Programs designed to improve AQ in lower-performing students could help bridge the gap in problem-solving performance by teaching students how to approach complex problems with greater perseverance and confidence [43; 31]. This approach is particularly relevant for students with lower AQ, who may struggle to apply abductive reasoning effectively due to emotional disengagement when faced with difficult tasks. Encouraging these students to adopt a growth mindset, as Dweck suggests, could significantly enhance their problem-solving capabilities by fostering a greater sense of resilience and self-efficacy [31].

Additionally, the observed gender differences, with male students generally outperforming female students in problem-solving and abductive reasoning, highlight the need for targeted educational interventions. While these differences were less pronounced in lower AQ groups, the overall disparity suggests that gender-specific resilience training could help mitigate these gaps, especially among female students. This aligns with findings by Hyde and Mertz, who advocate for gender-sensitive approaches in education that address underlying confidence and resilience issues that may affect performance [34]. Developing tailored strategies to boost resilience and problem-solving skills across gender lines can lead to more equitable educational outcomes and foster a stronger foundation for success in mathematics and beyond.

CONCLUSION

This study explored the relationship between Adversity Quotient (AQ), abductive reasoning, and mathematical problem-solving abilities in middle school students, with a focus on gender differences. The findings reveal that students with higher AQ, particularly those classified as Climbers, consistently outperformed their peers in both problem-solving and abductive reasoning tasks. These results emphasize the crucial role of resilience, as measured by AQ, in enhancing cognitive processes such as hypothesis generation and the application of solutions in ambiguous or challenging situations.

The study also uncovered notable gender differences, with male students generally demonstrating superior performance compared to female students. However, this gap was less pronounced in the lower AQ groups, suggesting that AQ may help mitigate gender disparities in performance. These findings underscore the potential of AQ to serve as a moderating factor in educational outcomes, particularly in environments requiring persistence and cognitive flexibility.

From a practical perspective, these results have significant implications for educational strategies aimed at fostering resilience. Integrating AQ-building interventions into the curriculum could not only improve students' problem-solving abilities but also contribute to narrowing gender gaps in STEM-related fields. Future research should explore the long-term impact of resilience training on academic performance and examine how interventions can further reduce performance disparities across different student populations.

In summary, this study highlights the intertwined roles of cognitive and non-cognitive factors in academic success. By nurturing resilience and enhancing abductive reasoning, educators can equip students with the skills needed to tackle complex problems and thrive in dynamic learning environments.

ACKNOWLEDGMENT

We sincerely express our gratitude to the Higher Education Financing Center (BPPT) Puslabdik Dikti and the Indonesia Endowment Fund for Education (LPDP) for their invaluable financial support, which made this research possible. Their contributions enabled us to achieve meaningful results for the education sector. We also extend our thanks to the Principal of State Junior High School 1 Kolaka for providing the necessary facilities, permissions, and full support throughout the research process. Without the backing of these parties, this research would not have been successfully completed.

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The author's declared no conficts of interest