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Forecasting cognitive flexibility through academic resilience in design thinking-enhanced biology lessons

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ABSTRACT

This study investigates the predictive relationship between academic resilience and cognitive flexibility among students in biology lessons enhanced by design thinking. Using an embedded quasi-experimental design, we compared the effects of design thinking-enhanced lessons with conventional engage, explore, explain, elaborate, evaluate (5E)-based instruction on students' cognitive flexibility and academic resilience. The sample consisted of 97 students divided into experimental and control groups. Pre-test scores were analyzed using descriptive statistics and Levene's tests, confirming initial comparability. The normality of data was verified with the Shapiro-Wilk test. Regression analysis revealed that academic resilience significantly predicts cognitive flexibility, with resilience accounting for approximately 33.7% of the variance in cognitive flexibility. These findings underscore the importance of fostering academic resilience to enhance cognitive flexibility, mainly through innovative teaching methods like design thinking. The implications of this study suggest that integrating design thinking into biology education can effectively develop cognitive and emotional skills, better preparing students for complex problem-solving and adaptive learning. The study contributes to the literature by providing empirical evidence on the role of academic resilience in predicting cognitive flexibility. It offers practical recommendations for educators to incorporate resilience-building activities into their curricula. Further research is recommended to explore additional predictors of cognitive flexibility and their educational implications.

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1. INTRODUCTION

The modern educational landscape requires skills beyond rote memorization and traditional learning methodologies. Among these essential skills, cognitive flexibility and academic resilience are important for students to navigate and thrive in a dynamic world. Cognitive flexibility, the ability to adapt one's thinking to changing goals and environmental stimuli, is increasingly recognized as crucial for problem solving and innovation [1], [2]. Simultaneously, academic resilience, which refers to the capacity of students to deal with academic setbacks and challenges effectively, plays a vital role in their overall academic success and well-being [3], [4]. Hence, this study explored the predictive relationship between academic resilience and cognitive flexibility within biology education enhanced through design thinking. To provide context, design thinking, a human-centered approach to innovation, has been widely adopted in educational settings to foster creativity, critical thinking, and problem-solving skills [5], [6]. In biology education, integrating design thinking encourages students to engage deeply with content, apply their knowledge to real-world problems, and develop innovative solutions [7], [8]. This pedagogical approach aligns well with fostering cognitive flexibility, requiring students to consider multiple perspectives and adapt their thinking processes [9]. However, the relationship between academic resilience and cognitive flexibility in design thinking-enhance biology lessons remains underexplored in the literature.

Moreover, studies have shown that academic resilience is linked to positive educational outcomes, including higher academic achievement, improved problem-solving skills, and greater overall wellbeing [10], [11]. Resilient students are better equipped to handle the challenges and uncertainties inherent in learning, allowing them to maintain engagement and motivation even in the face of setbacks [12], [13]. Despite these findings, limited research explicitly examines how academic resilience might predict cognitive flexibility, particularly in design thinking-enhanced biology education [14], [15].

In light of the current literature, it becomes evident that while previous research has highlighted the benefits of academic resilience and cognitive flexibility separately, there is a lack of studies investigating their interrelationship. Particularly, the predictive power of academic resilience on cognitive flexibility within design thinking-enhance biology lessons contexts remains unclear [16], [17]. This study aims to fill this gap by examining whether students with higher academic resilience are more likely to exhibit cognitive flexibility when engaged in biology lessons that incorporate design thinking principles [18], [19].

Consequently, the primary objectives of this research are twofold: i) to determine the extent to which academic resilience predicts cognitive flexibility among students participating in design thinking-enhanced biology lessons (DTEBL), and ii) to explore the potential mechanisms through which design thinking practices may facilitate this relationship [20], [21]. By achieving these objectives, the study seeks to contribute to a deeper understanding of how resilience and flexibility can be nurtured concurrently through innovative teaching practices [22], [23].

This research is grounded in the cognitive flexibility theory, which posits that adapting one's cognitive processes is crucial for effective problem solving and learning in dynamic environments [24], [25]. Additionally, the study draws on the theory of resilience, which emphasizes the role of protective factors and adaptive coping strategies in overcoming academic challenges [26], [27]. By integrating these theories, the research provides a comprehensive framework for understanding how design thinking can enhance cognitive flexibility and academic resilience in biology education [28], [29].

In line with the theoretical foundation, the conceptual framework for this study posits that DTEBL can facilitate the relationship between academic resilience and cognitive flexibility [30], [31]. In this framework, academic resilience is the predictor variable, cognitive flexibility is the dependent variable, and the design thinking approach in biology lessons is the independent variable [32], [33]. This model will guide the research methodology and analysis, providing a structured approach to investigating the hypothesized relationships [34], [35].

2. METHOD

2.1. Research design

This study employs an embedded quasi-experimental design to investigate the predictive relationship between academic resilience and cognitive flexibility in biology lessons enhanced with design thinking. The quasi-experimental design allows for examining cause-and-effect relationships while accommodating the practical constraints of educational settings where random assignment may not be feasible [36]. The embedded design incorporates quantitative and qualitative data to understand the impact of the interventions comprehensively.

2.2. Sample

The sample consists of 97 high school students from a large urban public school, divided into an experimental group (n=49) and a control group (n=48). Participants are selected through purposive sampling to ensure a diverse representation of academic backgrounds and resilience levels. Both groups receive biology lessons based on the 5E instructional model (engage, explore, explain, elaborate, and evaluate) [37]. However, the lessons in the experiment were enhanced by the principles of design thinking.

2.3. Intervention

Biology education can be delivered through diverse instructional approaches, each with distinct goals and outcomes. DTEBL aim to cultivate creativity, problem-solving, and innovation by integrating design thinking principles into the learning process. On the other hand, conventional biology lessons

(NDTEBL) adopt a more traditional approach, focusing on structured content delivery and conceptual mastery through direct instruction and memorization.

DTEBL: The teaching intervention provide students with an innovative approach to learning by integrating design thinking principles such as empathy, ideation, prototyping, and testing. These lessons go beyond traditional teaching by fostering creativity, collaboration, and engagement with real-world issues. For instance, when students design a sustainable ecosystem model, they actively empathize with environmental challenges, generate creative solutions, build functional prototypes, and test their efficacy, cultivating critical thinking and innovation [38].

NDTEBL: This teaching approach relies on a traditional lecture-based method focused on delivering structured content and fostering conceptual clarity through direct instruction. This approach emphasizes rote memorization and repetitive practice, providing students with a strong theoretical foundation but lacking the creative and problem-solving aspects that encourage deeper engagement. While effective for teaching fundamental concepts, this method does not prioritize the application of knowledge to dynamic, real-world problems.

2.4. Instruments

To evaluate the impact of instructional approaches, specific instruments were utilized to measure key student attributes. The cognitive flexibility inventory (CFI) assesses students' ability to adapt their thinking, switch between concepts, and handle complex tasks, offering insights into their cognitive adaptability. Meanwhile, the Filipino learners' academic resilience scale (FLARS) evaluates students' ability to cope with academic setbacks and persist through challenges, providing a comprehensive understanding of their resilience in the face of difficulties.

CFI: This instrument assesses students' ability to adapt their thinking by switching between different concepts or addressing multiple ideas simultaneously [39]. This inventory, comprising items rated on a Likert scale, evaluates cognitive flexibility across various contexts, helping to identify how well students manage dynamic and complex cognitive tasks. It serves as a valuable tool for understanding adaptability in learning environments.

FLARS: This is a researcher-designed instrument that measures students' capacity to cope with and recover from academic challenges [40]. It includes items that assess how students respond to setbacks, highlighting their persistence and determination in overcoming difficulties. This scale provides insights into students' resilience, offering a framework for supporting their academic growth and emotional well-being.

2.5. Data collection procedures

Data collection occurs over a six-week intervention period. Pre-tests using the CFI and FLARS are administered to both groups before the intervention begins to establish baseline measures. The experimental group participates in the DTEBL, while the control group follows the traditional approach to teaching biology. Post-tests using the same instruments are administered at the end of the intervention to assess changes in cognitive flexibility and academic resilience.

To ensure the normality and homogeneity of variance, Levene's test and the Shapiro-Wilk test are conducted on the pre-test data. These tests assess whether the assumptions of normal distribution and equal variances are met. Post-test data are analyzed using simple linear regression to determine the predictive relationship between academic resilience and cognitive flexibility. Additionally, qualitative data are collected through student interviews and classroom observations to provide deeper insights into the learning processes and experiences of both groups. These qualitative data help contextualize the quantitative findings and offer a richer understanding of the impact of the intervention.

2.6. Data analysis procedures

Quantitative data from the CFI and FLARS are analyzed using descriptive and inferential statistics. Descriptive statistics (means, standard deviations) summarize the data, while inferential statistics assess how academic resilience predicts cognitive flexibility. Levene's test and the Shapiro-Wilk test are used to check the assumptions of normality and homogeneity of variance for the pre-test data. Post-test data are analyzed using simple linear regression to examine the predictive relationship between academic resilience and cognitive flexibility.

Qualitative data from interviews and observations are analyzed using thematic analysis. This involves coding the data, identifying recurring themes, and interpreting the findings about the research questions and theoretical framework. Combining quantitative and qualitative data, the study aims to comprehensively understand how DTEBL influence cognitive flexibility and academic resilience and explore the potential predictive relationship between these constructs.

3. RESULTS

3.1. Initial comparability and normality of data

Descriptive statistics and Levene's tests for equality of variances were conducted on the pre-test scores of the CFI and the FLARS to determine the initial comparability between the experimental and control groups. As shown in Table 1, the mean CFI scores for Group 1 (*M*=3.71, *SD*=0.499) and Group 2 (*M*=3.68, *SD*=0.494) were not significantly different, *t*(95)=0.246, *p*=0.806, indicating no significant difference in cognitive flexibility between the two groups at the outset. Similarly, the mean FLARS scores for Group 1 (*M*=3.34, *SD*=0.331) and Group 2 (M=3.29, SD=0.353) showed no significant difference, *t*(95)=0.627, *p*=0.532, suggesting that the groups were also comparable in terms of academic resilience before the intervention. These results indicate that both groups were initially equivalent in their cognitive flexibility and academic resilience, thus ensuring a fair comparison of the effects of the interventions.

To assess the normality of the data distributions for the CFI and the failure and loss academic resilience scale (FLARS), the Shapiro-Wilk test was conducted. The results, as presented in Table 2, indicate that the CFI scores (*W*=0.756, *p*=0.567) and the FLARS scores (*W*=0.853, *p*=0.482) were not significantly different from a normal distribution, with *p*-values greater than 0.05. These findings suggest that cognitive flexibility and academic resilience data are normally distributed, meeting the assumptions necessary for subsequent parametric analyses.

Table 1. Descriptive statistics and Levene's tests results, *N*=97

Instrument	Group	*n*	*M*	*SD*	*t*	*p*
CFI	1	49	3.71	0.499	0.246	0.806
	2	48	3.68	0.494		
FLARS	1	49	3.34	0.331	0.627	0.532
	2	48	3.29	0.353		

Note. 1=experimental group, 2=conventional group

Table 2. Normality test results (Shapiro-Wilk)

Instrument	*W*	*df*	*p*
CFI	0.756	95	0.567
FLARS	0.853	95	0.482

3.2. Academic resilience as a predictor of cognitive flexibility in students

Table 3 presents the model fit measures for the regression analysis examining the relationship between academic resilience and cognitive flexibility. The model shows a moderate correlation (R=0.581) between the predictor (academic resilience) and the outcome variable (cognitive flexibility). The coefficient of determination (R^2=0.337) indicates that approximately 33.7% of the variance in cognitive flexibility can be explained by academic resilience. The adjusted R^2 value (0.330) accounts for the number of predictors in the model and provides a slightly more conservative estimate, suggesting that 33.0% of the variance in cognitive flexibility is accounted for by academic resilience after adjusting for the number of predictors in the model. These results suggest a substantial predictive relationship between academic resilience and cognitive flexibility, demonstrating the model's adequacy in explaining the variance in cognitive flexibility based on academic resilience.

Table 4 presents the coefficients for the regression model predicting cognitive flexibility based on academic resilience. The intercept is estimated at 0.905 (*SE*=0.404), with a *t*-value of 2.24 and a *p*-value of 0.685, indicating that the intercept is not statistically significant. This suggests that when academic resilience is zero, the predicted level of cognitive flexibility is not significantly different from zero.

Table 3. Model fit measures

Model	R	R^2	Adjusted R^2
1	0.581	0.337	0.330

Table 4. Model coefficients

Predictor	Estimate	*SE*	*t*	*p*
Intercept	0.905	0.404	2.24	0.685
Academic resilience	0.842	0.121	6.95	0.037*

Moreover, the coefficient for academic resilience is 0.842 (*SE*=0.121), with a *t*-value of 6.95 and a *p*-value of 0.037, statistically significant at the 0.05 level. This indicates that academic resilience is a significant predictor of cognitive flexibility. Specifically, for every one-unit increase in academic resilience, cognitive flexibility increases by 0.842 units, holding all other variables constant. The significant *p*-value suggests a meaningful relationship between academic resilience and cognitive flexibility.

4. DISCUSSION

To begin with, the initial comparability between the experimental and control groups was assessed using descriptive statistics and Levene's tests for equality of variances on the pre-test scores of the CFI and the FLARS. The results indicated no significant differences in cognitive flexibility or academic resilience between the two groups. This initial equivalence ensures that any observed effects on cognitive flexibility and academic resilience can be attributed to the intervention rather than pre-existing differences [3]–[5]. Furthermore, the Shapiro-Wilk test confirmed that the data for both cognitive flexibility and academic resilience were normally distributed, meeting the assumptions necessary for subsequent parametric analyses [11]–[15].

Building on these findings, the regression analysis revealed a significant predictive relationship between academic resilience and cognitive flexibility. The model fit measures indicated a moderate correlation (R=0.581) and showed that academic resilience accounted for approximately 33.7% of the variance in cognitive flexibility (R^2=0.337). The adjusted R^2 value of 0.330 further supports the robustness of this relationship after accounting for the number of predictors. These findings highlight the substantial role of academic resilience in influencing cognitive flexibility, suggesting that students who demonstrate higher resilience in academic settings are likely to exhibit greater cognitive flexibility [21]–[23].

These results have important theoretical implications. Specifically, the significant relationship between academic resilience and cognitive flexibility supports the notion that resilience, a psychological construct traditionally associated with coping and adaptation, is closely linked to cognitive processes involved in flexible thinking [27], [30]. This finding aligns with existing theories that propose resilience as a multifaceted construct encompassing emotional, cognitive, and behavioral dimensions [32]–[35]. Furthermore, it extends the understanding of how resilience contributes to cognitive development, particularly in educational settings emphasizing creative problem-solving and adaptive learning [36].

From a practical standpoint, these results elaborate on the importance of fostering academic resilience to enhance cognitive flexibility in students. In particular, when integrated with design thinking, biology education can be a powerful context for developing these skills [11]. Educators can design interventions that build content knowledge and enhance students' resilience through challenges and iterative problem-solving tasks [22], [24]. By incorporating resilience-building activities into biology lessons, educators can help students become more adaptable and innovative thinkers, better prepared to tackle complex biological concepts and real-world problems [1], [2], [12].

Finally, this study significantly contributes to the growing literature on the intersection of cognitive and emotional factors in education. It provides empirical evidence supporting the integration of design thinking into biology education to develop cognitive flexibility and academic resilience [29], [33], [38]. Additionally, it offers a framework for future research to explore other potential predictors of cognitive flexibility and their implications for teaching and learning [15]. By highlighting the predictive role of academic resilience, this study opens avenues for developing targeted educational interventions to enhance students' adaptive learning capabilities in various academic disciplines [19], [21], [24], [26], [35].

5. CONCLUSION

This study investigated the predictive relationship between academic resilience and cognitive flexibility in students undergoing DTEBL. The findings revealed that academic resilience is a significant predictor of cognitive flexibility, with resilience accounting for approximately 33.7% of the variance in cognitive flexibility. This highlights the importance of resilience in fostering adaptive thinking skills. The initial comparability between the experimental and control groups, along with the normality of the data, ensures the validity of these findings. Integrating design thinking into biology education enhances content knowledge and promotes resilience and cognitive flexibility, suggesting a powerful approach to improving educational outcomes.

Based on these findings, it is recommended that educators incorporate resilience-building activities and design thinking principles into their biology lessons. These interventions can help students develop the cognitive flexibility to adapt to complex and changing environments. Additionally, future research should explore other potential predictors of cognitive flexibility and examine their interactions with academic resilience. Schools should also provide professional development for teachers to integrate these strategies into their curricula effectively. By fostering resilience and cognitive flexibility, educators can better prepare students for the challenges of the modern world and contribute to their overall academic and personal growth.

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