Investigating the Integration of Nanotechnology and Fabric Art in the Metaverse

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Abstract

The purpose of this study is to identify and rank the most effective pricing strategies for innovative products in the Iranian market, with an emphasis on key influencing factors and the provision of a scientific framework for managerial decision-making. To this end, the main research question focused on determining the most critical factors affecting the selection of the optimal pricing strategy and how these factors can be applied within a systematic framework. The methodology employed was the Fuzzy Analytic Hierarchy Process (FAHP), which enabled precise prioritization of options based on multiple criteria and expert judgment. The statistical population of the study consisted of 10 individuals, including senior marketing managers and experts from companies active in the field of innovative products, as well as academic specialists in business management and marketing. The main criteria and sub-criteria were considered across four key dimensions—innovation (product development capability, life cycle, degree of innovativeness), marketing (target markets, launch timing, market scope, growth), product (ease of use, after-sales support, branding, patent protection), and technology (payment channels, consumption convenience, technological uniqueness). Six pricing strategies were evaluated as decision-making options: prestige pricing, versioning, windowing, exclusive products, fixed pricing, and dynamic pricing. Findings from the FAHP analysis revealed that prestige pricing (weight = 0.444) is the most suitable strategy for innovative products in the Iranian market. Versioning ranked second with a weight of 0.268, while other strategies such as windowing, exclusive product pricing, fixed pricing, and dynamic pricing occupied the subsequent ranks, respectively. The results, in addition to providing a clear picture of the prioritization of pricing strategies, confirm the use of fuzzy multi-criteria decision-making models as an effective tool for analyzing marketing challenges in the context of the Iranian market. These findings offer practical and scientific guidance for managers, policymakers, and researchers in the domain of innovative product pricing.

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1. Introduction

Academic performance has long been considered one of the most critical indicators of student success, shaping future opportunities in education, career, and personal development. Researchers and educators have devoted extensive efforts to understanding the determinants of academic outcomes, ranging from cognitive and metacognitive abilities to psychosocial, motivational, and environmental factors. Cognitive theories emphasize the role of intellectual and learning skills, while social and motivational perspectives highlight the importance of self-efficacy, engagement, and emotional regulation. Recent studies have further extended these discussions by integrating constructs such as academic resilience, academic

culture, psychological capital, and the effects of digital and blended learning environments on student outcomes [1-3].

The role of cognitive and metacognitive strategies remains central in predicting academic outcomes, as students who effectively regulate their thinking and learning processes tend to perform better. Research demonstrates that cognitive and metacognitive skills contribute significantly to academic achievement across diverse contexts [1]. Longitudinal analyses have provided consistent evidence that cognitive abilities strongly influence academic performance, though the interplay with non-cognitive skills is increasingly recognized [2]. Studies on higher education students also emphasize the combined contribution of cognitive and non-cognitive skills, revealing that success is not merely determined by intellectual ability but also by motivation, persistence, and emotional regulation [3]. This shift has encouraged a holistic view that places equal importance on both intellectual and psychosocial dimensions.

Motivation is another key predictor of academic achievement. Theories of intrinsic and extrinsic motivation suggest that students' persistence and engagement are shaped not only by internal drives but also by contextual influences such as parental control, institutional culture, and teacher support. For instance, research on the role of mindfulness has shown that cultivating present-moment awareness enhances psychological well-being and academic persistence, indirectly improving performance outcomes [4]. Moreover, motivational factors are closely linked with long-term trajectories of academic success. Findings on conditions such as ADHD illustrate how motivational deficits and self-regulation challenges can influence academic attainment over the lifespan [5]. These results highlight the necessity of addressing motivational structures in educational interventions.

The relevance of psychological support and academic counseling has also been emphasized. Experimental studies have shown that specially designed counseling interventions can enhance self-efficacy, motivation, and academic performance, particularly among students at risk of academic probation [6]. Complementary to this, scale development research in Iran has focused on creating validated measures for assessing academic motivational potential, which offers educators tools for diagnosing and fostering student engagement [7]. Such initiatives reinforce the importance of systematically supporting motivation as a precursor to academic achievement.

Mental skills and techniques also play a vital role in students' learning outcomes. Psychological research across education and sport has demonstrated the effectiveness of mental skills such as goal-setting, imagery, and concentration in shaping performance [8, 9]. The application of these skills has been investigated not only in athletic contexts but also in academic settings, where they contribute to better self-regulation and resilience. Indeed, studies among high school populations show a strong relationship between mental skills and academic achievement, indicating that these techniques can be instrumental in preparing students to manage academic challenges [10]. Similarly, surveys conducted in Southeast Asia demonstrate that mental techniques and psychological preparation significantly influence learning outcomes, underscoring their cross-cultural relevance [11].

The learning environment and its perception also play a decisive role in shaping academic outcomes. Findings suggest that when students perceive their learning environment as supportive, their engagement and self-efficacy increase, leading to better performance [12]. This supports the social-cognitive perspective that emphasizes the bidirectional relationship between environment and personal learning strategies. Furthermore, self-efficacy and self-esteem are intricately linked with behaviors such as academic procrastination, particularly among medical students where workload and stress are significant [13]. These findings reaffirm that both external conditions and individual self-beliefs converge to influence achievement.

Technological transformations have further reshaped the landscape of academic learning. The expansion of e-learning and blended education has introduced new avenues for enhancing academic outcomes. Recent research demonstrates the effectiveness of blended instructional design models in improving academic performance, particularly among teacher-training students, highlighting the importance of integrating digital tools into learning frameworks [14]. Virtual learning environments also strengthen academic engagement and perceived learning, thereby influencing performance outcomes in higher education [15]. These insights align with global shifts toward digital education and underscore the need to align pedagogy with emerging technologies.

At the same time, digitalization brings unique challenges, including internet overuse. Studies show that excessive internet use is associated with academic decline and health problems such as musculoskeletal disorders [16]. These findings illustrate the dual-edged nature of technological

integration: while digital learning environments can enhance engagement and outcomes, uncontrolled digital consumption may undermine them. This duality emphasizes the importance of promoting balanced and intentional technology use in education.

Another dimension of academic success involves psychosocial resources such as resilience, academic culture, and psychological capital. Research has shown that academic resilience—students' ability to adapt to challenges and setbacks—indirectly shapes performance through its impact on academic commitment [17, 18]. Academic culture, encompassing values, norms, and collective attitudes, similarly influences resilience and achievement, demonstrating that institutional climate matters for performance outcomes. Relatedly, psychological capital—defined by optimism, resilience, hope, and efficacy—has been found to mediate the relationship between academic engagement and academic support, thus improving student outcomes [19]. Together, these findings highlight the significance of psychosocial resources in sustaining high levels of performance.

Parental and family influences also remain vital. Recent evidence underscores that parental autonomy support and reduced control are associated with higher motivation and academic outcomes [20]. These findings resonate with self-determination theory, which emphasizes the nurturing of autonomy, competence, and relatedness as foundational for intrinsic motivation. Moreover, international perspectives confirm that academic outcomes are not only determined by individual abilities but also by socio-cultural dynamics and family practices.

Other psychological constructs, such as imposter syndrome, have also been studied in relation to academic achievement. Investigations among MBA students suggest that imposter feelings negatively impact self-efficacy, which in turn reduces academic performance [21]. These results bring attention to the hidden emotional struggles that affect academic success, even among high-achieving populations. Addressing such psychological barriers is increasingly recognized as an important dimension of academic support.

The complexity of academic performance is further reinforced by studies that integrate mindfulness and emotional well-being. Evidence shows that mindfulness not only promotes psychological health but also fosters greater engagement, resilience, and focus, thereby enhancing performance [4]. Interventions involving socio-emotional skills training for adolescents have also demonstrated effectiveness in improving academic outcomes, illustrating the impact of holistic educational approaches [22]. Collectively, these findings affirm that academic performance is a multi-determined construct requiring attention to both intellectual and emotional dimensions.

Finally, emerging discussions emphasize that the interplay of these diverse factors—cognitive abilities, motivation, resilience, psychological resources, digital learning, and family environment—requires integrated theoretical frameworks. Modern educational psychology highlights how learning strategies, motivational supports, and contextual variables converge to shape achievement [23]. As a result, contemporary research increasingly focuses on the multidimensional and dynamic nature of academic success, advocating for interventions that address not just isolated skills but the holistic ecosystem in which learning occurs.

In conclusion, the literature provides strong evidence that academic performance cannot be reduced to a single factor but is instead shaped by a constellation of cognitive, motivational, psychological, social, and technological elements. From the enduring impact of cognitive and metacognitive skills [1-3], to the role of motivation [4, 5], psychological capital [19], resilience [17], and digital learning models [14, 15], the evidence underscores the multifaceted nature of achievement. Contemporary challenges, including internet overuse [16] and imposter syndrome [21], further highlight the need for balanced and supportive educational strategies. The purpose of this study is to identify and rank the most effective pricing strategies for innovative products in the Iranian market, with an emphasis on key influencing factors and the provision of a scientific framework for managerial decision-making.

2. Methodology

For this study, goat, cow, and calf skin fabrics were sourced from Yazdbaf Co. (Persia). Titania nanoparticles were purchased from Sigma Aldrich (CAS number 13463-67-7). Non-ionic detergent (Kieralon F-OL-B), citric acid monohydrate, and sodium hypophosphite, used as a cross-linking and catalytic agent, were obtained from Merck (Germany). The equipment utilized included an oxygen plasma device (APPS-6 Plasma Etching Machine, Shanghai Textile Research Institute Co., LTD) and a Euronda ultrasonic bath model Eurosonic 4D, 350 W, 50/60 Hz (Italy).

The goat, cow, and calf skin fabrics were first soaked in a non-ionic detergent at 50 degrees Celsius for 30 minutes to

remove impurities. After soaking, the fabrics were rinsed with distilled water. They were then treated with an oxygen plasma at 150W for 5 minutes. A solution of 10% citric acid and 5% sodium hypophosphite was prepared, and 0.5% titania nanoparticles were added to this mixture. The solution was sonicated in an ultrasonic bath. The fabrics were then immersed in this solution and subjected to another 30 minutes of sonication at 50 degrees Celsius.

3. Findings and Results

Figure 1 illustrates the setup of an impedance tube. In this setup, the sample is placed in front of a movable piston within the apparatus, while a speaker at the end generates the sound source. The sound waves are directed onto the fabric, and the sound absorption coefficient is measured. This coefficient indicates the ratio of absorbed acoustic energy to the energy of the incident wave. In this study, since the fabric's structural properties are kept constant, the variations in sound absorption are attributed solely to the amount of Titania nanoparticles. Analysis of the sound absorption coefficient curves (Figure 2) shows that adding 0.5% Titania nanoparticles significantly improves the acoustic performance of the fabrics compared to untreated samples. This enhancement is likely due to the increase in the fabric's surface cavities created by the Titania nanoparticles.

The addition of nanoparticles to the fabric enhances its sound absorption properties. Due to their small size, nanoparticles interact with sound waves on a molecular level, leading to improved sound absorption and wave dampening. The incorporation of Titania nanoparticles specifically boosts sound absorption. While the sound absorption capabilities of the fabrics are generally similar, cow fabric demonstrates slightly superior performance compared to calf and goat skin fabrics. This improved sound absorption in cow fabric can be attributed to its more porous structure, which allows sound waves to penetrate more effectively and thus enhances absorption compared to the less porous goat and calf skin fabrics. Secondly, cow fabric has a higher collagen content than goat and calf skin fabrics, which contributes to better sound absorption. The addition of nanoparticles to cow fabric enhances the interaction between collagen fibers and sound waves, further improving its sound absorption capabilities.

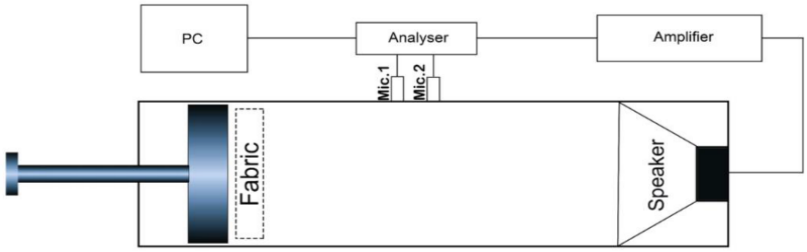

Figure 1. Schematic of impedance tube

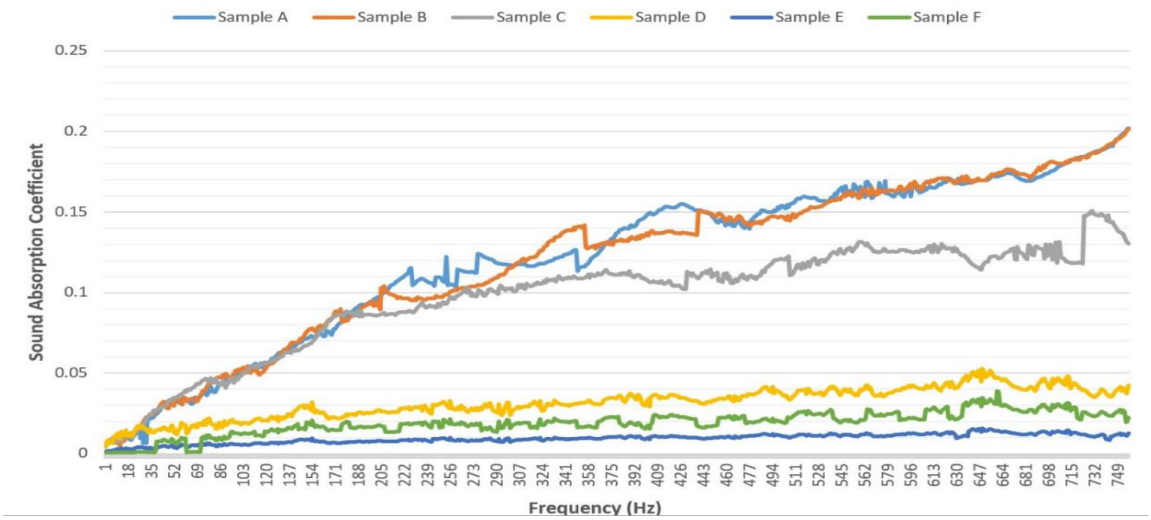

Figure 2. Sound absorption coefficient curves of samples

In a Metaverse simulation, the acoustic test was conducted exactly as it would be in real life, with all three fabrics treated and tested using nanomaterials in the same way. Although the process in the Metaverse replicated real-world procedures, the results were notably different. The finished fabrics in the Metaverse showed significantly greater sound absorption compared to their real-world counterparts, indicating that the fabrics were almost soundproof. This discrepancy can be attributed to several factors. One key factor is that in the Metaverse, nanomaterials are applied uniformly across the fabric's surface, which is challenging to achieve with complete accuracy in reality. Additionally, in the Metaverse, nanomaterial particles are organized in a precise, crystalline structure on the fabrics, while in reality, they may sometimes form an amorphous structure. These differences contribute to the disparity between the results observed in the Metaverse and those seen in the real world.

Enhancing textile art in the metaverse with sound-absorbing nanomaterials is a promising development that could significantly improve virtual environment experiences. As the metaverse—an expanding shared virtual space—gains popularity for gaming, socializing, and business meetings, it faces the challenge of providing realistic auditory experiences. Sound-absorbing nanomaterials can address this issue by integrating them into textiles used in the metaverse, leading to a more immersive and authentic virtual experience. These nanomaterials can absorb and attenuate sound waves, minimizing echoes and reverberations that might otherwise distort audio quality in virtual environments. As a result, users can experience clearer and more realistic soundscapes while engaging in the metaverse.

Moreover, incorporating sound-absorbing nanomaterials into textile art in the metaverse introduces new avenues for creativity and expression. While textile art is traditionally valued for its visual and tactile qualities, adding sound-absorbing nanomaterials allows it to contribute to a multi-sensory experience. Picture interacting with a finely crafted textile artwork in the metaverse, where you can not only see and touch it but also hear the subtle sounds it generates. Beyond enhancing the auditory experience, these nanomaterials also have practical applications within the metaverse. For instance, sound-absorbing nanomaterials can be used to design virtual environments that are acoustically tailored for specific functions, such as virtual concert halls or meeting rooms. This advancement opens up new opportunities for musicians, artists, and professionals who need high-quality audio in virtual settings. In summary, enhancing textile art in the metaverse with sound-absorbing nanomaterials could transform virtual experiences. By minimizing audio distortions and creating a more immersive environment, these materials improve the realism and quality of virtual spaces. They also provide new creative and practical possibilities across various fields. As technology progresses, further innovations in this area are anticipated, bringing us closer to truly lifelike virtual experiences.

The rise of the metaverse and advances in nanotechnology offer a thrilling opportunity to advance and enrich textile and clothing art. The metaverse is a virtual reality space where users can engage with one another and digital objects within a simulated setting. Nanotechnology involves manipulating materials at the nanoscale to develop new materials and capabilities. Integrating these two technologies has the potential to transform the creation, experience, and sharing of textile and clothing art. Nanotechnology can be employed to create fabrics with distinctive features that enhance both the look and functionality of clothing. For instance, integrating nanofibers into textiles can produce materials that are lightweight, breathable, and moisture-wicking. Furthermore, nanoscale coatings can be added to fabrics to make them resistant to stains, odors, and UV rays. These innovations in textile technology not only elevate clothing quality but also offer new avenues for artistic expression.

In the metaverse, artists can utilize nanotechnology to craft virtual textile and clothing art that is both immersive and interactive. These virtual garments can feature complex details and patterns that might be unachievable in the physical realm. Users can personalize and try on these virtual outfits within the metaverse, experiencing the art in a lively and engaging manner. Additionally, nanoscale sensors can be integrated into virtual textiles to collect data on body movements and environmental conditions, enhancing the realism and immersion of the virtual clothing experience. Overall, advancing textile and clothing art in the metaverse through nanotechnology offers significant potential for artistic innovation and creative expression. By harnessing these technologies, we can expand the limits of fashion, providing distinctive and personalized experiences for both artists and consumers. As the metaverse develops and nanotechnology progresses, the future of textile and clothing art appears highly promising.

The Metaverse is a virtual environment where individuals can interact with each other and digital objects in a three-dimensional space. It has become a popular platform for

artists and designers to display their creations and explore new creative opportunities. A recent trend in the Metaverse is the integration of nanotechnology with fabric art. Nanotechnology involves manipulating matter at the atomic and molecular scale and has applications across various fields such as medicine, electronics, and energy. In fabric art, nanotechnology can be utilized to develop materials with unique properties, including enhanced acoustic performance, self-cleaning capabilities, water resistance, and UV protection.

The integration of nanotechnology and fabric art within the Metaverse presents fresh opportunities for artists and designers. This combination allows for the creation of interactive and immersive experiences that blend physical and digital elements. For instance, a fabric art installation in the Metaverse could use nanotechnology to create an environment that responds and evolves based on user interactions and movements. This convergence also impacts visual art and design education, offering students a chance to engage with emerging technologies and explore novel creative avenues. By including nanotechnology and fabric art in their teaching, educators can better prepare students for future developments in art and design.

In summary, integrating nanotechnology with fabric art in the Metaverse represents a thrilling advancement that opens up new creative opportunities for artists and designers. It also impacts visual art and design education by offering students the chance to explore emerging technologies and prepare for future developments in the field.

4. Discussion and Conclusion

The findings of this study revealed that multiple psychological, cognitive, and contextual variables significantly influence students' academic performance. The results demonstrated that students with stronger mental skills, greater psychological capital, and higher levels of academic resilience tended to show better outcomes across various performance indicators. Furthermore, academic motivation and self-efficacy emerged as pivotal mediators in explaining how these internal and external factors contribute to achievement. Digital and blended learning environments were also shown to have a substantial impact on students' learning experiences and performance outcomes. Together, these results highlight that academic success is a multidimensional construct, shaped by the interplay of cognitive, motivational, socio-emotional, and contextual determinants.

The observation that mental skills positively predicted academic performance aligns with prior research emphasizing the role of cognitive and metacognitive strategies in shaping learning outcomes. Students who deployed goal-setting, imagery, and concentration techniques demonstrated stronger performance, which echoes findings from both educational psychology and sport psychology contexts [8, 9]. The present study confirmed earlier work which showed that metacognitive strategies help students regulate their learning processes and enhance achievement [1]. Similarly, longitudinal analyses that have linked cognitive abilities to long-term academic outcomes further support the present findings [2]. Collectively, these converging results emphasize that training in mental and metacognitive skills can serve as an effective intervention for enhancing performance across diverse educational settings.

Motivational constructs also played a central role in explaining differences in academic achievement. The results showed that students with higher intrinsic motivation and stronger self-determination consistently performed better. This finding is consistent with research highlighting the benefits of motivation and self-efficacy in predicting both short-term and long-term academic success [5]. Likewise, mindfulness as a psychological resource has been shown to improve persistence and concentration, enhancing performance [4]. In addition, evidence from scale development and validation studies supports the importance of academic motivational potential as a reliable predictor of student achievement [7]. The present study's results confirm that motivation is not a peripheral factor but a core determinant that interacts with other variables such as resilience and academic culture to drive achievement.

Resilience and academic culture emerged as strong predictors of academic performance. Findings indicated that students who demonstrated greater academic resilience were more committed and better able to adapt to stressors, which in turn improved their outcomes. This resonates with research that found resilience operates through academic commitment as a mediator of performance [17, 18]. Moreover, institutional culture shaped student achievement by reinforcing values and norms that supported perseverance. These findings confirm prior work showing that academic culture and resilience create a supportive environment for students, particularly in demanding higher education contexts.

Psychological capital was also identified as a key mechanism linking engagement and academic outcomes.

Students with high levels of hope, efficacy, resilience, and optimism were more likely to translate engagement into measurable performance improvements. This aligns with findings that psychological capital serves as a mediator between academic support and engagement, ultimately enhancing outcomes [19]. The present study adds to this body of work by demonstrating that psychological capital can act as a protective resource that sustains academic performance even in stressful or uncertain circumstances.

The findings further demonstrated that perceptions of the learning environment significantly influenced achievement. Students who perceived their environments as supportive and engaging reported greater self-efficacy, which then contributed to improved outcomes. This is consistent with research linking positive perceptions of the learning environment with enhanced engagement and academic performance [12]. Moreover, self-efficacy itself was found to be closely tied to procrastination, with higher efficacy reducing procrastinatory behavior and thereby enhancing performance [13]. The present findings reinforce the importance of supportive learning contexts in enabling students to thrive academically.

Digital and blended learning models were shown to play an increasingly important role in student outcomes. Students who participated in blended e-learning designs demonstrated higher levels of performance, echoing earlier findings that blended models improve achievement through active engagement and structured support [14]. Similarly, virtual education enhanced perceived learning and academic engagement, which in turn contributed to stronger performance outcomes [15]. These findings align with the rapid expansion of digital education, confirming that thoughtfully designed digital platforms can enhance achievement, particularly when they incorporate interactive and student-centered approaches.

At the same time, the study highlighted the negative implications of excessive digital engagement. Internet addiction was associated with decreased academic performance and heightened health problems, particularly musculoskeletal disorders [16]. This finding resonates with prior work cautioning against unregulated digital consumption, which undermines academic outcomes despite the potential benefits of digital learning. These contrasting results point to the necessity of balance in integrating digital technologies into education.

Parental influences were also reflected in the findings, as autonomy support was positively associated with higher levels of motivation and academic success. This supports evidence demonstrating that parental control can hinder academic motivation, while autonomy support enhances intrinsic drive and performance [20]. Such findings emphasize the role of family dynamics in shaping student achievement, particularly in formative years.

In addition to external supports, psychological challenges such as imposter syndrome were found to hinder academic achievement. Students reporting stronger imposter feelings demonstrated lower self-efficacy and weaker performance outcomes. This result is consistent with prior findings among MBA students, which showed that imposter syndrome exerts a negative influence on self-efficacy and academic performance [21]. Addressing such hidden psychological struggles is vital for supporting students' success.

The results also confirmed that socio-emotional skills training interventions significantly improved performance, aligning with research showing that social-emotional learning enhances multiple academic outcomes [22]. Moreover, psychological interventions such as counseling packages designed for probationary students were also effective in strengthening self-efficacy and achievement [6]. These findings collectively indicate that targeted interventions addressing emotional and motivational needs can yield measurable academic benefits.

Taken together, the present results highlight the multidimensional and interactive nature of academic performance. The convergence of evidence from mental skills training [8, 9], motivational constructs [4, 5], resilience and psychological capital [17, 19], learning environments [12], and digital education [14, 15] confirms that academic success is not explained by a single factor. Instead, it reflects the interplay between cognitive abilities, psychosocial supports, emotional resources, and contextual environments.

Despite its strengths, this study is not without limitations. First, the research was conducted within a specific educational and cultural context, which may limit the generalizability of the findings to other populations. Factors such as institutional structure, cultural norms, and socioeconomic backgrounds may influence the observed relationships differently in other contexts. Second, the reliance on self-report instruments for measuring constructs such as motivation, resilience, and psychological capital introduces the possibility of response bias. Third, while the study adopted a multidimensional framework, it did not exhaustively capture all factors influencing academic performance. Variables such as teacher quality, peer influence, and socioeconomic status were not directly

measured, yet they may play critical roles. Finally, the study's cross-sectional design restricts the ability to draw strong causal inferences, highlighting the need for longitudinal and experimental approaches to confirm the observed relationships.

Future studies should address these limitations by expanding the scope to diverse cultural and institutional settings, thereby enhancing the generalizability of the findings. Longitudinal research designs would provide deeper insights into how motivational, cognitive, and psychosocial factors interact over time to shape academic outcomes. Incorporating objective measures, such as actual academic records or physiological indicators of stress and resilience, could also complement self-reported data and improve validity. Additionally, exploring the interaction between teacher practices, peer networks, and institutional policies with psychological constructs like motivation and resilience would enrich the understanding of academic performance. Further research into emerging challenges, such as the role of artificial intelligence and virtual reality in shaping academic learning, may also provide valuable contributions to the evolving educational landscape.

The practical implications of this study are significant for educators, counselors, and policymakers. First, interventions that foster mental and metacognitive skills should be integrated into curricula to strengthen self-regulation and learning outcomes. Schools and universities should also prioritize developing students' psychological capital and resilience, equipping them with the resources to adapt to academic stressors. Furthermore, supportive learning environments must be cultivated, emphasizing engagement, autonomy support, and balanced use of technology. Institutions should design digital learning systems that enhance engagement without encouraging overuse, while parents should be encouraged to adopt autonomy-supportive approaches at home. Finally, addressing hidden psychological struggles such as imposter syndrome requires targeted counseling and mentoring programs, ensuring that students feel empowered and confident in their academic journeys.

Authors' Contributions

Authors equally contributed to this article.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

All procedures performed in this study were under the ethical standards.

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