Psychology Research and Behavior Management
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ORIGINAL RESEARCH

The Relationship Between Resilience, Interactive Distance, and College Students' Online Mathematics Learning Engagement: A Longitudinal Study

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Introduction: Resilience, a pivotal construct in positive psychology, remains incompletely understood in its facilitation of learners' online engagement. This study aims to investigate the relationship between resilience, transactional distance, and Online Mathematics Learning Engagement (OMLE) among first-year university students.

Methods: Utilizing a cross-lagged path analysis approach, the study surveyed 612 first-year students. Multiple models were constructed and compared to explore the mutual predictive relationships between resilience, transactional distance, and OMLE.

Results: Among the compared models, Model 4 demonstrated the best fit. The model revealed that: (1) resilience at Time 1 and Time 2 positively predicted transactional distance at Time 2 and Time 3; (2) transactional distance at Time 1 and Time 2 positively predicted OMLE at Time 2 and Time 3; (3) resilience at Time 1 significantly predicted OMLE at Time 3; and (4) transactional distance at Time 2 fully mediated the relationship between resilience at Time 1 and OMLE at Time 3. Furthermore, mediational model analysis confirmed that transactional distance played a mediating role in the longitudinal relationship between resilience and OMLE. Using a cross-lagged mediational model with 5000 bootstrap samples, the indirect effect of transactional distance on the relationship between resilience at Time 1 and OMLE at Time 3 was significant and remained stable over time.

Discussion: The findings suggest that resilience, as a positive psychological resource, stimulates students to seek and utilize protective resources in online environments, leading to more active participation in interpersonal communication and classroom interactions. Additionally, resilience helps students overcome emotional and practical difficulties encountered in online learning, thereby enhancing their OMLE. These insights offer valuable implications for educators, highlighting the potential to improve students' online learning engagement by fostering their psychological resilience.

Keywords: psychological resilience, transactional distance theory, online mathematics learning engagement, cross-lag model, university students

Introduction

In recent years, there has been a growing interest in online learning engagement.[1] Learner engagement is a crucial factor in ensuring the quality of online learning, but learners often experience anxiety and boredom in online environments,[2] which can negatively affect their learning outcomes.[3] Therefore, it is of great theoretical and practical significance to examine the impact of personal factors, such as emotions, on mathematics learning.[4] Resilience is an important topic in positive psychology,[5] as it helps learners perceive adverse factors in their environment, enhance positive emotions and interests,[6] and ultimately improve their engagement in learning.[7] However, previous research has mostly focused on factors such as motivation and social support in relation to online learning engagement,[8] paying less attention to the mechanisms through which resilience operates.[9] Individuals with higher levels of resilience are better able to cope with difficulties and pressures in long-term learning, thus recovering their motivation.[10] In particular, many students experience math anxiety,[11] and compared to other subjects, lack of focus and absenteeism are more pronounced in online math classes.[12] Based on this, the present study investigates the influence of resilience

Received: 14 November 2023
Accepted: 29 January 2024
Published: 13 March 2024

on mathematics learning engagement among college students in online environments, and explores potential mechanisms, with the aim of providing strategies to enhance students' online math learning engagement (OMLE).

Resilience and Online Learning Engagement

Resilience is a positive individual trait in positive psychology and plays an important role in mathematics learning.[13] Resilience refers to the psychological mechanism by which individuals continuously adapt and seek resources to adjust their own behavior in the face of difficulties.[14] It effectively maintains a dynamic balance between individual crisis factors (anxiety, stress, difficulties, etc.) and protective factors (psychological and environmental resources).[15] Previous studies have shown that individuals with good n individual crisis factors, and actively utilize protective resources to enhance adaptive behaviors.[16]

Learning engagement is an important indicator for evaluating the effectiveness of online learning.[15] Learning engagement refers to the time and effort students invest in meaningful learning activities.[17] Scholars have proposed a four-dimensional model of classroom learning engagement, including cognitive, affective, behavioral, and performance engagement.[18] Cognitive engagement refers to learners' use of online cognitive strategies, affective engagement refers to their attitudes and emotions towards learning, behavioral engagement refers to classroom participation and interaction behaviors, and performance engagement refers to the goal-oriented motivation to achieve good performance.[19] Dixson (2015) demonstrated the rationality of this four-dimensional structure through investigating learners' online learning engagement.[20]

Empirical research on how resilience influences online learning engagement is relatively scarce, but some studies have shown that resilience has a direct promoting effect on Online Math Learning Engagement.[21] Individuals with higher resilience are better able to adapt to challenges and difficulties in online learning, maintain positive learning attitudes and emotions, and demonstrate better self-control and self-motivation, thereby increasing their level of engagement and learning outcomes in online learning.[22] Resilience can transform social support, help from others, and other favorable factors during the learning process into protective resources for individual development.[23,24] These resources can create a relaxed and pleasant learning environment for learners and make them more willing to engage in learning.[25,26] Furthermore, resilience is the ability of learners to overcome difficulties in unfavorable educational environments.[23] Enhancing resilience can promote learners to actively adopt social and personal protective resources to maintain learning motivation, help students set learning goals, and promote mathematical learning behavior.[27] Additionally, related research has found that social skills, empathy, and interpersonal relationships are important factors of resilience that promote students to actively seek help and support from teachers, peers, and parents. Pitzer and Skinner (2017) found that resilience can help students gain more interpersonal resources and increase interactions between students and teachers.[28] Moreover, students with resilience are also willing to spend more time and effort on English reading materials.[29]

These studies generally support the view that resilience positively predicts classroom learning engagement. However, they have two main limitations. First, they all used cross-sectional methods instead of longitudinal designs, limiting the possibility of drawing causal conclusions. Second, the focus of the research was on middle school students. The impact of resilience on online learning engagement among college students is still unclear. Therefore, it is necessary to explore the longitudinal relationship between resilience and OMLE among young adults.

The Mediating Role of Transactional Distance

Transactional distance serves as a reference indicator for effective interactive behavior, reflecting learning attitudes and emotions.[30] Transactional distance refers to the perceived psychological distance between teachers and students due to physical distance, consisting of instructional dialogue, course structure, and student autonomy.[31] It exists in the temporally and spatially separated teaching process. Dialogues are the most powerful means of reducing psychological distance,[32] manifested in the interactive processes between teachers and students, students and students, and students and content.[33] Previous research has shown that interactions between teachers and students, interactions among students, and interactions between students and content positively predict cognitive, behavioral, and affective engagement in online learning.[34] Reducing the affective distance between students, teachers, peers, and learning content can also promote learners' classroom and extracurricular learning experiences and agency, enhancing their satisfaction and engagement in learning.[35] According to the theory of transactional distance, interactions between teachers and students, among students, and between students and content can effectively reduce transactional distance and mitigate the adverse effects of physical distance.[36] In student-centered online learning, interactions between teachers and students, peer-assisted learning, and student engagement with or reflection upon the learning content positively influence online learning engagement.[32] Therefore, this study further posits that resilience indirectly promotes online math learning engagement by reducing transactional distance.[37]

Therefore, transactional distance may serve as a potential mediator of the relationship between resilience and OMLE. Transactional distance acts as a mediator by affecting the relationship between resilience and online learning engagement. When transactional distance is large, learners may feel lonely and lack support, weakening resilience and online learning engagement. Conversely, when transactional distance is small, learners may find it easier to obtain support and engage in interactions, strengthening resilience and online learning engagement. Additionally, research has reported that psychological resilience in adolescents mediates the relationship between social support and learning engagement.[38] Therefore, this study innovatively investigates whether transactional distance mediates the relationship between resilience and OMLE using a longitudinal design.

This Study

Based on the aforementioned foundation, this study employed longitudinal data and cross-lagged analysis to examine the causal relationships between resilience, transactional distance, and OMLE. Specifically, we tested two objectives: the first was to investigate whether resilience and transactional distance influence the process of OMLE, and the second was to explore whether transactional distance moderates the relationship between resilience and OMLE. To achieve these objectives, we utilized Structural Equation Modeling (SEM) as an analytical tool and conducted data analysis using SPSS and Mplus statistical software. In our model, we identified resilience, transactional distance, and OMLE as latent variables and examined their direct and indirect effects through path analysis. Furthermore, we incorporated time as a factor by including data from different time points in the model to capture dynamic changes.[39,40] Through these analyses, we anticipated a deeper understanding of the relationships between resilience, transactional distance, and OMLE, as well as their patterns of change over time.

Methods

Study Participants

A cluster sampling method was employed in this study, selecting first-year students from the School of Mathematics and Big Data at a university in Huainan City, Eastern China. These students were ideal participants as they were required to take mathematics courses. Approval from the research ethics committee of the university was obtained prior to conducting the study. The survey was conducted in three waves using an online format in March, June, and September 2022. Considering that online courses were the norm for students at that time due to the absence of "herd immunity" policies in China, it was conducive to measuring students' OMLE. Before the survey, students were informed that the test was anonymous, their responses would remain confidential, and would be solely used for research purposes. They were free to withdraw from the test at any time. Participants signed an informed consent form online before completing the survey.

In the first wave of the survey, we collected demographic information from students, including gender, age, only child status, home address, parents' education level, and household economic status. Additionally, we assessed their resilience, transactional distance, and OMLE. A total of 776 questionnaires were distributed, and 713 valid responses were successfully collected, resulting in a high response rate of 91.88%. To ensure data continuity and accuracy, we specifically contacted students who provided valid contact information and completed the previous wave of the survey for the second and third waves. Through online questionnaires, we collected relevant data from them again (during this process, all participants and their guardians signed informed consent forms). The second and third waves of the survey re-evaluated participants' resilience, transactional distance, and OMLE, receiving 672 and 612 valid responses with response rates of 94.25% and 91.07%, respectively. As a token of appreciation for participants' contributions, each individual who completed the survey received a reward of 3 Chinese yuan.

Throughout the study, we noted that 612 participants consistently completed all three waves of the survey, accounting for 78.87% of the total sample. However, 164 participants were unable to complete the entire survey due to various reasons, resulting in an attrition rate of 21.13%. To ensure the accuracy and reliability of the data analysis, we excluded 52 questionnaires with missing critical information or exhibiting a systematic response pattern, ultimately obtaining 560 valid samples with an effective response rate of 91.50%.

Before conducting the final data analysis, we compared the attrited samples with the existing samples to examine whether there were significant differences between them. Through statistical analysis, we found no significant systematic biases in demographic variables or key study variables between the attrited and existing samples, which strengthened our confidence in the representativeness of the final sample.

The final analytical sample comprised 560 participants who completed at least two waves of the survey. Among them, 325 were male (53.11%), and 287 were female (46.90%). The average age of participants was 20.16 years (standard deviation SD = 2.03). This sample composition provided a solid foundation for our subsequent in-depth analysis of the relationships between resilience, transactional distance, and OMLE.

Research Instruments

Chinese Version of the Connor-Davidson Resilience Scale

The Connor-Davidson Resilience Scale (CD-RISC) was initially developed by Connor and Davidson (2003) as a measure of resilience.[41] The scale was later translated into Chinese by Yu and Zhang (2009) for assessing the resilience levels of participants in this study.[42] The scale consists of 25 items, encompassing three dimensions: strength (8 items), optimism (4 items), and toughness (13 items). Each item is rated on a 5-point Likert scale, ranging from 1 (never) to 5 (always), with a total score range of 25–125. Higher scores indicate higher levels of resilience. Studies have demonstrated good reliability and validity of this scale among Chinese university students.[42] In this study, the Cronbach's α coefficients for the three measurements were 0.85, 0.86, and 0.91, indicating good internal consistency.

Revised Short-Form Transactional Distance Scale (RSTD)

The Revised Short-form Transactional Distance Scale (RSTD) is a concise version of the Transactional Distance Scale developed by Paul et al (2015) based on Zhang's (2003) Transactional Distance Theory.[43] The scale consists of 12 items and is primarily used to measure the transactional distance between students and teachers, students and peers, and students and instructional content. Each item is rated on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating smaller transactional distance. The scale was modified in this study, with the item context set as "online mathematics learning". In this study, the Cronbach's α coefficients for the three measurements were 0.85, 0.86, and 0.91, indicating good internal consistency.

Online Learning Engagement Scale

The Online Learning Engagement Scale, developed by Dixson (2015), was used in this study to assess students' engagement levels in online mathematics learning.[20] The scale consists of four dimensions: cognitive engagement, affective engagement, behavioral engagement, and learning performance. Each item is rated on a 5-point Likert scale, ranging from 1 (completely does not apply to me) to 5 (strongly applies to me). The scale has shown good reliability and validity among Chinese university students.[44] In this study, the Cronbach's α coefficients for the three measurements were 0.87, 0.89, and 0.93, indicating good internal consistency.

Analytical Strategies

The effective data was imported into SPSS 25.0 statistical software for reverse scoring, centering, and computation of latent variable scores. Subsequently, a normality test was conducted on all measurement tools, and correlation analysis was performed on the standardized data. Additionally, the measurement invariance of the scales over time was examined. Finally, cross-lagged analysis was conducted using Mplus 7.0, employing the maximum likelihood robust estimation method (MLR). Model fit indices, including $\chi 2$/df, CFI, TLI, RMSEA, and SRMR, were used for model evaluation.

Results

Test for Common Method Bias

To control for common method bias, this study employed methods such as reverse scoring items and ensuring confidentiality of responses. Harman's single-factor test was conducted to assess the presence of common method bias. The results of the principal component analysis without rotation for the two waves of measurements revealed the number of factors with eigenvalues greater than 1 to be 4 and 6, respectively. The first factor accounted for 26.23% and 23.42% of the variance, which were both below the critical threshold of 40%, indicating the absence of significant common method bias in both waves of measurements.

Descriptive Statistics and Correlation Analysis

Table 1 presents the means, standard deviations, and correlation coefficients of the three variables at three time points. The skewness and kurtosis of these variables were within an acceptable range (ie, skewness < 2.0, kurtosis < 7.0). The correlation analysis showed significant correlations among the three variables at all three time points. Both concurrent and lagged correlations of the variables were significant.

Cross-Lagged Model

To examine the measurement invariance of the Resilience, Transactional Distance, and OMLE scales over time, this study first tested the configural invariance, metric invariance, and scalar invariance models. As shown in Table 2, the ΔCFI and ΔTLI values were less than 0.010, and the ΔRMSEA value was less than 0.015.[45] Therefore, the configural invariance, metric invariance, and scalar invariance of these latent constructs across different time points were confirmed. The constraints of scalar invariance will be retained in the subsequent analyses.

Using a series of competing cross-lagged path analyses, we sequentially tested four models to explore the mutual predictive relationships among the three variables, as shown in Table 3. Model 1 served as the baseline model, estimating the stability coefficients of the relationships among the three variables and accounting for the error terms between the

Table 1 Descriptive Statistics and Correlations Among Variables of Interest

Variables	1	2	3	4	5	6	7	8	9
1. T1Resilience	1								
2. T2Resilience	0.713***	1							
3. T3Resilience	0.643***	0.701***	1						
4. T1Transactional distance	0.296***	0.321***	0.254***	1					
5. T2Transactional distance	0.312***	0.346***	0.297***	0.678***	1				
6. T3Transactional distance	0.266***	0.346***	0.424***	0.448***	0.532***	1			
7. T1OMLS	0.287***	0.193***	0.197***	0.328***	0.312***	0.294***	1		
8. T2OMLS	0.224***	0.301***	0.239***	0.326***	0.348***	0.287***	0.346***	1	
9. T3OMLS	0.262***	0.246***	0.249***	0.376***	0.378***	0.423***	0.238***	0.464***	1
M	3.32	3.32	3.36	3.08	3.02	2.99	2.86	2.89	2.85
SD	0.78	0.81	0.83	0.87	0.84	0.91	0.68	0.67	0.67
Skewness	0.33	0.33	0.41	0.69	0.64	0.71	−0.27	−0.22	−0.28
Kurtosis	0.73	0.64	0.77	−0.62	−0.68	−0.75	0.21	0.31	0.24

Note: ***p<0.001.

Table 2 Measurement Model Tests of All Latent Variables

	χ^2/df	CFI	TLI	RMSEA (90% CI)	SRMR	ΔCFI	ΔTLI	ΔRMSEA
Configural invariance	1.84	0.996	0.995	0.018 ([0.014, 0.022])	0.013			
Metric invariance	1.78	0.996	0.995	0.018 ([0.014, 0.022])	0.013	0.00	0.01	0.01
Scalar invariance	2.07	0.995	0.994	0.021 ([0.017, 0.024])	0.014	0.001	0.001	0.002

Table 3 Resilience, Transactional Distance and Fit Indices for Each Model of OMLE

Model	χ^2	Df	GFI	TLI	RMSEA	$\Delta\chi^2$	Δdf	Correction
Model1	83.487	24	0.887	0.845	0.132			1.182
Model2	69.545	20	0.906	0.845	0.112	13.944**	4	1.202
Model3	41.191	16	0.952	0.901	0.055	29.545***	4	1.218
Model4	6.854	8	0.999	0.999	0.027	32.027***	8	1.097

Notes: $\Delta\chi2$ is the Satorra-Bentler chi-square test of variance; ***p < 0.001, **p < 0.01.

three measurement time points. The fit of Model 1 was acceptable Therefore, additional cross-lagged paths were added to further examine the relationships among the three variables. Model 2 included the paths from transactional distance to resilience and from OMLE to transactional distance, in addition to Model 1. The chi-square difference test indicated that Model 2 was a slight improvement over Model 1 ($\Delta\chi2 = 13.944$, $\Delta df = 4$, $p < 0.01$). Model 3 included all cross-lagged paths among the three variables in addition to Model 1. The chi-square difference test showed that Model 3 significantly outperformed Model 2 ($\Delta\chi2 = 29.545$, $\Delta df = 4$, $p < 0.001$). Model 4 examined the paths from resilience to transactional distance and from transactional distance to OMLE in addition to Model 1. This model achieved a relatively good fit. Further modifications to this model, as indicated by the chi-square difference test, significantly improved the fit indices compared to Model 3 ($\Delta\chi2 = 32.027$, $\Delta df = 8$, $p < 0.001$).

Overall, Model 4 exhibited the best fit, and the results of the cross-lagged model among the three variables are depicted in Figure 1. Resilience at Time 1 and Time 2 positively predicted Transactional distance at Time 2 and Time 3, respectively. Transactional distance at Time 1 and Time 2 positively predicted OMLE at Time 2 and Time 3, respectively. Resilience at Time 1 significantly predicted OMLE at Time 3. Transactional distance at Time 2 fully mediated the relationship between Resilience at Time 1 and OMLE at Time 3.

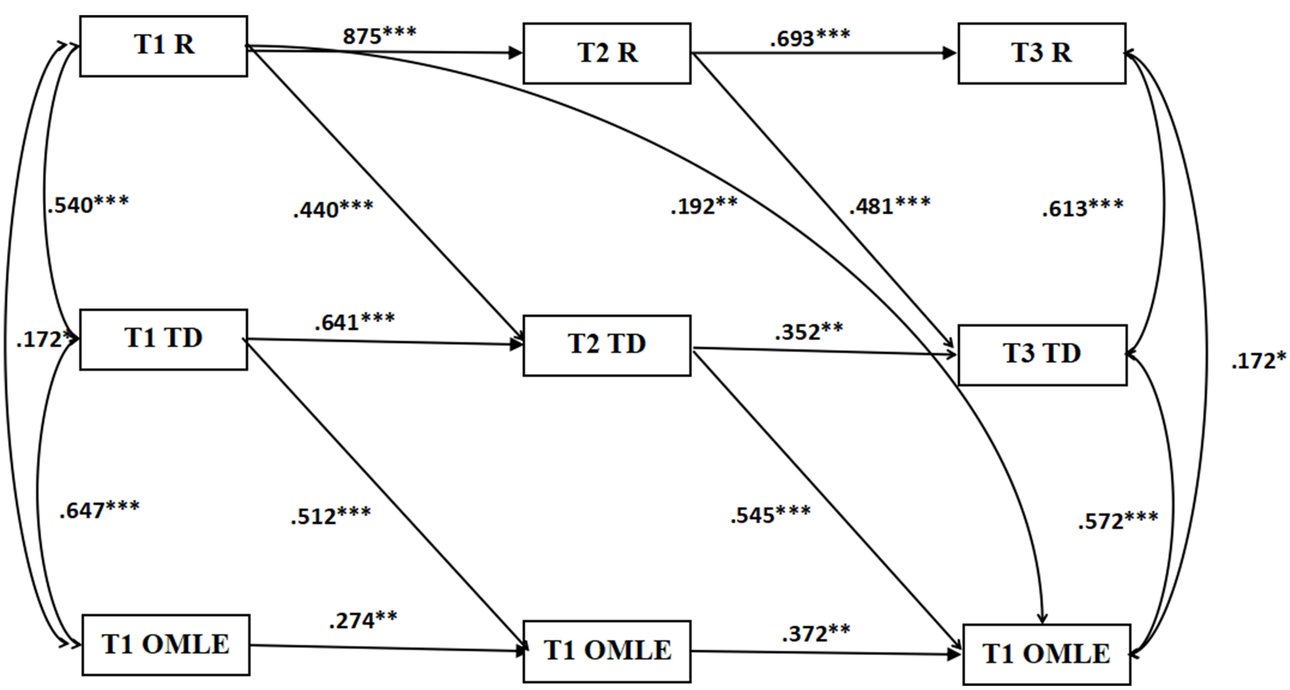

Figure 1 Three-variable cross-lagged model.
Notes: *p<0.05; **p<0.01; ***p<0.001.
Abberiviations: R, resilience; TD, Transactional distance; OMLE, Online Maths Learning Engagement.

Mediation Model

To investigate whether Transactional distance acts as a mediator in the longitudinal relationship between resilience and OMLE, we conducted a cross-lagged mediation model. Specifically, using 5000 bootstrap samples, we tested the indirect effect of Transactional distance on the relationship between resilience at T1 and OMLE at T3. The results indicated a standardized indirect effect of 0.252 with a confidence interval that did not include zero (95% CI [0.003, 0.047]). These findings suggest that Transactional distance mediates the association between resilience and OMLE, and this mediation effect remains stable over time.

Discussion

In recent years, with the rapid development of positive psychology in the field of education, resilience has gradually been applied to mathematics teaching and has provided a strong explanatory power for learners' psychology, motivation, and behavior.[46] However, the mechanism of resilience in online learning is still not well understood. To fill this gap, the present study examined the longitudinal relationships between resilience, Transactional distance, and OMLE among 612 first and second-year college students using a 9-month follow-up design. The results revealed a significant positive predictive effect of resilience on subsequent OMLE among college students. Furthermore, we further revealed the longitudinal mediating effect of Transactional distance in the association between resilience and college students' OMLE.

The Delayed Predictive Effect of Resilience on OMLE

The cross-lagged model revealed that resilience significantly and positively predicted subsequent OMLE. This means that students with higher levels of resilience at present tend to have higher levels of OMLE six months later, indicating an enhancing predictive effect. These findings support and enrich previous theories and research, suggesting that enhancing resilience can promote learners' cognitive and behavioral engagement.[7] According to the broaden-and-build theory[47] positive learning emotions and relatively comfortable learning environments can broaden students' attention, cognition, and behavioral range, motivating them to invest time and energy in acquiring knowledge and experiences that are beneficial for goal achievement, and stimulating the use of learning strategies. From a positive psychology perspective, resilience is the psychological energy that enables learners to adapt positively in adversity, enhancing subjective well-being, reducing learning stress,[48] and continuously promoting mental and physical health as well as learning engagement. Therefore, resilience, as a core positive psychological trait, can regulate cognition, behavior, and psychology in the learning process, creating a conducive learning atmosphere and exerting sustained positive effects on OMLE in the future.

The Mediating Role of Transactional Distance

This study innovatively confirmed the important mediating role of transactional distance in explaining the relationship between resilience and OMLE. The results were consistent with expectations, showing that transactional distance mediated the longitudinal relationship between resilience and OMLE, with resilience at Time 1 potentially indirectly influencing OMLE at Time 3 through transactional distance at Time 2.

In online learning, the separation of time and space causes learners to lose their "social attributes" and easily experience negative emotions such as loneliness, boredom, and anxiety, leading to psychological imbalance.[49] In such situations, resilience can quickly activate learners' protective mechanisms, such as actively seeking teacher support through the internet, engaging in communication and collaboration with peers, or continuously contemplating relevant knowledge, thereby maintaining mental and physical balance.[48] According to the Transactional Distance Theory, enhancing communication and dialogue between teachers and students, students and students, and students and content can reduce the negative impact of distance education and shorten transactional distance.[49] Reducing transactional distance can promote engagement in online learning.[50] The results also indicated that interactive learning enhances learners' use of cognitive strategies and participation in classroom interactions, thereby enhancing OMLE, which is consistent with previous research conclusions.[19] Therefore, an increase in resilience levels can reduce transactional distance within six months and subsequently influence OMLE.

Furthermore, although the direct effect of resilience on online learning engagement is relatively small (effect=0.192, $p<0.01$), it can produce indirect effects by increasing interaction behaviors between teachers and students, students and students, and students and content. This may be because resilience can maintain a dynamic balance between individual stress factors and protective factors, promoting stable individual development.[15,48] The partial mediating effect of transactional distance between resilience and online learning engagement is greater than the direct effect of resilience, which may be due to the instability of individual behavioral effects of resilience, which are easily influenced by various stress factors,[10] while instructional interaction keeps learners constantly in the "learning field", having motivating and protective effects on learning psychology and engagement.[49]

Practical Implications and Applications of Artificial Intelligence

This study, grounded in Transactional Distance theory, examines OMLE through individual and environmental lenses, highlighting resilience's significant impact on online mathematics learning. It extends the theory's application in online engagement and reveals a cross-lagged mediated effect of transactional distance on resilience and OMLE over time. This underscores the importance of considering historical factors in studying college students' problematic behaviors. Practically, the study emphasizes the role of personalized teaching interactions and cooperative assistance in boosting motivation and engagement.[36,49] Educators should address transactional distance issues by fostering learner communication and interaction through questioning, guidance, and feedback. Cultivating students' positive psychological qualities, particularly resilience, is also crucial.

Against the backdrop of AI advancements, our findings provide a solid basis for utilizing these technologies in assessing and intervening in students' mental health. AI can analyze behavioral data, such as online engagement and emotional responses, to assess mental well-being. For instance, NLP techniques can identify negative emotions or stress signals in forum posts. Machine learning algorithms can predict future mental health issues based on historical data.[51] Once identified, AI can aid in timely interventions, automated or semi-automated, to enhance psychological resilience and coping mechanisms in online learning environments. Furthermore, AI can optimize online learning designs by pinpointing factors leading to isolation or anxiety and adapting course designs accordingly. This approach enhances student engagement, satisfaction, resilience, and overall well-being.

Contributions and Limitations

This study preliminarily revealed the longitudinal relationship between resilience and OMLE, as well as the mediating effect of transactional distance. However, there are some limitations. Firstly, the study only focused on students from a specific university, which limits the representativeness and generalizability of the sample. Secondly, self-reported longitudinal data was used, and further experimental verification is needed to establish causality between variables. Finally, only the overall effect of resilience was analyzed, and future research should explore the different dimensions of resilience to gain deeper insights into its mechanisms.

Conclusion

This longitudinal study analyzed the impact of psychological resilience on Chinese college students' online math learning engagement (OMLE), as well as the mediating role of transactional distance over time. The results showed that learners' psychological resilience had a direct positive impact on OMLE, although the effect size was not high. On the other hand, transactional distance played a significant mediating role between psychological resilience and OMLE, and its effect was significantly greater than the direct impact of psychological resilience. These findings indicate that psychological resilience, as a positive psychological resource for learners, can stimulate protective resources in online learning environments, prompting students to actively engage in interpersonal communication and classroom interaction. This helps students overcome positive emotions and objective difficulties in online learning, thereby increasing the level of OMLE.

Data Sharing Statement

Data generated or analyzed during this study are available from the corresponding author upon request.

Ethics Statement

Research involving humans was approved by both the University of Glasgow Institutional Review Board and the ethics committee at the university in Huainan City. The study was conducted in accordance with local laws and institutional requirements. Participants gave informed written consent to participate in this study.

Acknowledgments

I would like to express our gratitude to all those who helped us while writing this article.

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Disclosure

The author declares no conflict of interest.

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