Infinity Journal of Mathematics Education
Volume 15, No. 3, 2026
p-ISSN 2089-6867
e–ISSN 2460-9285
https://doi.org/10.22460/infinity.v15i3.p757-772

Profiles of K–12 mathematics teachers’ innovative behavior: A latent profile analysis

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Received: Feb 2, 2026 | **Revised**: Jul 18, 2026 | **Accepted**: Jul 22, 2026 | **Published Online**: Jul 27, 2026

Abstract

This study aims to identify the profiles of K–12 mathematics teachers’ innovative behavior in China using a latent profile analysis approach. Previous studies have mostly used variable-centered methods to examine factors associated with teachers’ innovative behavior, such as school support, professional knowledge, motivation, rewards, and anxiety. However, these approaches provide limited understanding of how mathematics anxiety and innovative behavior coexist within different groups of teachers. To address this gap, this study adopts a person-centered approach to classify mathematics teachers into distinct profiles based on their mathematics anxiety and innovative behavior. Survey data were collected from 336 mathematics teachers from primary, junior high, and senior high schools in China. Latent profile analysis was conducted to identify the optimal number of teacher profiles, and further analyses were used to examine whether the identified profiles differed in social influence, facilitating conditions, engagement, rewards, and technological-pedagogical-mathematical knowledge. The results identified four distinct teacher profiles. These profiles showed different combinations of mathematics anxiety and innovative behavior, indicating that teachers with similar professional contexts may still differ substantially in their emotional responses and innovation practices. Further comparison across profiles showed differences in social influence, facilitating conditions, engagement, rewards, and technological-pedagogical-mathematical knowledge, suggesting that mathematics teachers’ innovative behavior is shaped by the combined influence of emotional, professional, motivational, and contextual factors. Notably, the presence of Anxious–Innovative Teachers indicates that high innovative behavior can coexist with high anxiety, highlighting that innovation should not be interpreted only as a sign of confidence or psychological readiness.

Keywords:
Innovative behavior, K–12 mathematics teachers, Latent profile analysis, Mathematics anxiety, Teacher professional development

How to Cite:
Hendriana, H., Chen, X., Korenova, L., & Wijaya, T. T. (2026). Profiles of K–12 mathematics teachers’ innovative behavior: A latent profile analysis. *Infinity Journal*, *15*(3), 757-772. https://doi.org/10.22460/infinity.v15i3.p757-772

1. INTRODUCTION

Educational systems are increasingly shaped by rapid technological transformation and the growing integration of artificial intelligence into educational practices (Gill et al., 2024; Quan, 2025). Schools are no longer expected merely to reproduce existing knowledge structures; they are also expected to cultivate adaptability, creativity, critical inquiry, and innovation among learners (Abdullah et al., 2021; Desania et al., 2020). As educational priorities shift towards more dynamic and student-responsive forms of learning, teachers occupy a central role in translating educational reforms into classroom practice (OECD, 2022, 2025; Wijaya, Hidayat, et al., 2024). Teaching innovation has therefore increasingly been recognised as an important educational priority because it enables teachers to redesign instructional processes, respond flexibly to diverse learner needs, and sustain meaningful learning experiences in rapidly evolving educational environments (Fidalgo-Blanco et al., 2017; Gurzynski-Weiss et al., 2015; Hidayat et al., 2025; Lee et al., 2016; Setambah et al., 2024).

Innovative behavior in education refers to teachers' willingness and capacity to adopt, develop, and implement instructional practices that enhance the quality of teaching and learning (Klaeijsen et al., 2018). In educational contexts, such behavior is reflected in teachers' efforts to redesign instructional processes, respond adaptively to students' learning needs, and create more engaging learning environments. Within mathematics education, innovative teaching has increasingly been associated with mathematical discussion, inquiry, reasoning, and active student participation in learning processes (Angraini et al., 2023; Darmawijoyo et al., 2025; Hendriana et al., 2025; Hunter et al., 2020; Rohaeti et al., 2023; Santana-Ramírez et al., 2025; Tak et al., 2025), as well as the meaningful integration of technology to support students' conceptual and procedural understanding of mathematics (Hendriana et al., 2025; Hidayat & Aripin, 2023; Mandala et al., 2025; Marhaeni et al., 2024; Zulnaidi & Zamri, 2017). These approaches emphasise active student participation in mathematical reasoning, discussion, and inquiry rather than passive procedural reproduction (Hunter et al., 2020). These perspectives suggest that innovative behavior in mathematics education extends beyond the adoption of technological tools alone and also involves the use of inquiry-oriented and student-centred instructional approaches that support students' mathematical reasoning and engagement.

Previous research has identified numerous factors associated with teachers' innovative behavior. Organisational and contextual conditions, such as leadership practices and job autonomy, as well as facilitating conditions, social influence, and reward structures (Wu et al., 2022), have been recognised as important enabling conditions for innovative instructional practices. At the same time, individual and professional characteristics, including occupational self-efficacy and intrinsic motivation (Klaeijsen et al., 2018), together with technological-pedagogical knowledge and information literacy (Wu et al., 2022), have consistently been linked to teachers' willingness to adopt innovative approaches. Emotional and occupational pressures, including anxiety, technostress, and work stress (Wu et al., 2022), may nevertheless discourage teachers from departing from familiar instructional routines. These findings suggest that teachers working within similar educational environments may still respond differently to innovation depending on how contextual, motivational, and emotional characteristics coexist within individuals.

Despite growing interest in teachers' innovative behavior, existing studies (e.g., Li et al., 2024; Wu et al., 2022) have predominantly adopted variable-centred approaches to examine relationships among innovation-related variables. Although these approaches have contributed valuable insights into the predictors of innovation, they provide limited understanding of how multiple characteristics combine within individual teachers. Teachers with similar levels of innovative behavior may nevertheless differ considerably in anxiety, engagement, confidence, or perceived support. Consequently, a person-centred perspective may offer a more nuanced understanding of teachers' professional functioning by identifying distinct subgroups that share similar emotional, contextual, and motivational configurations. Latent Profile Analysis (LPA) is particularly useful in this regard because it enables the identification of hidden profiles within heterogeneous populations based on shared response patterns.

K–12 mathematics teachers are expected to integrate student-centred and technology-enhanced instructional approaches (Wu et al., 2022). These expectations may generate diverse professional and emotional responses among mathematics teachers, making it important to understand how innovation-related characteristics cluster within different groups of teachers. This study, therefore, adopts a person-centred approach to examine profiles of K–12 mathematics teachers' innovative behavior in China. LPA was used to identify distinct teacher profiles based on anxiety related to innovative behavior. In doing so, the study seeks to provide a more differentiated understanding of how these characteristics coexist within different groups of mathematics teachers and to contribute evidence that may support more targeted and profile-sensitive professional development practices in mathematics teacher education.

2. METHOD

2.1. Participants

A total of 336 K–12 mathematics teachers in China participated in this study. Among them, 150 were male teachers (44.64%) and 186 were female teachers (55.36%). Regarding school location, 243 participants (72.32%) worked in urban schools, while 93 participants (27.68%) were from rural schools. In terms of educational background, 241 teachers (71.73%) held an undergraduate degree, 82 teachers (24.40%) held a master's degree, and 13 teachers (3.87%) held a doctoral degree.

With respect to teaching experience, 47 teachers (13.99%) had less than five years of experience, 74 teachers (22.02%) had between five and tenth years, and 215 teachers (63.99%) had more than tenth years of teaching experience. The sample also covered different school stages: 132 teachers (39.29%) taught at the primary school level, 105 teachers (31.25%) taught at the junior high school level, and 99 teachers (29.46%) taught at the senior high school level.

All participants completed the questionnaire online on a voluntary basis. They were mathematics teachers who had joined a workshop on improving teaching effectiveness and student achievement. Because participants were recruited from teachers who were accessible through this workshop and agreed to complete the survey, the study employed a convenience sampling approach.

2.2. Measurement

The questionnaire used in this study was adopted from Li et al. (2024), who developed and validated an instrument to examine factors affecting elementary mathematics teachers' innovative behavior in China. The original instrument consisted of 22 items across eight constructs: facilitating conditions, social influence, rewards, technological-pedagogical-mathematical knowledge (TPACK), work engagement, self-efficacy, anxiety, and innovative behavior. The items were measured using a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. In the present study, the items were adapted to the broader context of K–12 mathematics teachers, including primary, junior high, and senior high school teachers. Mathematics anxiety and innovative behavior were used as the indicators for latent profile analysis, while the remaining constructs were used as auxiliary variables to examine differences across teacher profiles. Li et al. (2024), reported acceptable reliability and validity for the instrument, with Cronbach's alpha values ranging from 0.827 to 0.896 and composite reliability values ranging from 0.897 to 0.944.

2.3. Data Analysis

LPA was conducted to identify distinct profiles of K–12 mathematics teachers based on mathematics anxiety and innovative behavior. Following prior LPA procedures in mathematics education, a series of models ranging from one to five profiles were estimated and compared. Model selection was based on multiple fit indices, including the Akaike information criterion (AIC), Bayesian information criterion (BIC), sample-size adjusted Bayesian information criterion (SABIC), entropy, and the Lo-Mendell-Rubin adjusted likelihood ratio test (LMRT) (Xu, 2024). Lower AIC, BIC, and SABIC values indicate better model fit, meaning that the model explains the data more efficiently (Nylund et al., 2007; Resende & Cirillo, 2025). However, these indices usually continue to decrease as the number of profiles increases; therefore, they should not be used alone to select the final solution. Entropy was used to evaluate classification accuracy, with values closer to 1 indicating clearer separation among profiles (He et al., 2025). In general, entropy values above 0.80 are considered good, although entropy should also be interpreted together with other statistical and substantive criteria. The LMRT was used to compare a k-profile model with a k−1-profile model (Wijaya, Yu, et al., 2024). A significant LMRT p-value, usually $p < 0.05$, indicates that the model with one additional profile provides a significantly better fit than the previous model. In addition, profile size was considered. Following Westphal et al. (2024), very small profiles, particularly those representing less than 5% of the total sample, were treated cautiously because they may indicate unstable or less interpretable profile solutions. Therefore, the final model was selected by jointly considering statistical fit, entropy, LMRT significance, profile size, theoretical justification, and substantive interpretability. This procedure is consistent with prior LPA research in mathematics education, where the final solution is not determined by a single index but by a comprehensive evaluation of model fit and profile clarity.

3. RESULTS AND DISCUSSION

3.1. Results

Before conducting the latent profile analysis, descriptive statistics and bivariate correlations among the study variables were examined. As shown in Table 1, facilitating conditions, social influence, rewards, TPACK, self-confidence, engagement, and self-efficacy were positively and significantly correlated with innovative behavior, whereas anxiety was negatively and significantly associated with innovative behavior. The positive professional and contextual factors were also significantly interrelated, while anxiety showed negative correlations with these variables. These preliminary results indicate meaningful associations among the study variables and provide an initial basis for further examining whether distinct teacher profiles can be identified.

Table 1. Bivariate correlations and descriptive statistics for study variables (N = 336)

No	Variables	M	1	2	3	4	5	6	7	8	9
1	FC	3.46	–								
2	SI	3.49	0.84**	–							
3	R	3.40	0.83**	0.80**	–						
4	TPACK	3.48	0.84**	0.77**	0.79**	–					
5	SC	3.58	0.75**	0.74**	0.70**	0.82**	–				
6	ENG	3.52	0.83**	0.78**	0.76**	0.85**	0.81**	–			
7	SE	3.55	0.83**	0.77**	0.76**	0.84**	0.81**	0.86**	–		
8	ANX	3.07	−0.49**	−0.39**	−0.41**	−0.41**	−0.38**	−0.42**	−0.42**	–	
9	IB	3.32	0.80**	0.73**	0.74**	0.78**	0.71**	0.78**	0.79**	−0.40**	–

3.1.1. Profiles of K–12 Mathematics Teachers' Innovative Behavior

Based on the model fit indices, the four-profile solution was selected as the optimal model. The AIC, BIC, and SABIC values decreased consistently from the one-profile to the five-profile solution, indicating that models with more profiles generally provided better fit. The two-profile and three-profile models showed significant improvement over the previous models, as indicated by significant LMRT results. The four-profile model also showed a statistically significant improvement over the three-profile model, with LMRT = 166.956, $p = 0.0319$, and demonstrated good classification quality, with an entropy value of .864. Although the five-profile model had slightly lower AIC, BIC, and SABIC values and a slightly higher entropy value (0.877), its LMRT result was not significant, LMRT = 46.290, $p = 0.1914$. This indicates that the five-profile model did not provide a statistically meaningful improvement over the four-profile model. Moreover, the five-profile solution produced a very small profile, representing only 3.46% of the sample, which may weaken the stability and substantive interpretability of the classification. Therefore, considering statistical fit, classification accuracy, profile size, and theoretical interpretability, the four-profile solution (see Table 2) was retained as the most appropriate model.

Table 2. Model fit indices for latent profile solutions

Classes	AIC	BIC	SABIC	LMRT	LMRT p-value	Entropy	Class proportions
1	5036.711	5074.882	5043.161	—	—	—	—
2	4627.048	4688.122	4637.368	409.918	0.0000	0.832	31.66%, 68.34%
3	4457.858	4541.835	4472.048	176.143	0.0001	0.859	13.80%, 61.09%, 25.11%
4	4298.118	4404.997	4316.178	166.956	0.0319	0.864	14.23%, 53.83%, 22.44%, 9.50%
5	4262.502	4392.284	4284.432	46.290	0.1914	0.877	14.65%, 52.64%, 21.80%, 7.45%, 3.46%

In the four-profile solution, Profile 2 contained the largest number of participants with an estimated N = 180.87, accounting for 53.83% of the sample. This was followed by Profile 3 with N = 75.39 participants, representing 22.44% of the sample. Profile 1 included N = 47.82 participants, or 14.23%, while Profile 4 was the smallest profile, with N = 31.92, accounting for 9.50% of the sample. Overall, most participants were concentrated in Profile 2, whereas Profile 4 contained the fewest participants.

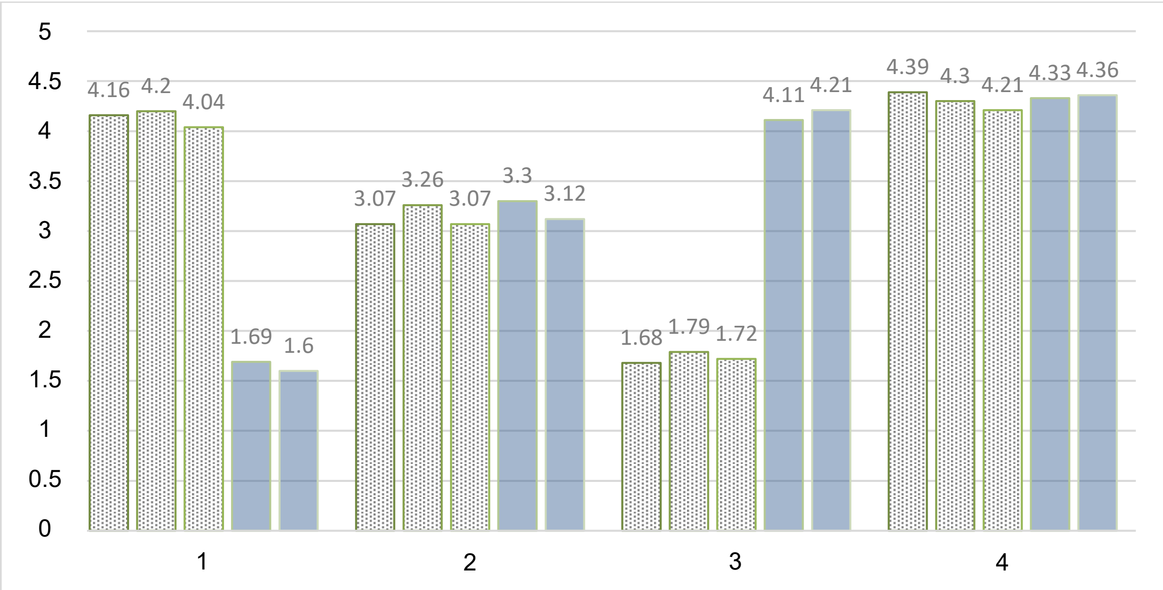
After selecting the four-profile solution as the optimal model, the next step was to interpret the substantive characteristics of each profile. The profiles were examined based on the mean scores of mathematics anxiety and mathematics teacher innovative behavior indicators. This interpretation allowed the study to identify how different groups of K–12 mathematics teachers combined emotional responses toward mathematics teaching with their engagement in innovative teaching practices. As shown in Figure 1 and Table 2, the four profiles demonstrated distinct patterns and were labeled as High Anxiety–Low Innovation Teachers, Moderate Anxiety–Moderate Innovation Teachers, Confident–Innovative Teachers, and High Anxiety–High Innovative Teachers.

Profile 1 included approximately 48 teachers, representing 14.23% of the sample. This profile was characterized by consistently high mathematics anxiety and low mathematics teacher innovative behavior. The anxiety indicators were high, with ANX1 = 4.16, ANX2 = 4.20, and ANX3 = 4.04. In contrast, the innovation indicators were low, with INV1 = 1.69 and INV2 = 1.60. Therefore, this group was labeled High Anxiety–Low Innovation Teachers. This profile suggests that these teachers may experience strong anxiety in relation to mathematics teaching, which may be associated with limited willingness or readiness to adopt innovative teaching practices.

Profile 2 was the largest group, including approximately 181 teachers, or 53.83% of the sample. This profile showed moderate levels of both mathematics anxiety and innovative behavior. The anxiety indicators were around the middle level, with ANX1 = 3.07, ANX2 = 3.26, and ANX3 = 3.07. Their innovative behavior was also moderate, with INV1 = 3.30 and INV2 = 3.12. Thus, this group was labeled Moderate Anxiety–Moderate Innovation Teachers. Teachers in this profile may experience some anxiety in mathematics teaching, but they still demonstrate a moderate level of engagement in innovative teaching practices.

Profile 3 included approximately 75 teachers, accounting for 22.44% of the sample. This profile was characterized by the lowest mathematics anxiety and high innovative behavior. The anxiety indicators were low, with ANX1 = 1.68, ANX2 = 1.79, and ANX3 = 1.72. At the same time, the innovation indicators were high, with INV1 = 4.11 and INV2 = 4.21. Therefore, this group was labeled Confident–Innovative Teachers. This profile represents teachers who appear emotionally more comfortable with mathematics teaching and are more likely to engage in innovative teaching behaviors.

Profile 4 was the smallest group, including approximately 32 teachers, representing 9.50% of the sample. This profile showed a distinct pattern of high mathematics anxiety and high innovative behavior. It had the highest anxiety scores, with ANX1 = 4.39, ANX2 = 4.30, and ANX3 = 4.21. However, it also showed the highest innovative behavior, with INV1 = 4.33 and INV2 = 4.36. Thus, this group was labeled High Anxiety– High Innovative Teachers. This profile indicates that high anxiety does not necessarily prevent teachers from being innovative. Teachers in this group may feel pressure, uncertainty, or concern in mathematics teaching, but they still actively engage in innovative practices.



Note: The polka-dot bars represent teachers' mathematics anxiety indicators, while the blue bars represent teachers' innovative behavior indicators

Figure 1. Latent profiles with the factor mean scores of the indicators

3.1.2. Differences in Internal and External Factors Related to Mathematics Teachers' Innovative Behavior Across the Four Latent Profiles

To further characterize the four latent profiles of mathematics teachers' innovative behavior, this study examined whether they differed significantly in several internal and external factors. These factors included anxiety, TPACK, social influence, facilitating conditions, rewards, and engagement. A series of one-way ANOVA tests was conducted, followed by Tukey's HSD post hoc comparisons to identify specific differences between profiles. The results are presented in Table 3.

The analysis revealed clear differences in anxiety across the four profiles. Teachers in Profile 3 reported the lowest anxiety level (M = 1.68, SD = 0.64), followed by those in Profile 2 (M = 3.07, SD = 0.66). In contrast, teachers in Profile 1 (M = 4.16, SD = 0.74) and Profile 4

(M = 4.39, SD = 0.50) showed substantially higher anxiety. The post hoc results indicated that Profile 3 had significantly lower anxiety than Profile 2, which in turn had significantly lower anxiety than Profiles 1 and 4. However, Profiles 1 and 4 did not differ significantly from each other, suggesting that both groups experienced similarly high levels of anxiety.

Table 3. Results of ANOVA analysis and post hoc comparisons across the four profiles

Variables	Profile 1		Profile 2		Profile 3		Profile 4		Post hoc
	M	SD	M	SD	M	SD	M	SD	
Anxiety	4.16	0.74	3.07	0.66	1.68	0.64	4.39	0.50	3 < 2 < 1 = 4
TPACK	2.03	0.68	3.39	0.72	4.24	0.56	4.27	0.65	1 < 2 < 3 = 4
Social influence	2.09	0.66	3.44	0.78	4.19	0.62	4.13	0.73	1 < 2 < 3 = 4
Facilitating conditions	1.96	0.60	3.41	0.69	4.25	0.57	3.99	0.70	1 < 2 < 3 = 4
Rewards	2.11	0.70	3.30	0.70	4.16	0.59	4.00	0.86	1 < 2 < 3 = 4
Engagement	2.01	0.70	3.44	0.68	4.26	0.57	4.31	0.61	1 < 2 < 3 = 4

Note: In the post hoc comparisons, "<" indicates a statistically significant lower mean, whereas "=" indicates no statistically significant difference between profiles

For TPACK, a progressive increase was observed from Profile 1 to Profiles 3 and 4. Teachers in Profile 1 reported the lowest TPACK level (M = 2.03, SD = 0.68), whereas Profile 2 showed a moderate level (M = 3.39, SD = 0.72). The highest levels were found in Profile 3 (M = 4.24, SD = 0.56) and Profile 4 (M = 4.27, SD = 0.65). Post hoc comparisons showed that Profile 1 scored significantly lower than Profile 2, and Profile 2 scored significantly lower than Profiles 3 and 4. No significant difference emerged between Profiles 3 and 4, indicating that these two groups possessed similarly strong technological, pedagogical, and content-related knowledge.

A similar pattern appeared for social influence. Teachers in Profile 1 had the lowest perceived social influence (M = 2.09, SD = 0.66), followed by those in Profile 2 (M = 3.44, SD = 0.78). Teachers in Profile 3 (M = 4.19, SD = 0.62) and Profile 4 (M = 4.13, SD = 0.73) reported the strongest social influence. The post hoc results showed significant differences between Profile 1 and Profile 2, and between Profile 2 and Profiles 3 and 4. Profiles 3 and 4 did not significantly differ, suggesting that both groups perceived similarly strong encouragement or support from their professional and social environments.

Regarding facilitating conditions, teachers in Profile 1 again obtained the lowest score (M = 1.96, SD = 0.60), indicating limited access to supportive resources or institutional conditions for innovative teaching. Profile 2 showed a higher but still moderate level (M = 3.41, SD = 0.69). Teachers in Profile 3 (M = 4.25, SD = 0.57) and Profile 4 (M = 3.99, SD = 0.70) reported comparatively strong facilitating conditions. The post hoc analysis confirmed that Profile 1 was significantly lower than Profile 2, and Profile 2 was significantly lower than Profiles 3 and 4. The difference between Profiles 3 and 4 was not statistically significant, indicating that both groups experienced similarly favorable external support conditions.

The results for rewards also showed meaningful distinctions among the four profiles. Teachers in Profile 1 reported the lowest perception of rewards (M = 2.11, SD = 0.70), while Profile 2 had a moderate score (M = 3.30, SD = 0.70). Higher scores were observed for Profile 3 (M = 4.16, SD = 0.59) and Profile 4 (M = 4.00, SD = 0.86). The post hoc results indicated that Profile 1 scored significantly lower than Profile 2, and Profile 2 scored significantly lower than Profiles 3 and 4. Profiles 3 and 4 were not significantly different, suggesting that these teachers perceived similarly strong recognition, incentives, or professional rewards associated with innovative behavior.

Finally, engagement differed substantially across the profiles. Teachers in Profile 1 reported the lowest level of engagement (M = 2.01, SD = 0.70), whereas Profile 2 showed a moderate level (M = 3.44, SD = 0.68). The highest engagement was found in Profile 3 (M = 4.26, SD = 0.57) and Profile 4 (M = 4.31, SD = 0.61). Post hoc comparisons showed that Profile 1 was significantly lower than Profile 2, and Profile 2 was significantly lower than Profiles 3 and 4. No significant difference was detected between Profiles 3 and 4, indicating that teachers in these two profiles were comparably highly engaged in their teaching and professional activities.

3.2. Discussion

This study identified four distinct profiles of K–12 mathematics teachers' innovative behavior based on mathematics anxiety and innovative behavior. The findings show that mathematics teachers are not a homogeneous group in terms of their emotional responses and innovation practices. Instead, teachers with similar professional roles may display different combinations of anxiety and innovative behavior. This supports the value of using a person-centered approach, as latent profile analysis allows researchers to identify subgroups of teachers that may be overlooked in variable-centered analyses.

The first profile, High Anxiety–Low Innovation Teachers, represents teachers who experienced strong mathematics anxiety and reported low levels of innovative behavior. This pattern suggests that anxiety may constrain teachers' willingness or readiness to adopt new instructional practices. Teachers in this profile may feel less confident in experimenting with new approaches, integrating new resources, or taking pedagogical risks in mathematics teaching. Their low levels of TPACK, social influence, facilitating conditions, rewards, and engagement further indicate that limited professional competence and weak contextual support may reinforce their low innovation. Therefore, this group may require targeted professional development that simultaneously addresses emotional support, instructional confidence, and practical competence in innovative mathematics teaching.

The second profile, Moderate Anxiety–Moderate Innovation Teachers, was the largest group in the sample. This finding suggests that many Chinese K–12 mathematics teachers experience a moderate level of anxiety while still maintaining a moderate level of innovative behavior. This profile may reflect a common professional condition in which teachers face pressure and uncertainty but still respond to changing expectations in mathematics education. For this group, professional development should not only aim to reduce anxiety but also strengthen the conditions that may help them move toward higher levels of innovation, such as improving TPACK, increasing collaborative support, and providing more recognition for innovative practices.

The third profile, Confident–Innovative Teachers, reflects a more expected pattern in which low anxiety is associated with high innovative behavior. Teachers in this profile reported low mathematics anxiety and high levels of innovative behavior, TPACK, social influence, facilitating conditions, rewards, and engagement. This suggests that teachers who feel emotionally comfortable in mathematics teaching may be more willing to explore new instructional strategies, use unfamiliar resources, and implement student-centered or technology-supported practices. This finding is consistent with previous research suggesting that lower teaching anxiety and stronger confidence may support more flexible and innovative teaching behavior (Musgrove & Schussler, 2022; Mutlu & Solhi, 2024).

The fourth profile, High Anxiety–High Innovative Teachers, is particularly important because it shows that high anxiety does not necessarily prevent teachers from being innovative. Although teachers in this profile reported the highest levels of anxiety, they also showed the highest innovative behavior. This finding challenges a simple negative interpretation of anxiety and suggests that anxiety may operate differently across teacher groups. In some cases, anxiety may function as an adaptive pressure that encourages greater effort, problem solving, and active attempts to improve teaching practices (Muñoz & González, 2017; Vanstone & Hicks, 2019). Previous studies have also indicated that challenge-related stressors may, under certain conditions, support thriving at work and innovative behavior (Cage & McManemy, 2022).

The contrast between Profiles 1 and 4 is especially meaningful. Both groups experienced similarly high levels of anxiety, but they differed greatly in innovative behavior. Profile 1 showed low innovation, whereas Profile 4 showed high innovation. This indicates that anxiety alone cannot fully explain teachers' innovative behavior. Instead, the broader configuration of professional knowledge, engagement, social influence, rewards, and facilitating conditions appears to shape whether anxiety becomes a barrier or coexists with innovation. Teachers in Profile 4 may have sufficient professional resources and contextual support to continue innovating despite emotional pressure, while teachers in Profile 1 may lack these protective factors.

TPACK appears to be one of the key factors distinguishing highly innovative teachers from less innovative teachers. Profiles 3 and 4 both demonstrated high innovative behavior and similarly high TPACK, despite having very different levels of anxiety. This suggests that strong technological, pedagogical, and mathematical knowledge may help teachers translate innovative ideas into classroom practice. Teachers with strong TPACK may be better prepared to select appropriate technologies, redesign mathematics instruction, and adapt teaching strategies to students' learning needs (Sofyan et al., 2023; Valtonen et al., 2017; Wah & Hashim, 2021). Therefore, TPACK may function as an important professional resource that supports innovation even when teachers experience anxiety.

Social influence also played an important role in differentiating the profiles. Teachers in the two highly innovative profiles reported stronger social influence than teachers in the low or moderate innovation profiles. This suggests that encouragement from colleagues, school leaders, and professional communities may motivate teachers to adopt new ideas, experiment with teaching approaches, and remain engaged in instructional improvement (Li et al., 2024). In this sense, innovative behavior should not be understood only as an individual characteristic, but also as a socially supported professional practice.

Facilitating conditions and rewards further contributed to differences across the profiles. Teachers in Profiles 3 and 4 reported more favorable institutional conditions and stronger perceptions of rewards than those in Profiles 1 and 2. This indicates that access to resources, institutional support, and professional recognition may strengthen teachers' willingness and capacity to innovate. When schools provide adequate support and recognize teachers' innovative efforts, teachers may feel more able to try new approaches and sustain innovation in their daily practice (Yuan et al., 2023). Conversely, when such support is limited, teachers may be less likely to engage in innovative teaching, especially when they also experience high anxiety.

Engagement was also highest among the two highly innovative profiles. This finding suggests that teacher engagement may be closely connected to innovative behavior. Teachers who are more engaged in their work may be more likely to invest time and effort in improving their teaching, experimenting with new strategies, and responding to students' learning needs. The high engagement of Profile 4 is especially notable because it suggests that some teachers remain professionally active and committed even when they experience strong anxiety. Thus, engagement may help explain why some anxious teachers continue to demonstrate high levels of innovation.

Our findings suggest that mathematics teachers' innovative behavior is shaped by the combined influence of emotional, professional, motivational, and contextual factors. Anxiety is important, but its relationship with innovation is not uniform. High anxiety may be associated with low innovation when teachers lack sufficient support, knowledge, rewards, and engagement. However, high anxiety may coexist with high innovation when teachers possess strong professional competence and work in supportive environments. Therefore, efforts to promote innovative mathematics teaching should be profile-sensitive. Teachers with high anxiety and low innovation may need emotional support and foundational professional development, while teachers with high anxiety and high innovation may need strategies for sustaining innovation without increasing psychological burden. Meanwhile, teachers with moderate profiles may benefit from structured support that helps them move toward higher levels of confidence and innovation.

4. CONCLUSION

This study provides a deeper understanding of mathematics teachers' innovative behavior by identifying distinct teacher profiles. Importantly, the study found that high levels of innovative behavior can emerge under two distinct conditions: among teachers with low levels of anxiety and among teachers with high levels of anxiety. These findings suggest that anxiety does not necessarily prevent teachers from engaging in innovative practices. Instead, mathematics teachers' innovative behavior should be understood as a complex pattern shaped by emotional states and supporting internal and external factors.

These findings also show that mathematics teachers' innovative behavior should be understood as a combination of internal and external factors, rather than as a single general tendency. The four profiles indicate that teachers differ not only in their knowledge and engagement, but also in the level of support, rewards, and anxiety they experience. This supports the use of a person-centered approach to explain teacher innovation more clearly.

An important finding is the contrast between Profiles 3 and 4. Both groups reported similarly high TPACK, social influence, facilitating conditions, rewards, and engagement, but they differed greatly in anxiety. This suggests that strong professional competence and external support do not always reduce anxiety. In theory, anxiety should therefore be treated as a distinct factor in understanding innovative behavior, rather than simply as the opposite of readiness or competence.

This study has several limitations that should be considered when interpreting the findings. First, the participants were recruited through a convenience sampling approach from mathematics teachers who voluntarily attended a workshop on improving teaching effectiveness and student achievement. Although this strategy enabled access to a relevant group of K–12 mathematics teachers, it may limit the generalizability of the findings. Teachers who participate in professional development workshops may be more motivated, more engaged, or more open to innovation than the broader teacher population. Future studies should use probability-based or more diverse sampling strategies across different provinces, school types, and professional backgrounds to examine whether the identified profiles can be replicated in broader populations of mathematics teachers.

Second, this study employed a cross-sectional survey design, which provides a snapshot of teachers' anxiety, innovative behavior, and related characteristics at a single point in time. As a result, the findings cannot capture how teacher profiles may change over time or how contextual and professional factors contribute to transitions between profiles. Future research could adopt longitudinal designs to investigate the stability and development of these profiles, as well as whether teachers move from less adaptive profiles to more adaptive ones following professional development, institutional support, or changes in school conditions.

Acknowledgments

The authors sincerely extend our gratitude to Institut Keguruan dan Ilmu Pendidikan Siliwangi, Universitas Negeri Malang, China West Normal University, and Comenius University Bratislava for their support of our research.

Declarations

Author Contribution	: HH: Conceptualization, Investigation, Project administration, Resources, Supervision, and Writing - review & editing; XC: Conceptualization, Validation, Writing - original draft, and Writing - review & editing; LK: Methodology, Validation, and Writing - review & editing; TTW: Data curation, Formal analysis, Methodology, Software, Visualization, Writing - original draft, and Writing - review & editing.
Funding Statement	: The author discloses no receipt of the following financial support for this article's research, authorship, and publication.
Conflict of Interest	: The authors declare no conflict of interest.
Additional Information	: Additional information is available for this paper.

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