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A VALIDATED MEASUREMENT MODEL AND CUT-OFF SCORES FOR ASSESSING STUDENTS' CREATIVITY AND INNOVATION

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This This study aimed to develop and validate a Creativity and Innovation (C&I) scale for 1,290 Thai high school students, based on a three-component framework: Think Creatively, Work Creatively with Others, and Implement Innovation. The scale demonstrated excellent content validity (CVR = 0.99) and high reliability (0.953 overall). Item Response Theory (IRT) using a Graded Response Model (GRM) showed that most items have very high discriminatory power. A second-order Confirmatory Factor Analysis (CFA) confirmed the three-component structure with excellent model fit (χ^2 = 52.337, RMSEA = 0.017, CFI = 0.999). Additionally, Latent Class Analysis (LCA) successfully identified four distinct student subgroups with varying C&I behavioral patterns. The four-class model was the most accurate (Entropy = 0.958). This research provides a robust psychometric tool and a practical framework for classifying students, which can inform tailored interventions to foster creativity and innovation.
Keywords: Creativity and innovation; High school students; Confirmatory factor analysis; Latent class analysis; Graded response model

In the 21st century, driven by a knowledge-based economy and technological advancements, the development of Creativity and Innovation (C&I) skills is recognized as a primary goal of education worldwide (Berríos-Riquelme & Buxarrais, 2022; Seechaliao, 2017). These skills are no longer considered merely supplementary, but rather essential for students to adapt, solve problems, and create new value in a rapidly changing world (Ribeiro, 2020; Suharyat et al., 2023). For Thailand specifically, fostering these skills is crucial for enhancing the quality of education and preparing the youth for the future workforce.

However, to effectively develop these skills, it is imperative to have accurate and reliable measurement tools to precisely assess students' capabilities. To date, there is a limited number of C&I scales that have been rigorously developed and psychometrically validated for the specific context of Thai students. This lack of appropriate tools leads to ineffective assessment and development, preventing the design of curricula and learning activities that genuinely meet students' needs.

Consequently, the main objective of this research is to develop and validate the psychometric properties of a Creativity and Innovation scale for Thai high school students. This study goes beyond simple scale development by employing advanced statistical methods to deeply analyze and understand student behaviors. Item Response Theory (IRT), specifically the Graded Response Model (GRM), was utilized to examine the properties of each individual item, enabling a more precise differentiation between students of varying abilities (Embretson & Reise, 2000; Trizna & Hecker, 2023). Additionally, the research applied Latent Class Analysis (LCA), a person-centered approach, to identify and categorize subgroups of students who exhibit distinct response patterns (Nylund-Gibson & Choi, 2018; Collins & Lanza, 2010; Schultze-Krumbholz et al., 2024). The insights gained from this analysis can help educators design targeted development and promotion strategies that are specifically tailored to each student group. The study thus posits the following hypotheses: (1) The three-component structural model of the C&I scale will demonstrate an acceptable fit to the empirical data based on CFA criteria; (2) The scale will possess strong psychometric properties, including both content validity and reliability; and (3) The student sample can be meaningfully classified into distinct subgroups with significant differences in their creative and innovative behaviors.

LITERATURE REVIEW

Concepts and Measurement of Creativity and Innovation

The literature review reveals a clear evolution of the concept of creativity, from an initial focus on individual abstract thought to a modern emphasis on complex, interactive processes (Plucker, Beghetto, & Dow, 2004;

Suharyat et al., 2023). Influential theoretical models such as Teresa Amabile's Componential Theory of Creativity define creativity as the production of ideas or outcomes that are both novel and appropriate to a goal (Amabile, 1983; Amabile, 2012). This theory posits that creativity depends on three individual components—domain-relevant skills, creativity-relevant processes, and intrinsic task motivation—and one external component, the social environment. Other foundational models, such as Csikszentmihalyi's (1996) System Model of Creativity, also highlight the interaction between the individual, the domain of expertise, and the social field or "gatekeepers." This research framework is particularly relevant as it aligns with the modern understanding that creativity and innovation are deeply intertwined, with creativity serving as the source of innovation (Seechaliao, 2017).

The scale developed in this study reflects this integrated perspective by comprising three main components: (1) Think Creatively, (2) Work Creatively with Others, and (3) Implement Innovation. This structure is consistent with the literature, which increasingly views creativity as a multi-faceted construct that is not limited to mere ideation (Plucker, Beghetto, & Dow, 2004; Cao, Wang, Ji, & Chen, 2023). The "Think Creatively" component captures the cognitive processes of generating novel ideas and flexible thinking, which is a core tenet of divergent thinking (Ribeiro, 2020; Suharyat et al., 2023). The "Work Creatively with Others" component directly addresses the social and collaborative nature of creativity, emphasizing that the ability to work effectively in teams is a crucial 21st-century skill (Binkley et al., 2012; Seechaliao, 2017). Finally, the "Implement Innovation" component acknowledges that for creativity to have real-world value, it must be put into practice to create a tangible outcome, a concept that aligns with the distinction between creativity (the idea) and innovation (the implementation) (Singh et al., 2021; Khan et al., 2022).

This domain-specific approach to creativity assessment, particularly in adolescents, is supported by recent psychometric validation studies. For example, Cao, Wang, Ji, and Chen (2023) validated a version of the Kaufman Domains of Creativity Scale (K-DOCS) for Chinese adolescents, emphasizing the importance of measuring creativity across different domains. Similarly, Freiberg-Hoffmann et al. (2019) and Gough (1979) have contributed to the development and validation of scales like the Creative Personality Scale (CPS), underscoring the ongoing need for robust, context-specific instruments. This body of work justifies the present study's focus on developing a new, psychometrically sound tool tailored to Thai high school students.

To validate this theoretical structure, second-order Confirmatory Factor Analysis (CFA) is an ideal statistical tool (Hooper, Coughlan, & Mullen, 2008). CFA allows researchers to precisely evaluate the congruence between a theoretical model and empirical data using multiple fit indices (Byrne, 2010). The study's results, showing a high degree of fit for the second-order model (e.g., $\chi^2 = 52.337$ with a p-value of 0.0608, and high CFI and TLI values of 0.999 and 0.997), provide significant evidence that the three-component framework is a valid and reliable representation of the C&I construct.

Advanced Psychometric Approaches in Applied Psychology

Modern applied psychological research increasingly utilizes sophisticated methodologies to enhance the accuracy and depth of analysis (Berríos-Riquelme & Buxarrais, 2022). Moving beyond traditional Classical Test Theory (CTT), this study employs advanced techniques like Item Response Theory (IRT), specifically the Graded Response Model (GRM) (Embretson & Reise, 2000; Trizna & Hecker, 2023). GRM is a suitable model for a 5-point Likert scale (Reise & Waller, 2009) and is designed to examine the psychometric properties of scales with polytomous response items (Reise & Waller, 2009). The use of IRT provides several advantages over CTT, including the ability to calculate standard errors for each individual and to assess the measurement precision of items across the entire latent trait continuum (Trizna & Hecker, 2023; Depaoli, Tiemensma, & Felt, 2018). GRM analysis provides not only item discrimination parameters (a) but also threshold parameters (b), which indicate the level of ability required to endorse higher response categories (Depaoli, Tiemensma, & Felt, 2018). This more nuanced understanding of the scale's functioning ensures greater measurement precision and is critical for developing robust instruments in educational and psychological research (Embretson & Reise, 2000; Matovu, 2014; S_R31).

The second key methodological approach employed in this study is Latent Class Analysis (LCA), a person-centered approach (Nylund-Gibson & Choi, 2018; Collins & Lanza, 2010). Unlike traditional variable-centered methods like regression, which examine relationships between variables across an entire sample, LCA is designed to identify unobserved subgroups of individuals who share similar patterns of responses (Lanza & Collins, 2007; Nylund-Gibson et al., 2007). In educational and developmental research, this approach is invaluable for uncovering heterogeneity within a population that might otherwise be masked by a single total score (Nylund-Gibson, Bellmore, Nishina, & Graham, 2007; Schultze-Krumbholz et al., 2024). For instance, recent studies have successfully used LCA to identify different profiles of self-regulated learning among online students (Mindrila & Cao, 2022) and to categorize cyberbullying roles among adolescents (Schultze-Krumbholz et al., 2024). These studies demonstrate how LCA can provide a richer, more descriptive understanding of a population, which is essential for designing effective and targeted interventions. The decision

to use LCA in this research, therefore, is rooted in its proven ability to reveal meaningful, actionable subgroups based on complex behavioral patterns, thereby moving beyond a simple high/low categorization of student ability.

METHODOLOGY

Instrument Development

The Creativity and Innovation scale was developed by synthesizing components and indicators from a theoretical framework comprising three main components: Think Creatively, Work Creatively with Others, and Implement Innovation. Each component was systematically developed with specific indicators and items, resulting in a complete scale of 30 items.

SAMPLE

The sample for this study consisted of 1,290 high school students in Thailand.

Data Analysis

Data analysis was conducted in several stages: assessing content validity using the CVR index and evaluating reliability using coefficient alpha. Subsequently, the Graded Response Model (GRM) was used to assess the parameters of each item, and a second-order Confirmatory Factor Analysis (CFA) was conducted to verify the theoretical structure of the scale. The final and critical step was the Latent Class Analysis (LCA) to classify students based on their distinct behavioral patterns.

RESULTS

Psychometric Properties of the Scale

The content validity of the indicators for the C&I components was evaluated, and the Content Validity Ratio (CVR) was found to be 0.99, indicating an excellent level of content validity.

The overall reliability of the scale was 0.953, indicating very high dependability. When analyzed by subcomponent, the reliability values were 0.866 for Think Creatively, 0.890 for Work Creatively with Others, and 0.897 for Implement Innovation, all of which demonstrate excellent reliability.

TABLE 1 Discrimination and Reliability Values of the Scale

Component	Number of Indicators	Number of Items	Discrimination Value	Reliability
Creativity and Innovation (Overall)				0.953
1.1 Think Creatively (TC)	4	8	0.571-0.710	0.866
1.2 Work Creatively with Others (WC)	6	12	0.505-0.686	0.890
1.3 Implement Innovation (II)	5	10	0.485-0.713	0.897

Item Response Theory (IRT) Analysis

An analysis using the Graded Response Model (GRM) was conducted to evaluate the item-level psychometric properties. The results showed that the discrimination parameters (a) for most items were high to very high. Specifically, no items had a low discrimination value ($a < 0.65$). Five items were found to have a moderate discrimination value (0.65-1.34), four items had a high discrimination value (1.35-1.70), and twenty-one items demonstrated a very high discrimination value ($a > 1.70$). These findings suggest that the scale is highly effective at differentiating among students with varying levels of C&I ability. The analysis of the threshold parameters (b1 to b4) confirmed that these values were appropriately distributed and increased sequentially, indicating that students with lower C&I ability were more likely to select lower-score response options, while those with higher ability were more likely to select higher-score options.

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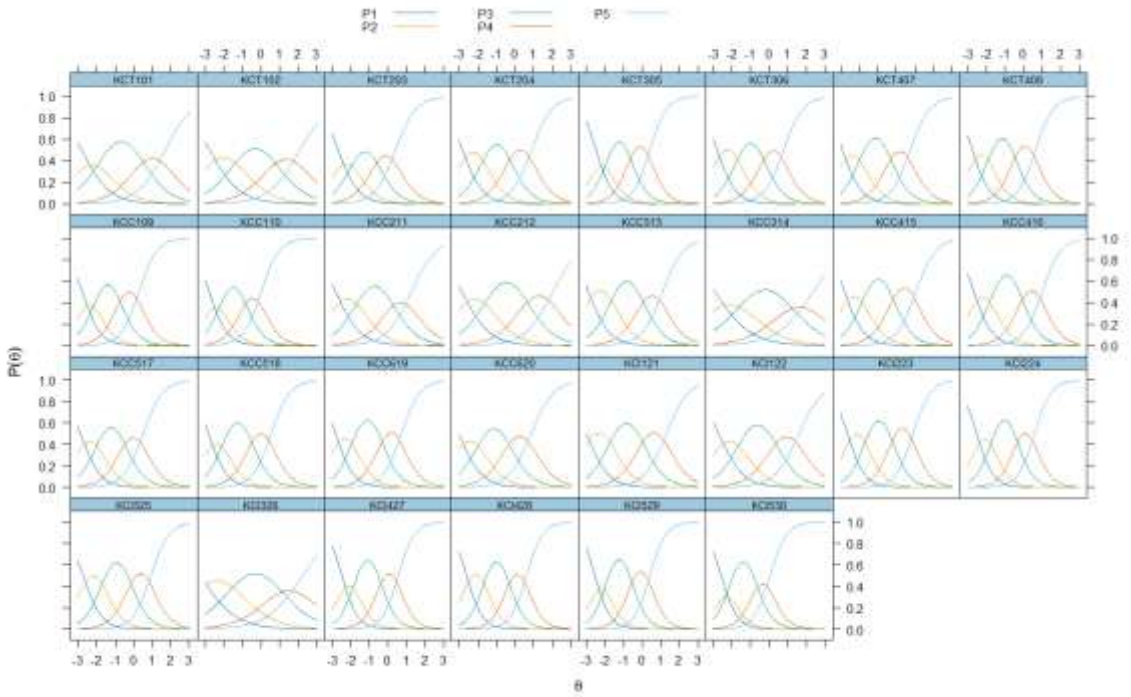

FIGURE 1 Item Characteristic Curve Creativity and Innovation

Test Information Function

The test information curve (depicted by the solid blue line in the graph) shows how much measurement precision the scale provides across the latent trait continuum (θ). The peak of the information curve is located in the lower-to-moderate ability range (approximately -2 to 0 on the θ axis), indicating that the scale is most informative and provides the most precise measurement for students in this range. The standard error curve (dashed red line) is the inverse of the information curve and shows the lowest error in this same range, confirming the scale's precision for this specific group of students.

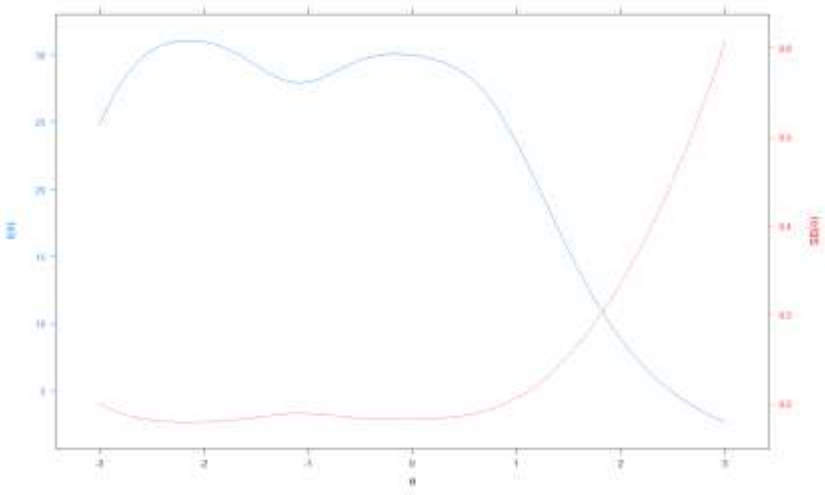

FIGURE 2 Test information curve Creativity and Innovation

Confirmatory Analysis of the Model Structure

The results of the second-order Confirmatory Factor Analysis (CFA) showed that the C&I measurement model has an excellent fit with the empirical data. The model fit indices after modification were: $\chi 2 = 52.337$, df = 38, p-value = 0.0608, RMSEA = 0.017, SRMR = 0.011, CFI = 0.999, TLI = 0.997. These values confirm that the three-component model is structurally valid and highly suitable for measuring creativity and innovation in this sample.

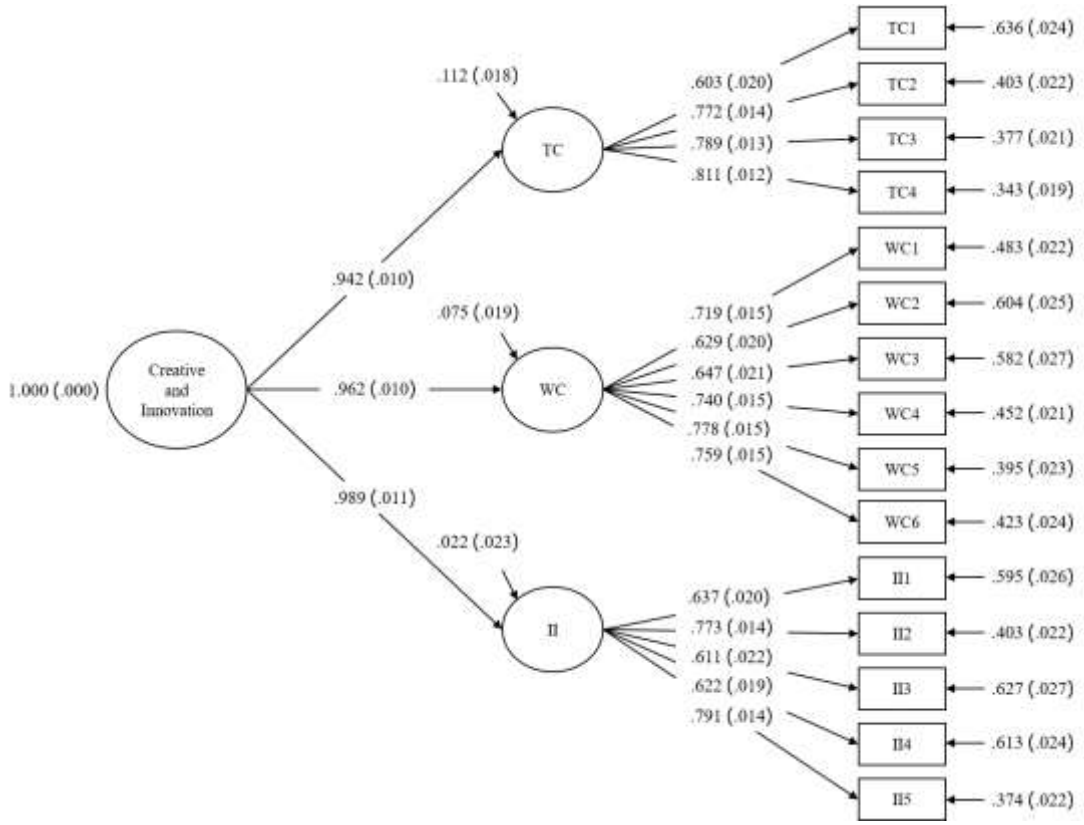

FIGURE 3 Creativity and Innovation measurement model

Latent Class Analysis Results

The Latent Class Analysis (LCA) found that the four-class model was the most appropriate and parsimonious for explaining the data. This was supported by the lowest AIC, BIC, and ABIC values. Furthermore, the Entropy value for the four-class model was 0.958, which is very close to 1, indicating a high degree of accuracy and clarity in the classification.

TABLE 2 Results of Latent Class Analysis for Creativity and Innovation

Class	Log Likelihood	Number of free parameters	AIC	BIC	ABIC	Entropy
2	-46364.382	241	93210.763	94454.901	93689.363	0.94
3	-44196.046	362	89116.093	90984.881	89834.986	0.949
4	-42757.284	483	86480.567	88974.005	87439.754	0.958
5	-41888.349	604	84984.698	88102.786	86184.178	0.951

The analysis of mean scores for each latent class revealed distinct behavioral profiles, classifying students into four main groups:

- Latent Class 1 (Developing): Comprising 13.49% of the sample, students in this group show an overall moderately low level of C&I behaviors, particularly in the "Think Creatively" component.
- Latent Class 2 (Moderate): Comprising 13.88% of the sample, this group exhibits moderate C&I behaviors across all components.
- Latent Class 3 (High): As the largest group, comprising 44.11% of the sample, these students show moderately high C&I behaviors across all components.
- Latent Class 4 (Very High): Comprising 28.53% of the sample, this group exhibits a high overall level of C&I behaviors across all components.

TABLE 3 Mean Scores of Creativity and Innovation Behaviors in Each Latent Class

Item No.	Creativity and Innovation Behavior	Class 1 (13.49%)	Class 2 (13.88%)	Class 3 (44.11%)	Class 4 (28.53%)
TC101	I often see problems as opportunities to learn	2.41	3.02	3.34	3.96
TC102	I often initiate the use of new things for the benefit of work	2.22	2.89	3.15	3.76
TC203	When starting a task, I often ask for others' opinions to get diverse perspectives	2.75	3.2	4.1	4.59
TC204	I often plan in multiple ways to complete a task	2.52	3.17	3.75	4.43
TC305	I think there are many ways to get a job done	2.67	3.25	4.06	4.74
TC306	I think that even if old methods work, new methods can also be used to succeed	2.57	3.09	3.8	4.53
TC407	When planning a task, I usually consider both the pros and cons	2.76	3.12	3.82	4.55
TC408	If I find mistakes in my work, I will try to succeed	2.79	3.11	3.91	4.6
WC109	I listen to others' opinions even if they are new or strange	3.01	3.26	4.2	4.73
WC110	I often give group members a chance to offer opinions to hear diverse ideas	3.14	3.34	4.36	4.84
WC211	If there is group work, I often give my opinion	2.47	2.99	3.49	4.1
WC212	People in the group often agree with my opinion	2.39	2.95	3.21	3.83
WC313	If I work in a group, I am often enthusiastic about starting the work	2.56	3.02	3.56	4.3
WC314	I often express opinions that differ from my group members and they are accepted	2.42	2.84	3.04	3.63
WC415	I think that new ideas that can bring change need time and the right situation	2.61	3.13	3.64	4.38
WC416	I can accept if new ideas have limitations in practical use	2.52	3.07	3.6	4.41
WC517	I often think that failed experiences lead to learning	2.91	3.14	3.98	4.61
WC518	I often think that I learn from making mistakes	2.86	3.13	4.01	4.58
WC619	I can understand if there is a failure at work	2.79	3.06	3.84	4.54

Table 2 (continued)

Item No.	Creativity and Innovation Behavior	Class 1 (13.49%)	Class 2 (13.88%)	Class 3 (44.11%)	Class 4 (28.53%)
WC620	I can accept it if what I do is not as expected	2.82	3.12	3.79	4.45
II121	I can create work based on my own ideas	2.66	3.04	3.53	4.19
II122	I often create work that is practical from my ideas	2.42	2.99	3.3	4.05
II223	If I have to do a project, I will plan carefully before starting	2.51	3.07	3.71	4.49
II224	Doing a project must come from step-by-step planning	2.66	3.06	3.85	4.66
II325	I often evaluate the work while I am doing it	2.65	3	3.67	4.43
II326	The work I create is often new and unique	2.57	2.9	3.07	3.7
II427	I often check the quality of the work after it is finished	2.74	3.05	3.93	4.65
II428	When the work is complete, we should evaluate the project	2.68	3.04	3.83	4.63
II529	If I find a defect, I will fix it to be better	2.84	3.12	4.07	4.74

II530	I believe that all work can be improved	3.06	3.22	4.31	4.85

Determination of Cut-off Scores and Interpretation

Based on the latent class analysis and the distribution of trait scores, four ability levels were established using the total scores from the scale:

- Level 1 (Needs Development): Total scores of 30-86, which predominantly corresponds to students in Latent Class 1.
- Level 2 (Moderate): Total scores of 87-99, corresponding to students in Latent Class 2.
- Level 3 (High): Total scores of 100-124, corresponding to students in Latent Class 3.
- Level 4 (Very High): Total scores of 125-150, corresponding to students in Latent Class 4.

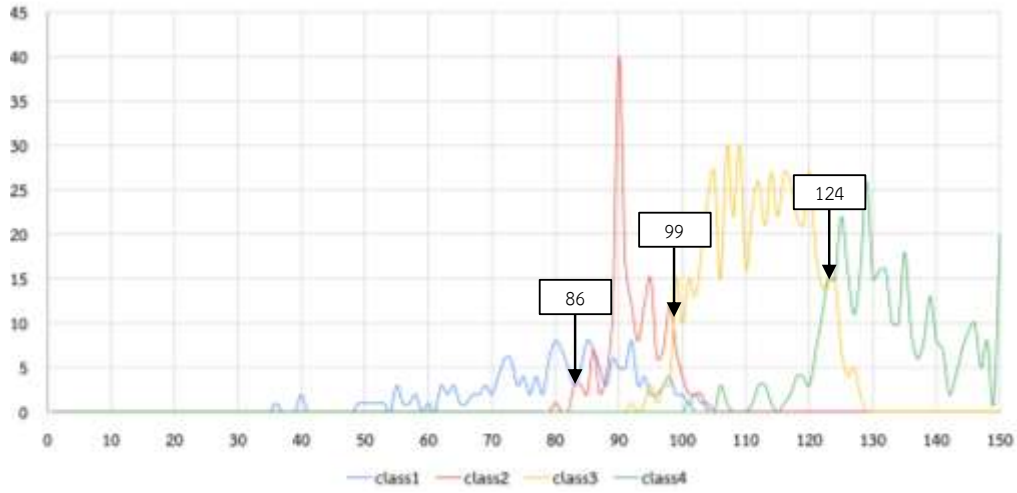

FIGURE 4 Cut-off scores levels of Creativity and Innovation attributes

These cut-off scores provide a clear framework for identifying appropriate development strategies for each student group. For example, students in the "Needs Development" group (scores 30-86) should be supported in seeing opportunities and initiating new ideas, while those in the "Very High" group (scores 125-150) should be encouraged to fully express their creative and innovative ideas in group work contexts.

DISCUSSION

This study successfully developed and validated a psychometrically robust Creativity and Innovation (C&I) scale for Thai high school students. The findings confirm that the scale's three-component structure Think Creatively, Work Creatively with Others, and Implement Innovation is a valid and reliable framework for measuring C&I in this population. This is a significant contribution given the limited number of such validated tools in the Thai context. The model aligns with contemporary, holistic views of creativity that extend beyond simple ideation to include collaboration and the practical implementation of ideas (Binkley et al., 2012; Singh et al., 2021). The excellent fit indices from the second-order Confirmatory Factor Analysis (CFA) provide strong empirical evidence for the structural integrity of this framework, in line with best practices for model validation (Hooper, Coughlan, & Mullen, 2008; Byrne, 2010).

The psychometric rigor of the scale is further demonstrated by its high reliability coefficients (0.953 overall) and the detailed item-level analysis using Item Response Theory (IRT). The Graded Response Model (GRM) analysis revealed that most items have high to very high discriminatory power, meaning the scale is highly effective at differentiating between students of varying C&I abilities (Embretson & Reise, 2000; Depaoli, Tiemensma, & Felt, 2018; Trizna & Hecker, 2023). This advanced approach provides a more nuanced understanding of the scale's functioning compared to traditional Classical Test Theory (CTT), ensuring greater measurement precision. Furthermore, the test information function highlights that the scale is most informative in the lower-to-moderate ability range, which is particularly useful for identifying students who require developmental support and for tracking their progress.

The most novel and practically significant finding of this study is the identification of four distinct latent classes of students through Latent Class Analysis (LCA). This person-centered approach, which differs from traditional variable-centered methods, revealed that C&I behaviors are not merely a single continuum but manifest in heterogeneous subgroups with unique profiles (Nylund-Gibson & Choi, 2018; Collins & Lanza,

2010). The existence of these distinct groups from "Needs Development" to "Very High" provides a powerful tool for educators to move beyond a one-size-fits-all approach and implement targeted, evidence-based interventions (Mindrila & Cao, 2022; Schultze-Krumbholz et al., 2024). For example, students in the "Needs Development" class could benefit from foundational activities that foster risk-taking and divergent thinking, while those in the "Very High" class could be challenged with complex, collaborative projects that require them to implement innovative solutions. This differentiation is critical for fostering C&I effectively and moves toward a more personalized educational model (Suharyat et al., 2023).

The findings from the LCA are particularly insightful for educational practice. The clear delineation of four classes with different behavioral profiles from students with low overall C&I to those who excel in all three components provides a new lens for understanding student capabilities beyond a single numerical score. This approach addresses a key limitation of traditional assessments, which can often mask the unique strengths and weaknesses of individual students (Nylund-Gibson, Bellmore, Nishina, & Graham, 2007; Lanza & Collins, 2007). The cut-off scores derived from this analysis offer a practical and easy-to-use tool for teachers to assign students to specific developmental tiers, thereby facilitating the customization of learning activities and resources.

CONCLUSION

This study's primary contribution is the development of a psychometrically robust three-component Creativity and Innovation scale for Thai high school students. The validation process, utilizing both CFA and IRT, confirms the scale's structural validity and reliability. The most impactful finding, however, is the successful classification of students into four distinct latent classes. This evidence of heterogeneity in C&I behavior provides educators and psychologists with a valuable framework for designing tailored educational interventions. Future research should build on these findings by conducting longitudinal studies to explore the developmental trajectories of these latent classes and investigating how specific educational environments or pedagogical approaches might influence a student's membership in a particular C&I profile. Such studies will further solidify the role of this instrument as a critical tool for promoting creativity and innovation in the Thai educational system.

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