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Exploring and developing instrument measuring special education teachers' knowledge in digital game-based learning pedagogy

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Abstract

The teachers' role has shifted from being solely knowledge transmitters and authority figures to facilitators who guide and support students through structured and pedagogically sound learning approaches. Digital game-based learning (DGBL) is an effective teaching pedagogy for students with learning disabilities, as it simplifies complex information by breaking it down into manageable steps and incorporating game design elements into instruction. This study aims to establish a foundational knowledge base for integrating game-based teaching within the context of special education teachers. It employed a cross-sectional design, utilizing a questionnaire for data collection. The data were analyzed through a pre-test, pilot test, and Exploratory Factor Analysis (EFA). Results show that the Kaiser-Meyer-Olkin (KMO) value ranges from 0.814 to 0.950, and Bartlett's Test of Sphericity is significant (<0.001). For each construct, the total variance explained indicates good eigenvalues (>60%). Two items with factor loading below 0.6 were omitted. Finally, 52 items left were tested with Cronbach's Alpha and show high reliability (>0.8). The findings suggest that the Technological Pedagogical Content Knowledge – Games (TPACK-G) instrument has strong content validity, face validity, criterion validity, and internal reliability. This study provides a data-driven foundation that bridges teachers' knowledge with the integration of digital game practices in special education classrooms. The EFA process contributed to the validation of the TPACK-G instrument, enabling accurate measurement of teachers' knowledge in digital game-based learning pedagogy. Empirical data from this study indicate that special education teachers are prepared to implement instructional strategies involving digital game-based learning within inclusive digital learning environments.

Keywords: Digital game-based learning, Exploratory factor analysis, Game knowledge, Special education teacher, Technological pedagogical content knowledge.

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Contribution of this paper to the literature

This study positions special education teachers' knowledge in digital game-based learning within an extended Technological Pedagogical Content Knowledge (TPACK) model, incorporating digital game knowledge as a distinct theoretical criterion. This study also contributes by developing and validating the Technological Pedagogical Content Knowledge – Games (TPACK-G) instrument at the end of the study.

1. Introduction

The rapid pace of technological innovation is reshaping industries, economies, the workplace, and our daily lives. Digitalization has become a crucial component for enhancing teaching efficiency and improving the learning experience (Fernández-Batanero, Román-Graván, Reyes-Rebollo, & Montenegro-Rueda, 2021). From the Malaysia National Education Blueprint 2013-2025, the Minister of Education shows their initiative to enhance quality in educational instruction through the application of Information and Communication Technology (ICT). Smart schools, School Transformation Program 2025 (TS25), digital textbooks, Delima 2.0 Programme, and the introduction of Google Classroom among teachers and students are among the Malaysian government's efforts to empower education through digital transformation within the Blueprint.

Education can be viewed as an instructional game design process, tailored with curriculum standards and specific learning objectives. In digital game-enhanced pedagogy, challenges are deliberately designed throughout the learning journey, considering accessibility and user-centred design that is responsive to the needs of diverse users (Maxim & Arnedo-Moreno, 2025). Digital game-based learning, which emphasizes a student-centered approach, is designed to keep learners engaged throughout their learning journey (Kulkarni, Deshpande, & Tokekar, 2024). With the use of digital games and technology applications, students will be able to experience a fun, immersive, and self-motivated learning experience (Videnovik, Vold, Kiønig, Madevska Bogdanova, & Trajkovik, 2023).

When integrating digital learning games, teachers play a pivotal role in offering consistent resources and serving as instructional designers for students. However, despite the growing recognition of the benefits provided by digital game-based learning, there is a lack of clear understanding regarding special education teachers' knowledge to effectively integrate digital game-based learning pedagogy (Sharma, Tan, Gomez, Xu, & Dubé, 2025; Tramonti et al., 2024; Videnovik et al., 2023). As educators, teachers need to master new knowledge on delivering teaching pedagogy assisted by digital technology and educational games (Blažič & Blažič, 2024). Achieving the desired learning objectives through digital game-based learning pedagogy requires teachers to systematically organize, map, and demonstrate a comprehensive understanding of the subject matter (Mafa & Govender, 2025).

Teachers' knowledge is a vital resource for teachers in their teaching. Effective gamified teaching relies heavily on teachers being proficient in educational technology. It also requires teachers to master game-related knowledge, including gamification elements, game genres, teaching pedagogy, and subject matter. Without sufficient knowledge in both digital games and their pedagogical integration, teachers may struggle to harness the full benefits of digital game-based learning (Wei, Abdullah, & Nordin, 2023).

Besides that, existing tools are insufficient for measuring teachers' knowledge of digital game-based learning pedagogy within the context of teachers who teach students with learning disabilities (Kuo & Kuo, 2024; Sharma et al., 2025). To address the gaps identified in the previous study, the objective of this study is to identify types of knowledge possessed by special education teachers namely technological knowledge, digital game knowledge, pedagogical knowledge, content knowledge, and technological pedagogical content knowledge in digital game-based learning pedagogy. This study also aims to explore and validate the TPACK-G instrument, which measures teachers' game-related understanding in digital game-based learning pedagogy.

2. Literature Review

2.1. Gamified Teaching Context

When integrating digital game-based learning pedagogy, teachers need to have the ability to interact with various genres of games in their teaching, tailored to students' interests and learning levels. Game literacy refers to teachers' capabilities to effectively understand, design, implement, and facilitate games in the students' learning process, but teachers sometimes have misconceptions about what constitutes serious games (Gravelsina & Daniela, 2025). Games are generally categorized into two different types: entertainment games and serious games. According to Maxim and Arnedo-Moreno (2025), entertainment games are designed to be captivating, emphasizing fun, emotional immersion, and intrinsic motivation to sustain player involvement. In comparison, serious games are designed with explicit extrinsic goals, focusing on knowledge acquisition, developing new skills, promoting behavioral changes, and enhancing learning outcomes.

Digital game-based learning is a teaching pedagogy that incorporates game mechanics and gamification to promote an immersive and enjoyable learning atmosphere (Beck, Morgado, & O'Shea, 2020; Capogna et al., 2022; Dengel, Buchner, Mulders, & Pirker, 2021). Nonetheless, the key elements of game design for teaching were required to include game mechanics, visual aesthetics, narrative development, reward systems, audio design, and targeted content and skills (Zheng, Tu, Hwang, Yu, & Huang, 2024). While students act as passive recipients in conventional teaching methods, teaching using games offers students greater autonomy in their learning process (Tramonti et al., 2024). Teachers' knowledge of game mechanics and gamification remains unclear, raising concerns about their capacity to effectively integrate game-based learning.

Digital game-based learning offers interactive and simulated real-world situations, simplifying complex information (Bengel & Peter, 2024; Kulkarni et al., 2024). An immersive and gamified environment enables students to strengthen their learning and deepen their understanding (Videnovik et al., 2023). The integration of game design promotes hand-eye coordination, embracing "safe failure" rather than penalizing mistakes, refines student skills through a rewarding system, and fosters behavior change (Tramonti et al., 2024). Additionally, game settings in the classroom provide real-time feedback, foster self-assessment, and create personalized learning activities tailored to students' needs (Collie & Martin, 2025).

Although previous studies have demonstrated various benefits, significant gaps remain in implementing digital game-based learning, particularly concerning the vital role of teachers in this process. Low adoption of educational technology among teachers is influenced by insufficient knowledge regarding online instruction (Collie & Martin, 2025). Nonetheless, few studies provide insufficient details to explain specific gamification elements that influence teacher teaching pedagogy (Videnovik et al., 2023). There is a paucity of research that considers practical constraints on primary teachers' digital game-based learning knowledge within the context of special education.

2.2. Teacher Knowledge in TPACK

The use of modern technology in the classroom today is ubiquitous, and teachers have more technical knowledge compared to 15 years ago (Fernández-Batanero et al., 2021). Nevertheless, during the current shift toward digitalization in education, there are discrepancies in bridging teachers' Pedagogical Knowledge (PK) into real-world practice for teaching. The transition process from theory to teaching practice and the application of knowledge, particularly in implementing technology and game-based teaching, remains insufficient (Czok & Weitzel, 2025).

Research on digital game-based learning pedagogy has to narrow down and focus on preparing teachers' knowledge and their digital capabilities (Falloon, 2020). Teachers' responsibility is to motivate students in their learning. Technological tools can be utilized to maximize learning outcomes. The initial results revealed that teachers experience a high level of stress and anxiety when they need to employ different uses of educational technology based on students' age and developmental stage (Fernández-Batanero et al., 2021). It was found that there is no single definitive method in digital gamified teaching, as learners vary in their abilities, interests, and educational levels.

Teachers need to become knowledgeable and competent in digital game-based teaching. Based on Pitura, Turula, Nowak, Jakubik, and Asotska-Wierzba (2024), teachers need to be competent in students' learning theories, teaching pedagogy, game design, and technology-related applications. Pedagogical competences encompass a deep understanding of learning theories, teaching methods, and effective teaching practices. Teachers' pedagogical competences are fundamental to effective educational game design. Game design competencies encompass the skills developed through planning, designing, and integrating games in instructional contexts.

Technological Knowledge (TK) is defined as understanding both traditional and modern technologies, employing various technological teaching aids to support learning objectives in teaching curricula (Goodarzi & Rezai, 2025; Koehler, Mishra, Kereluik, Shin, & Graham, 2014; Smiling & Hollebrands, 2025). Technology competences are a concern in planning from an ICT perspective. They can help solve issues when implementing technology-related applications in teaching. However, teachers demonstrated a mean score of 2.89, reflecting a moderate level of efficacy across several websites (Anud Jr, Fuentes, Sagadrata, Sultiz, & Tan, 2024). This result possesses teachers' knowledge in solving technology-related problems may not yet be sufficient to meet the growing demands of digital integration in education. Based on the synthesis, being digitally literate not only underscores the pressing need to understand technology but also highlights the critical challenges related to its underlying mechanisms, societal impacts, and fostering awareness of its potential negative consequences (Bengel & Peter, 2024).

Despite delivering lessons, checking email, and surfing information from websites, the top concern in digital game-based learning pedagogy is improving instruction to integrate various features of digital resources into lessons (Anud Jr et al., 2024). Teachers equipped with TK are empowered with practical and technology-based resources that effectively support the achievement of their instructional goals (Smiling & Hollebrands, 2025). These teachers, who are well-versed in TK, are willing to accept modern teaching methods with an open mind and are more likely to engage actively in their digital game-based teaching activities. Existing literature widely covers technological competence within educational research; however, its application and specification in digital game-based learning remain ambiguous, presenting a critical research gap addressed by this study.

Pedagogical knowledge (PK) is defined as the knowledge of using methods in teaching, classroom management, and evaluating students' learning (Goodarzi & Rezai, 2025). Teachers are obliged to utilize instructional strategies to effectively execute their lesson plans (Smiling & Hollebrands, 2025). A strong understanding of pedagogy enables teachers to comprehend cognitive, social, and developmental learning theories; how these theories inform students' learning and behavior in the classroom (Anud Jr et al., 2024). However, the issue is the shortfall in delivery methods' alignment with the modern pedagogical approach (Blažič & Blažič, 2024). For students with learning disabilities, teachers need to diversify teaching pedagogies, utilizing their creativity to provide flexible learning sessions based on different students' needs and abilities (Ramakrishnan, Salleh, & Alias, 2020; Tohara, Shuhidan, Bahry, & Nordin, 2021).

Content knowledge (CK) refers to the knowledge that teachers possess regarding specific topics, subjects, or fields that they are responsible for teaching in the classroom (Goodarzi & Rezai, 2025; Mishra & Koehler, 2006). CK encompasses an in-depth understanding of the facts, theories, and concepts inherent to a specific discipline, along with how thinking within a domain can be interrelated and connected to other fields (Smiling & Hollebrands, 2025). Teachers demonstrate comprehensive knowledge in their field of teaching content when compared to other areas such as technologies, games, teaching pedagogies, and TPACK. Almost all teachers demonstrate expertise and possess thorough knowledge in their subject matter (Anud Jr et al., 2024). Further research should emphasize integrating CK with appropriate technological and pedagogical strategies to optimize students' learning (Smiling & Hollebrands, 2025).

Technological pedagogical content knowledge (TPACK) embodies the implementation of pedagogic strategies grounded in conceptual knowledge, combined with technological integration to enhance students' learning outcomes (Falloon, 2020; Graham, 2011). To measure teacher knowledge in integrating educational technology and digital game-based learning, TPCAK is an essential quality that captures readiness in teacher knowledge (Oner, 2020).

Current educators need to expand their knowledge of differentiated instruction in technology (Han, 2025). Effective educational technology teaching hinges on a thorough understanding of the synergistic correlations among technology, teaching pedagogy, and content to enhance a relevant instructional strategy tailored to the learning context (Aqib, Ekawati, & Khabibah, 2025).

2.3. Digital Game Knowledge

Game knowledge (GK), also known as digital game knowledge, is defined as knowledge of the general usage of digital games (Kuo & Kuo, 2024). Teachers' prior game-related knowledge is one of the factors that influence teachers' decisions to recognize or decline the use of game-based teaching (Sharma et al., 2025). Digital GK can be understood as teachers' understanding of the rules and settings in digital games, as well as how to apply teaching sessions using different game genres (Lengyel, 2020; Ramli, Maat, & Khalid, 2022; Topping, Douglas, Robertson, & Ferguson, 2022).

Despite greater access to technology in schools, many teachers still use digital games as a mere substitute for conventional teaching methods, rather than employing digital game-based teaching as a transformative learning approach. The problem is exacerbated, as creating digital game-based learning requires teachers to receive sufficient and ongoing support for skills and resources to integrate educational technology and game genres effectively (Villa III, Sedlacek, & Pope, 2023). Teachers often perceive games as merely entertainment or tools for rote practice, mainly focusing on low-level, drill-and-practice games rather than deeper learning tools (Pierce, Woodward, & Bartel, 2020). Hence, this study aims to integrate GK with the TPACK framework to facilitate effective digital game-based learning practices.

3. Methodology

3.1. Research Design

A cross-sectional approach was adopted in this study. A questionnaire was utilized to assess the validity and reliability of the TPACK-G instrument on teachers' knowledge in TK, digital GK, PK, and CK within digital game-based learning. This study conducted a pilot test from December 2023 to January 2024 in Putrajaya and Kuala Lumpur. The schools participating in the pilot test are presented in Appendix 1.

3.2. Sample Size

Sample size in this study was divided into two parts, that is pre-test and pilot test. During the pre-test, a total of 14 experts were invited to check the validity and reliability of the instrument. Ten experts from special education, educational technology, and curriculum development were involved in checking content validity; three language experts were involved in checking face validity; and one measurement expert was involved in checking criterion validity.

For the pilot test, 113 respondents participated in this study. Respondents were selected randomly using cluster sampling to ensure homogeneity within the population. All respondents share the same characteristics: they are special education teachers, currently serving in Malaysian public primary schools, and teaching students with learning disabilities. After data cleaning, three respondents were removed, leaving 110 respondents for further analysis using Exploratory Factor Analysis (EFA).

3.3. Research Instrument

This study adopts a TPACK-G questionnaire that consists of 52 items to evaluate teachers' knowledge of digital game-based learning pedagogy. There are five constructs: TK, GK, PK, CK, and TPACK. This study employs a 10-point Likert scale adapted questionnaire, where a rating of "1" indicates "strongly disagree" and a rating of "10" indicates "strongly agree"(Shkeer & Awang, 2019).

3.4. Data Analysis Method

Data were analyzed in three stages: pre-test, pilot test, and EFA. In the pre-testing phase, a review by experts was carried out to verify all items in the questionnaire, validate the items, and construct the questionnaire through content validity, face validity, and criterion validity (Awang, Afthanorhan, Hui, & Zainudin, 2023; Hair, Black, Babin, & Anderson, 2019). Consequently, items were edited, refined, and deleted based on expert review and research objectives. During the pilot test, a preliminary study based on the main study was conducted. Questionnaires were distributed to teachers who instruct students with learning disabilities in elementary schools.

Data cleaning was carried out upon completion of the pilot test data collection. EFA was performed to delineate the underlying constructs and the factor structure of a measurement instrument, assess its internal validity, evaluate sample size adequacy, and determine data matrix factorability (Ehido, Awang, Halim, & Ibeabuchi, 2020; Hair et al., 2019; Shrestha, 2021). EFA was conducted using IBM SPSS AMOS version 24.0. By utilizing Principal Component Analysis and Varimax Rotation in the EFA procedure, it will extract components for each item (Shkeer & Awang, 2019). Low factor loading items will be omitted during the EFA procedure. The last step in EFA is to assess reliability with Cronbach's Alpha to evaluate internal consistency.

4. Results

A total of 52 items were retained after the EFA procedure. All the items are grouped into five constructs: GK, TK, PK, CK, and TPACK.

4.1. Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity

Table 1 shows the results of KMO and Bartlett's Test of Sphericity for constructs GK, TK, PK, CK, and TPACK. The KMO values indicate excellent results when the value exceeds .80 (Shkeer & Awang, 2019). Respectively, the KMO values for GK, TK, PK, CK, and TPACK are 0.814, 0.950, 0.835, 0.848, and 0.948, which are excellent values. Bartlett's Test of Sphericity for GK, TK, PK, CK, and TPACK shows highly significant values with $p < 0.001$

(Effendi, Matore, Khairani, & Adnan, 2019). All these values exceed the target value for KMO and Bartlett's Test of Sphericity. Thus, the data are sufficient to continue with the subsequent EFA analysis.

Table 1. KMO and Bartlett's Test of Sphericity for Construct GK, TK, PK, CK, and TPACK.

Statistical Tests for Each Construct		**GK**	**TK**	**PK**	**CK**	**TPACK**
KMO measure of sampling adequacy		0.814	0.950	0.835	0.848	0.948
Bartlett's test of sphericity	Approx. Chi-Square	189.930	2112.874	1057.271	512.863	5207.575
	df	6	120	10	21	231
	Sig.	0.000	0.000	0.000	0.000	0.000

4.2. Total Variance Explained

Table 2 presents the total variance explained for constructs GK, TK, PK, CK, and TPACK. The eigenvalues for GK, TK, PK, CK, and TPACK ranged from 1.049 to 17.933, exceeding the minimum requirement of greater than 1.0. The variance explained is shown in the extraction sums of squared loadings. Based on these, GK explained 69.66% of the variance, TK explained 72.89%, PK explained 79.31%, and CK explained 62.79%. For TPACK, the total variance explained for component 1 is 81.52%, while component 2 is 86.28%. Both GK, TK, PK, CK, and TPACK show excellent eigenvalues, with total variance exceeding 60% (Shkeer & Awang, 2019). The total variance explained for the constructs GK, TK, PK, and CK consists of a single component, whereas the construct TPACK comprises two components.

Table 2. Total variance explained for constructs GK, TK, PK, CK, and TPACK.

Construct	Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
		Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of Variance	Cumulative %
GK	1	2.786	69.655	69.655	2.786	69.655	69.655	-	-	-
TK	1	11.662	72.887	72.887	11.662	72.887	72.887	-	-	-
PK	1	3.966	79.313	79.313	3.966	79.313	79.313	-	-	-
CK	1	4.395	62.788	62.788	4.395	62.788	62.788	-	-	-
TPACK	1	17.933	81.515	81.515	17.933	81.515	81.515	10.038	45.627	45.627
	2	1.049	4.766	86.281	1.049	4.766	86.281	8.944	40.654	86.281

4.3. Scree Plot

A scree plot is a technique used to determine whether an eigenvalue is large enough to represent a meaningful factor (Hung & Swanto, 2023). Figure 1 illustrates a scree plot for the GK construct. All four items within the GK construct were combined into a single component.

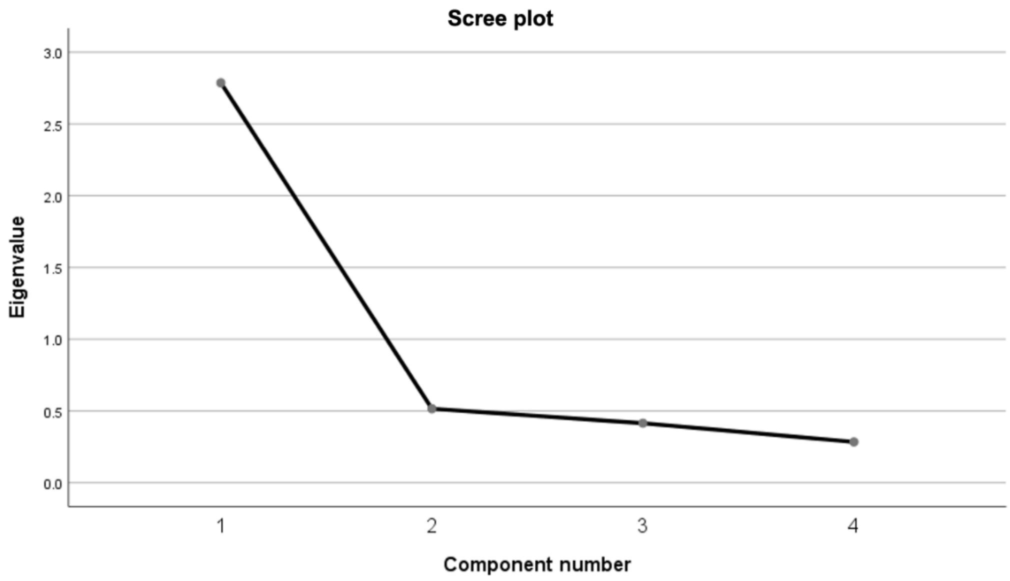

Figure 1. Scree plot analysis of the GK construct.

Figure 2 portrays a scree plot analysis of the TK construct. Note that all 16 items within the TK construct were combined into a single component.

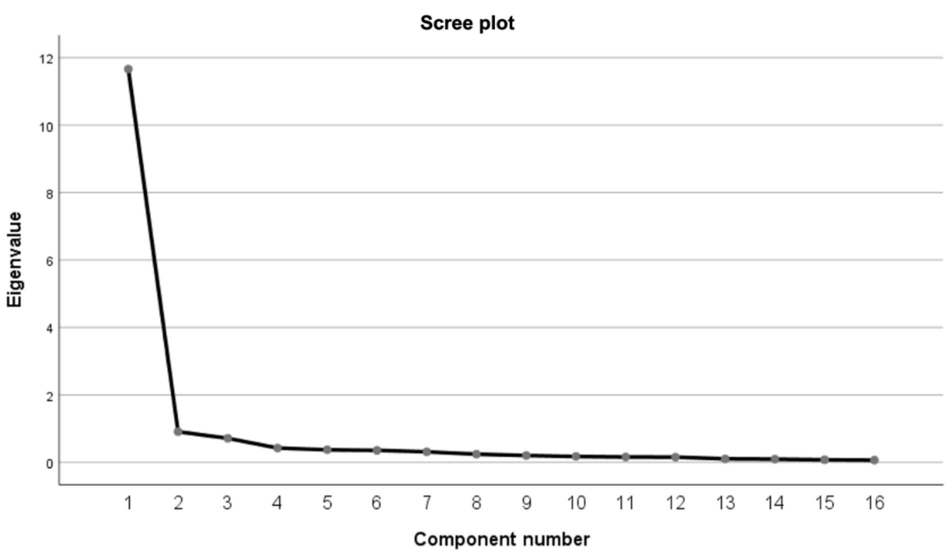

Figure 2. Scree plot analysis of the TK construct.

Figure 3 shows a scree plot for the PK construct. All five items within the PK construct were combined into a single component.

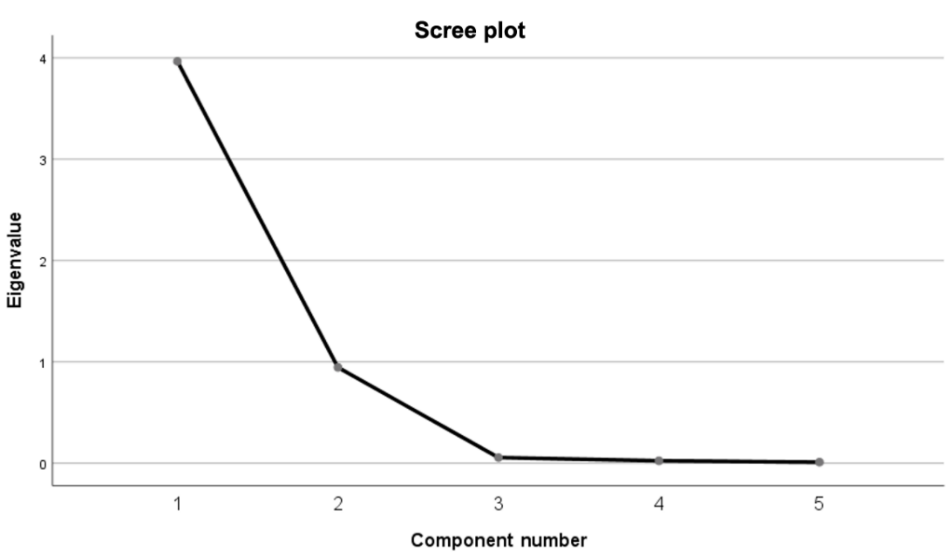

Figure 3. Scree plot analysis of the PK construct.

Figure 4 depicts a scree plot for the CK construct. All seven items within the CK construct were grouped into one component.

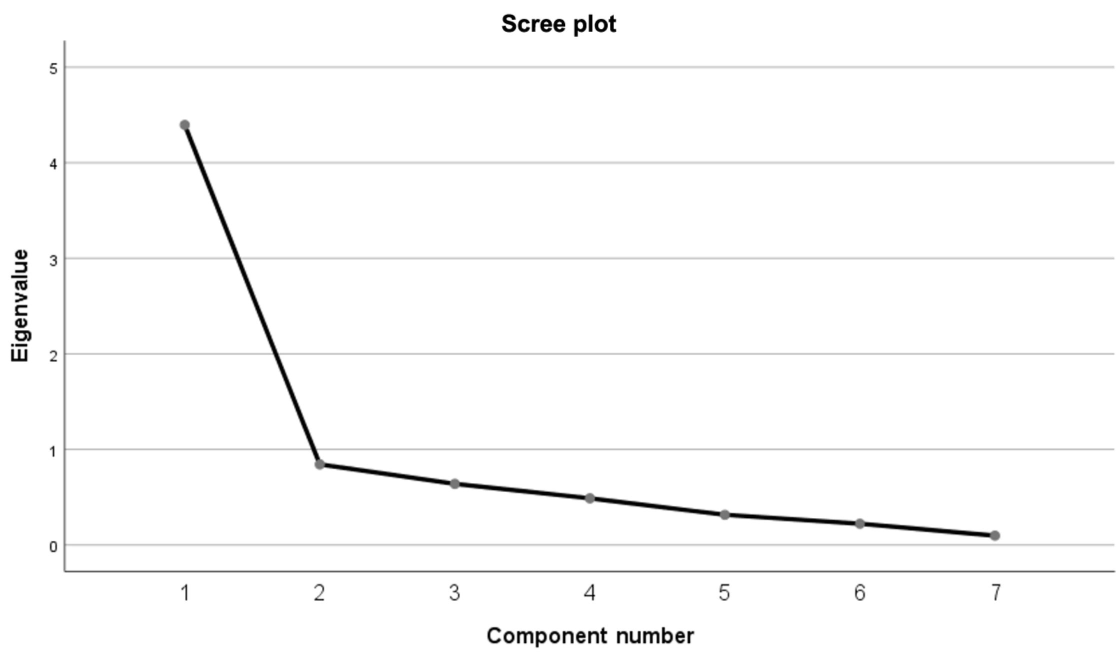

Figure 4. Scree plot analysis of the CK construct.

Figure 5 shows a scree plot for the TPACK construct. All 22 items within the TPACK construct were grouped into two components.

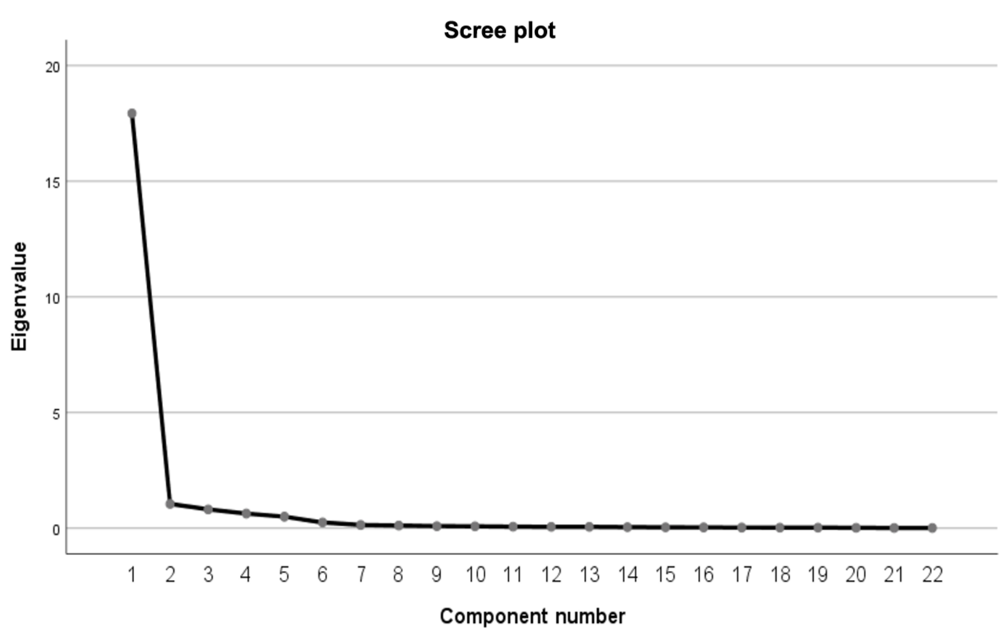

Figure 5. Scree plot analysis of the TPACK construct.

4.4. Final EFA Results with Items and Its Factor Loadings

This study conducted a rotated component matrix with varimax rotation to illustrate the correlation between items and their corresponding factors. Items with factor loadings greater than .6 were retained (Awang et al., 2023; Hair et al., 2019).

Table 3 presents the factor loadings for items measuring GK. The factor loadings for items GK1 to GK4 range from 0.775 to 0.873, indicating a strong correlation between the items and the GK factor. All four items were retained and grouped under one component.

Table 3. Factor loadings for items measuring GK.

Rotated component matrix	
	Component
	1
GK1	0.872
GK2	0.814
GK3	0.873
GK4	0.775

Note: Extraction method: Principal component analysis.
a. 1 components extracted.

Table 4 shows the factor loadings for items measuring TK. The factor loadings for items TK5 to TK20 range from 0.751 to 0.937, indicating a strong correlation between the items and the TK factor. All 16 items were retained and grouped under one component.

Table 4. Factor loadings for items measuring TK.

Rotated component matrix	
	Component
	1
TK5	0.806
TK6	0.821
TK7	0.865
TK8	0.845
TK9	0.869
TK10	0.841
TK11	0.937
TK12	0.904
TK13	0.916
TK14	0.813
TK15	0.840
TK16	0.879
TK17	0.916
TK18	0.751
TK19	0.796
TK20	0.839

Note: Extraction method: Principal component analysis.
a. 1 Components extracted.

Table 5 displays the factor loadings for items measuring PK. The factor loadings for items PK21 to PK24 range from 0.979 to 0.991, indicating a high correlation between these items and the PK factor. Four items were retained, while item PK25 was dropped due to a low factor loading. All four retained items are grouped under one component.

Table 5. Factor loading for items measuring PK.

Rotated component matrix	
	Component
	1
PK21	0.991
PK22	0.987
PK23	0.989
PK24	0.979
PK25	Dropped

Note: Extraction method: Principal component analysis.
a. 1 components extracted.

Table 6 exhibits factor loadings for items measuring CK. The factor loadings for items CK27 to CK32 range from 0.759 to 0.894, indicating a strong correlation between these items and the CK factor. Six items were retained, while item CK26 was dropped due to a low factor loading. All six items are grouped under one component.

Table 6. Factor loading for items measuring CK.

Rotated component matrix	
	Component
	1
CK26	Dropped
CK27	0.759
CK28	0.803
CK29	0.786
CK30	0.857
CK31	0.894
CK32	0.844

Note: Extraction method: Principal component analysis.
a. 1 Components extracted.

Table 7 indicates the rotated component matrix for TPACK. The factor loadings for items K33 to K54 range from 0.689 to 0.833, indicating a strong correlation between items and the TPACK factor. All 22 items were retained and grouped into two components. Items K33-K35 and K40-K49 are grouped under Component 1. Items K36-K39 and K50-K54 are grouped under Component 2.

Table 7. Factor loading for items measuring TPACK.

Rotated component matrix		
	Component	
	1	2
K33	0.812	
K34	0.791	
K35	0.792	
K36		0.708
K37		0.794
K38		0.810
K39		0.798
K40	0.784	
K41	0.765	

Rotated component matrix		
	Component	
	1	2
K42	0.689	
K43	0.784	
K44	0.784	
K45	0.772	
K46	0.790	
K47	0.798	
K48	0.806	
K49	0.788	
K50		0.818
K51		0.829
K52		0.833
K53		0.826
K54		0.781

Note: Extraction method: Principal component analysis.
a. 2 components extracted.

4.5. Internal Reliability Analysis

Internal reliability refers to consistency, examining the degree of intercorrelation among items with a construct (Bougie & Sekaran, 2019; Nassir, Rauf, Zainol, & Afthanorhan, 2024). According to rules of thumb, the Cronbach's Alpha shows a value of 0.8 or higher, indicating good internal consistency (Pallant, 2010). Table 8 presents the Cronbach's Alpha for the constructs. Overall, the items in the construct of teachers' knowledge in digital game-based learning demonstrate good reliability and can show consistent results.

Table 8. Cronbach alpha reliability test.

Construct	Component	No of Item	Cronbach's Alpha
GK	-	4	0.850
TK	-	16	0.975
PK	-	4	0.992
CK	-	6	0.906
TPACK	1	13	0.985
	2	9	0.982
Total		52	

5. Discussion

EFA results showed that TK, digital GK, PK, CK, and TPACK are the five new constructs to measure teachers' knowledge in optimizing the implementation of digital game-based learning in special education. Effective gamified instruction requires teachers' competencies in aspects such as educational technology, pedagogy in teaching diverse student populations, and subject content. This study aligns with previous research that emphasizes a new construct GK to merge with TPACK (Hsu, Liang, Chuang, Chai, & Tsai, 2021; Pondee, Panjaburee, & Srisawasdi, 2021). To create a successful digital game-based learning pedagogy, teachers must understand the game itself and how to incorporate playful learning to provide students with emotional engagement and hedonic motivation, ultimately achieving learning objectives (Maxim & Arnedo-Moreno, 2025).

This study has significant implications for educators, administrators, and policymakers in enhancing readiness for future education through the integration of game-based learning and gamification. Teachers' knowledge will accelerate the integration of a gamified classroom setting, promoting a shift towards more technology-driven and innovative teaching practices in special education (Fei, Khairuddin, & Nasri, 2025). A successful implementation of educational technology encourages more advanced technology adoption in teaching pedagogy to support the diverse needs of different students. Teacher preparation emphasizes technocratic principles and evidence-based practices, as well as the application of educational approaches that must also align with the requirements of modern teaching and students' needs (Blažič & Blažič, 2024).

Teachers fully recognize the potential of digital game-based learning. Nevertheless, gaps in teacher knowledge regarding real classroom practice, coupled with unfamiliarity in using digital games and limited experiences, hinder the implementation of game-based pedagogy (Kuo & Kuo, 2024). This study demonstrates the applicability of digital game-based learning pedagogy by focusing on key stakeholders in the education field specifically, teachers and examining the preparedness of special education teachers' knowledge in integrating digital game-based learning within elementary school settings. The EFA procedure for this study offers a validated and reliable TPACK-G instrument to measure special education teachers' knowledge in digital game-based learning pedagogy.

6. Conclusion

As a conclusion, this study validates the TPACK-G instrument as a measure of teachers' digital game-based learning knowledge in contexts for special education teachers who teach students with learning disabilities in primary schools. EFA procedure shows good results, with KMO values for GK, TK, PK, CK, and TPACK indicating excellent scores with KMO > 0.80. Additionally, the items in the questionnaire demonstrate a strong correlation between variables and factors, as items in the five knowledge constructs TK, GK, PK, CK, and TPACK have factor loadings greater than 0.6.

For construct TK, GK, PK, CK, and TPACK, the total variance explained ranged between 62.79% and 86.28%, which exceeds 60%. This indicates an acceptable level of explanatory power for the extracted factors. It is sufficient to represent the underlying constructs that the instrument measures. Regarding Cronbach's Alpha, the values for constructs TK, GK, PK, CK, and TPACK ranged between 0.850 and 0.992, demonstrating an exceptional level of internal reliability, with all constructs having values greater than 0.80. Further research is necessary to determine the influences on teachers' knowledge in digital game-based learning by utilizing the existing instrument through a confirmatory factor analysis procedure.

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Appendix 1.

Appendix 1. List of schools participating in pilot test data collection.

No.	School identification code	List of participating schools
1	WBA2006	Putrajaya Precinct 9 (2) National School
2	WBA2009	Putrajaya Precinct 14(1) National School
3	WBA2007	Putrajaya Precinct 16(2) National School
4	WBA0011	Bukit Bandaraya National School
5	WBA0043	Seri Petaling New City National School
6	WBA0051	Taman Desa National School
7	WBA0057	Taman Tun Dr. Ismail (2) National School
8	WBC0135	Sam Yoke National School (Chinese)
9	WBC0158	Salak South National School (Chinese)
10	WBA0008	Police Depot National School
11	WBA0010	Setapak National School
12	WBA0047	Wangsa Maju Section 2 National School
13	WBA0067	Setapak Village National School
14	WBD0171	Fletcher National School (Tamil)
15	WBA0080	South Lake City National School
16	WBC0149	Kepong 1 National School (Chinese)
17	WBA0013	Kampung Bharu National School
18	WBA0070	Lake City National School
19	WBD0175	Sentul National School (Tamil)
20	WBA0056	Police Cooperative Park National School
21	WBA0065	Taman Seri Sinar National School