

# Development and psychometric validation of Game-Based Mathematics Attitude Scale (GBMAS)

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## Abstract

This study aimed to develop and psychometrically validate a tool to gauge students' attitudes concerning the game-based learning method in mathematics. Recognizing the growing integration of digital and game-based pedagogies in mathematics classes, the research intended to build a reliable and valid scale that measured cognitive, affective, and behavioral elements of students' perceptions. The study involves three phases: expert validation, pilot testing, and factor validation. Six experts in mathematics education and educational research established the content validity of the initial 25-item instrument. The instrument was pilot-tested with 120 senior high school students. Results showed positive attitudes toward GBL in math (mean=3.44, SD=0.53), with high agreement across cognitive, affective, and behavioral aspects. Based on the findings, the Scale-Level CVI (S-CVI/Ave) of 0.86 indicates adequate content validity for the instrument measuring students' attitudes toward game-based learning in mathematics. KMO (0.890) and Bartlett's Test ( $\chi^2 = 1.489$ ,  $df = 190$ ,  $p < .001$ ) confirm data suitability for factor analysis. Cronbach's Alpha values demonstrate excellent internal consistency: Cognitive Attitude ( $\alpha = 0.923$ ), Affective Attitude ( $\alpha = 0.912$ ), and Behavioral Attitude ( $\alpha = 0.904$ ), with an overall reliability of 0.882. After Varimax rotation, three distinct dimensions emerged: cognitive (7 items), behavioral (7 items), and affective (6 items), all with strong factor loadings (0.755 to 0.851). These findings highlight the GBMAS as a useful instrument that promotes evidence-based instructional design, assessment of innovative pedagogies, and research in mathematics education. The study's limitations include small sample size and single-institution focus, suggesting a need for broader validation and correlation with academic success.

**Keywords:** *game-based learning, mathematics education, attitude scale, instrument validation, students, exploratory factor analysis*

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## 1. Introduction

Traditional teaching techniques, such as lectures and textbooks, have been the primary source of mathematical instruction. However, studies have demonstrated that these strategies fail to motivate students and increase academic performance (Chen et al., 2020, as cited in Paglomutan, 2024). To improve students' academic performance and excitement for mathematics, educators have resorted to innovative methods of instruction, including game-based learning (Paglomutan, 2024). In recent years, educational innovation has placed a greater emphasis on integrating technology and interactive pedagogies to improve learning engagement, especially in mathematics. One such innovation that creates interactive learning experiences by utilizing the cognitive and motivational advantages of gaming is game-based learning (GBL). It involves the application of games and game components in learning environments to involve pupils and encourage learning (Al-Khayat et al., 2023). Based on pedagogical research, GBL can increase and sustain students' motivation to learn, which is one of the key elements that maintains students' learning (Jaaska et al., 2022). From three different but complementary angles, Hellin et al. (2023) noted that games can be extremely effective instruments for enhancing learning processes: as a means for imparting knowledge or skills, as an object of the learning project itself, and as a philosophy to be considered while creating the learning procedure.

Given that GBL is being used in more classrooms, little is known about how students feel about it, particularly in the context of secondary school in the Philippines. According to Kahu and Nelson (2018, as cited in Johnson et al., 2018) a key element influencing student success is attitude (Johnson et al., 2022). Important aspects of learning include students' attitudes toward mathematics and their involvement in their own mathematical learning (Irvine, 2020). Those who have a strong competitive attitude typically put in more effort and perform better (Eber et al., 2021; Wang et al., 2018, as cited in Ma & Chen, 2024; ). Thus, measuring students' attitudes toward GBL is essential for understanding how they perceive its worth, satisfaction, and effectiveness in mathematics education. Since mathematics is a fundamental subject in STEM education, it is crucial to examine students' attitude toward innovative teaching methods like GBL in order to improve their engagement, problem-solving abilities, and conceptual comprehension.

Despite the fact that several attitude scales have been created in the field of mathematics education, the majority of these tools focus on specific psychological components like

enjoyment, value, or anxiety and mainly measure broad mathematics attitudes (Aiken, 1976; Fennema & Sherman, 1976; Tapia & Marsh, 2004; Yaşar, 2014). The Mathematics Attitude Scale for Adults (Szczygieł, 2022) and other, even more extensive tools that use a tripartite framework of cognitive, affective, and behavioral dimensions were not developed in the context of GBL. Similarly, rather than focusing on students' attitudes toward GBL specifically in mathematics, attitude measures in games in education either focus on instructors' opinions of board games (Kuo et al., 2025) or on collaborative learning using video games (Del Pozo et al., 2019). In the study of Coban et al. (2019), they develop an attitude scale on educational games but for classroom and pre-school teachers and not specifically for students. In addition, most existing attitude scales in education (e.g., Schepman & Rodway, 2023; Sindermann et al., 2021, as cited in Sultana, 2025) largely focus on general technology (Sultana, 2025). Due to a lack of adequate scales, research on mathematics attitudes has led to unclear and conflicting findings (Wen & Dube, 2021).

As indicated by Gülburnu and Yıldırım (2021), attitude is a multifaceted concept that needs to be measured in a context-specific and updated manner. However, there are few measures that accurately assess attitudes toward GBL in mathematics, capturing a variety of cognitive, affective, and behavioral characteristics. Creating such an instrument is critical for thoroughly assessing the psychological and behavioral effects of GBL approaches to mathematics education. This study aimed to develop and psychometrically validate an instrument that measures senior high school students' attitudes toward GBL in mathematics. The study aimed to address a methodological gap in mathematics education research by developing an instrument that was contextually accurate, reliable, and valid. Through this tool, educators and researchers can better assess whether students' ideas, emotions, and behavioral attitudes correspond with GBL approaches.

The importance of this study stems from its ability to inform curriculum design, instructional practice, and policy decisions. With the Department of Education (DepEd) supporting digital literacy and innovative pedagogy in the K-12 curriculum, assessing students' attitudes toward game-based learning is important. This instrument, which provides empirical data, can help teachers develop game-based activities that promote engagement, motivation, and mathematics proficiency. This study specifically aimed to:

1. Develop an instrument that measures students' attitudes toward game-based learning in mathematics.

2. Determine the content validity of the instrument through expert validation.
3. Establish the construct validity of the instrument using Exploratory Factor Analysis (EFA).
4. Determine the reliability of the instrument through Cronbach's alpha.
5. Identify the underlying dimensions representing students' attitudes toward GBL.

## 2. Literature Review

### *2.1. Students' Attitude Toward Game-Based Learning in Mathematics*

Instructional materials are the elements that contribute to making mathematics classes enjoyable and rewarding (Orbon & Sapin, 2022). GBL, as one of the 21st century's latest trends in education (Hui & Mahmud, 2023), has become an engaging instructional approach utilized across numerous academic areas, including mathematics (Hidayat et al., 2024). GBL is a method of active learning that promotes the utilization of actual games, both physical and digital, to motivate and improve student learning and engagement (Theobald, 2024). It is regarded as an active learning strategy to improve student learning which frequently incorporates existing and creative games (Whitton, 2012, as cited in Lozano et al., 2023). Students can be effectively engaged and motivated by GBL, especially when it comes to learning mathematics (Dele-Ajayi et al., 2019; Gil-Doménech & Berbegal-Mirabent, 2019; Serrano, 2019; Beserra et al., 2017; CózarGutiérrez & Sáez-López, 2016, as cited in Lozano et.al., 2023). Effective methods and games plays an important role in fostering mathematical comprehension because they help students build, reinforce, and connect various models of concepts in mathematics (Debrenti, 2024). Ergu and Dogan's (2022) study revealed that mathematics game-based design activities had a favorable impact on students' learning. Similarly, Vankus (2021) found that game-based learning had a significant (84%) beneficial impact on students' motivation, engagement, attitudes, enjoyment, state of flow, and other factors.

Attitude can be characterized as how we perceive a particular individual or thing (Cherry, 2025). Consequently, Fishman et al. (2021) defined attitude as how favorably or positively one responds towards utilizing a specific evidence-based practice. Rosenberg et al. (1960) proposed a tripartite model of attitude that included cognitive (knowledge of the object, ideas and beliefs towards the object), affective (feelings associate with the object) and

behavioural (actions towards the object) (Wen & Dube, 2021; Johnson et al., 2022) which remains the most prominent model used to gauge attitudes in education. In the context of GBL, this pertains to students' perceptions about the value of games (cognitive), their enjoyment and interest (affective), and their desire to participate or engage (behavioral) components (Krath et al., 2021). The model offers a solid and theoretically sound framework for analyzing how students feel about GBL in mathematics. This approach has been widely used in educational research since students' learning attitudes are influenced not only by their emotions, but also by their views about instructional effectiveness and willingness to participate in learning activities (Manzana et al., 2019). Prior mathematics attitude scales frequently focused on affective aspects such as satisfaction or anxiety (Suren & Kandemir, 2020; Mutegi et al., 2021; Dela Hera et al., 2023), leading to an inadequate evaluation of students' educational experiences. Wen and Dube (2022) recommended that a multidimensional definition of mathematics attitudes should be adopted which include mathematical cognitions, affects and behavioral intentions. Thus, a more thorough and theoretically sound assessment of attitudes toward GBL in mathematics can be made possible by using the Tripartite Model as the critical lens.

## ***2.2 Instrument Development and Validation***

Instrument is the term commonly used by researchers for an evaluation tool like survey, test, and questionnaire. Instrument development and validation involves necessary components – quantitative and qualitative procedures (Perrenoud et al., 2023) which include, item generation, expert review, pilot testing, and statistical validation. One crucial step in the research process is the validation of a survey instrument. Face validity and content validity are crucial elements in confirming the extent to which the survey instrument can measure the anticipated outcomes (Elangovan & Sundaravel, 2021). A survey instrument is typically evaluated in the face and content validation process by professionals from the field or industry as well as experts from academics. On the other hand, Factor analysis is a multivariate method used to investigate latent factors and examine connections between numerous observed variables (Yanai & Ichikawa, 2006). Using statistical techniques, factor analysis (FA) enables us to simplify a collection of complex variables or items in order to investigate the underlying dimensions that account for the correlations between the various variables or items (Tavakol & Wetzel, 2020). Assessing the suitability of the data for factor analysis using KMO test and

Bartlett's test (Miljiko, 2020) is essential. Following a Principal Component Analysis (PCA) to establish the possible quantity of data-driven variables, a varimax rotation becomes a viable next step (Allen, 2017). Bruin (2006) emphasized that PCA assumes that there is no unique variance, hence the total variance is equivalent to the common variance. To make the interpretation easier, varimax rotation redistributes the explained variance among all rotated components (Acal et al., 2020). As explained by Bruin (2006), the rotation of principal components seeks to achieve simple structure in order to improve interpretability. In terms of internal consistency and reliability, commonly tested using Cronbach's alpha, is a method for determining how effectively a test or survey is measuring what you want it to. Conceptually, a test's internal consistency indicates whether items on a test (or a subscale of a composite test) meant to evaluate the same construct generate consistent scores (Tang et al., 2014).

Several studies have validated attitude instruments in educational settings, especially in the field of Mathematics (e.g., Cerna et al., 2024; Aquilina et al., 2024; Toscano et al., 2025; Hidayat et al., 2021), but none concentrated solely on GBL in mathematics. Thus, this study fills a gap by developing an empirically validated measure to assess students' attitude toward GBL in the Philippine high school context.

### **3. Methodology**

#### ***3.1. Research Design***

A descriptive developmental research design, including quantitative and qualitative approach, was employed in this study, as it allows for a thorough investigation of current teaching strategies and the systematic development of instrument. According to Gaña (2022), descriptive developmental method is a systematic study of developing, generating, and systematically evaluating educational materials, methods, and outputs that must meet standards or criteria. The developmental part of this study focused on creating and establishing the Game-Based Mathematics Attitude Scale (GBMAS) using expert evaluation, pilot testing, and statistical validation approaches like EFA. Meanwhile, the descriptive part includes interpreting quantitative data and gathering qualitative insights from participants in order to further enhance the instrument. This design is suitable as it not only guarantees the psychometric quality of the developed tool but also offers valuable insights into students' attitudes concerning game-based learning in mathematics, hence facilitating evidence-based instructional improvement and innovation.

### ***3.2. Participants of the Study***

Participants included senior high school students from a private school in Santiago City, Philippines, during the School Year 2025–2026, with a total population of 467. Having 20-items for pilot testing, 120 participants involved is considered acceptable based on subject-to-item ratio guidelines. Methodological literatures such as Gorsuch (1983), Hatcher (1994), Suhr (2006), and Hair et al. (2018) suggests a minimum ratio of 5:1 (Memon et al., 2020). Even Bryant and Yarnold (1995) in Garson (2008), Gorsuch (1983) in MacCallum et al. (1999), Everitt (1975) in Arrindell and van der Ende (1985), and Gorsuch (1974) in Arrindell and van der Ende (1985), as cited in Zhao (2009), mentioned that subject-to-item ratio should be no lower than 5 (Zhao, 2009). As suggested by Hatcher (1994), the number of subjects should be 5 times larger than the number of variables, or 100 (Zhao, 2009). Similarly, Kline (1994) in Fein et al. (2022) and Kyriazos (2018) and Gorsuch (1983, as cited in Dalawi et al., 2025), recommended a minimum sample size generally at least 100. In most EFA applications, a sample size of 100 provides acceptable statistical power and reliability (Ady-Hameme, 2024). Thus, the study's sample size of 120 meets the minimal requirement for stable factor extraction.

Furthermore, non-proportionate stratified random sampling was used to guarantee that the participants were representative of the diverse population. This type of sampling is appropriate for ensuring that specified attributes are equally represented in the sample (Thomas, 2023). This technique was chosen suitable since attitudes toward game-based learning may differ across academic strands (ABM, TVL, HUMSS, & STEM) due to variations in learning habits, technological experience, and academic orientation. This technique decreases sample bias, enabling researchers to predict outcomes within and between strata, and increases the accuracy of results (Howell et al., 2020; Elfil, 2017; Teddlie, 2007, as cited in Howell et al., 2020).

In the selection of six experts in mathematics education and educational research to assess the instrument's content validity, purposive sampling was utilized. Purposive sampling, sometimes referred to as judgmental or expert sampling, involves choosing participants based on the researcher's assessment of who will be most helpful in gathering the necessary data (Andrade, 2020; Ahmed, 2024). In this case, the six experts were high school teachers, having research expertise in educational measurement or pedagogy. Each validator is a licensed math teacher with at least three years of experience working in various public secondary schools.

Three of the experts have earned master's degrees in mathematics education, one has a doctorate, and the other two are active math educators with an extensive classroom experience utilizing innovative methods of teaching. Their combined expertise in pedagogy as they evaluate the GBMAS guaranteed that each item was concise, pertinent, and consistent with the desired notions of cognitive, affective, and behavioral attitudes toward game-based learning.

### ***3.3. Instrumentation and Data Gathering Process***

Several literature and studies about Student's Attitude on GBL were reviewed, including the works of Attah et al. (2024), Pan et al. (2022), Hung et al. (2014), Chang et al. (2014), Jaaska et al. (2022), and Irwanto et al. (2024). Based on reviews and the tripartite attitude model, the initial pool of 25 items had been developed. Each item was rated using a 4-point Likert scale: 1 – Strongly Disagree, 2 – Disagree, 3 – Agree, 4 – Strongly Agree. The 4-point Likert scale was used to encourage participants to give precise answers rather than the neutral choice, which could lead to feedback that are unclear or unsure (Saputro et al., 2025). After content validation, 20 items were retained. Consequently, to assess clarity as well as item comprehension, pilot testing was conducted among senior high school students.

### ***3.4. Data Analysis***

The content validity was computed using Content Validity Index (CVI), a widely used statistic for measuring expert agreement on item relevance (Hakim et al., 2025). An acceptable CVI having 6 expert validators is at least 0.83 (Polit & Beck, 2006; Polit et al., 2007, as cited in Alabot, 2023). Consequently, data were analyzed using SPSS. Exploratory Factor Analysis (EFA) using Principal Component Analysis to establish the construct validity of the instrument, as well as Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity. On the other hand, reliability was computed using Cronbach's alpha.

### ***3.5. Research Ethics***

The study adhered to ethical standards of research involving human participants. Approval was obtained from the Institution – Northeastern College, Basic Education Center. Participants were informed of the study's purpose, confidentiality, and their right to withdraw at any time. Data were anonymized and stored securely.

## 4. Findings and Discussion

For the item generation, a total of 25 items were initially developed to measure students' attitudes toward game-based learning in mathematics as shown in Table 1.

**Table 1**

*Initially developed items for game-based mathematics attitude scale*

Statement	1	2	3	4
<b>A. Cognitive Attitude</b>				
1. Game-based learning helps me understand mathematical concepts better.				
2. Using games in math classes makes lessons easier to remember.				
3. Games help me apply what I have learned in real-life situations				
4. Game-based learning makes mathematics more interesting to study.				
5. Learning mathematics through games helps improve my problem-solving skills.				
6. Game-based learning encourages me to think critically in solving math problems.				
7. I believe that games are an effective tool for learning mathematics.				
8. Game-based learning is not helpful in mastering math lessons.				
<b>B. Affective Attitude</b>				
9. I enjoy learning mathematics when games are used in class.				
10. I feel excited when playing math-related games.				
11. Game-based learning reduces my anxiety when learning difficult math topics.				
12. I find math lessons more fun and engaging when games are involved.				
13. I feel more confident in learning math through games.				
14. I prefer game-based activities over traditional math lessons.				
15. I get distracted when games are used in math class.				
16. I feel anxious during math games.				
<b>C. Behavioral Attitude</b>				
17. I actively participate in math games during class.				
18. I am motivated to learn when the teacher uses games in math lessons.				
19. I put more effort into math lessons that include games.				
20. I encourage my classmates to join math game activities.				
21. I like to explore additional math games outside class to improve my skills.				
22. I pay more attention when math lessons are taught using games.				
23. I am willing to try new games that can help me learn mathematics.				
24. I tend to ignore math games because they are too easy.				
25. I rely on classmates instead of focusing on math games.				

**Legend:** 1 – Strongly Disagree, 2 – Disagree, 3 – Agree, 4 – Strongly Agree.

The statements were anchored on three main dimensions: Cognitive attitude, which focus on beliefs and perceptions about the usefulness and effectiveness of game-based learning in mathematics (8 items); Affective attitude, which pertains to the feelings and emotions toward game-based learning in mathematics (8 items); and Behavioral attitude, which includes the actions and willingness to participate in game-based learning activities (9 items).

For the content validation, 6 experts validated the tool using a Content Validity Form by College of St. John -Roxas from Alabot (2023). Table 2 shows the result of validators ratings.

**Table 2**

*Content validity index of the GBMAS items based on expert evaluation*

Statement	Expert in Agreement	I-CVI	Remarks
<b>A. Cognitive Attitude</b>			
1. Game-based learning helps me understand mathematical concepts better.	6	1	Valid
2. Using games in math classes makes lessons easier to remember.	6	1	Valid
3. Games help me apply what I have learned in real-life situations	6	1	Valid
4. Game-based learning makes mathematics more interesting to study.	6	1	Valid
5. Learning mathematics through games helps improve my problem-solving skills.	6	1	Valid
6. Game-based learning encourages me to think critically in solving math problems.	6	1	Valid
7. I believe that games are an effective tool for learning mathematics.	6	1	Valid
8. Game-based learning is not helpful in mastering math lessons.	2	0.33	Not Valid
<b>B. Affective Attitude</b>			
9. I enjoy learning mathematics when games are used in class.	6	1	Valid
10. I feel excited when playing math-related games.	6	1	Valid
11. Game-based learning reduces my anxiety when learning difficult math topics.	6	1	Valid
12. I find math lessons more fun and engaging when games are involved.	6	1	Valid
13. I feel more confident in learning math through games.	6	1	Valid
14. I prefer game-based activities over traditional math lessons.	5	0.83	Valid
15. I get distracted when games are used in math class.	4	0.67	Not Valid
16. I feel anxious during math games.	2	0.33	Not Valid
<b>C. Behavioral Attitude</b>			
17. I actively participate in math games during class.	6	1	Valid
18. I am motivated to learn when the teacher uses games in math lessons.	6	1	Valid
19. I put more effort into math lessons that include games.	6	1	Valid
20. I encourage my classmates to join math game activities.	6	1	Valid
21. I like to explore additional math games outside class to improve my skills.	6	1	Valid
22. I pay more attention when math lessons are taught using games.	6	1	Valid
23. I am willing to try new games that can help me learn mathematics.	6	1	Valid
24. I tend to ignore math games because they are too easy.	0	0	Not Valid
25. I rely on classmates instead of focusing on math games.	2	0.33	Not Valid
<b>S-CVI/Ave</b>		<b>0.86</b>	<b>Valid</b>

*Legend:* CVI > 0.83 (Valid).

The Item-Level CVI (I-CVI) demonstrates that most items had perfect agreement (1.00), indicating that the experts agreed they were extremely relevant and representational of their respective constructs. However, a few poorly constructed items, such as Items 8, 15, 16, 24, and 25, had lower I-CVI values, indicating the need for change or removal. The Scale-Level CVI (S-CVI/Ave) of 0.86 suggests that the entire instrument has adequate content validity, indicating that the majority of the items are relevant and appropriate to measure students' attitudes concerning game-based learning in mathematics.

Prior to Factor Analysis, KMO and Bartlett's Test were computed. Consequently, Exploratory Factor analysis was conducted. Results were presented as follows.

**Table 3**

*KMO and Bartlette's test result*

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.890
Approx. Chi-Square		1.488E3
Bartlett's Test of Sphericity	Df	190
	Sig.	.000

KMO value of 0.890 and a significant Bartlett's Test of Sphericity ( $\chi^2 = 1.489$ ,  $df = 190$ ,  $p < .001$ ) confirmed that the data were suitable for factor analysis. Results of Exploratory Factor Analysis were analyzed using SPSS (*see Appendix A*). Based on the scree plot, there were three components to be retained: the Cognitive, Affective, and Behavioral Attitude dimensions. In terms of eigenvalues greater than 1.00, three components were found with eigenvalues of 6.424, 4.285, and 2.822. The communalities indicated that the items were well represented by the extracted components, ranging from .600 to .751.

Consequently, to examine students' responses during pilot testing, descriptive statistics were computed and presented in table 4.

Students showed a favorable attitude toward game-based learning in mathematics, with an overall mean of 3.44 (SD=0.53), interpreted as "Agree". While cognitive and affective aspects reported high mean scores and low standard deviations, behavioral attitudes received lower means and slightly greater standard deviations. This is to be anticipated as situational and environmental factors frequently affect behavioral responses. These results offer empirical evidence for the scale items' consistency, relevance, and clarity. The stability of GBMAS is

further supported by the alignment of the observed mean and standard deviation patterns, which further supports moving towards reliability and exploratory factor analyses.

**Table 4**

*Mean and standard deviation results of pilot testing*

Statement	Mean	SD
<b>A. Cognitive Attitude</b>		
1. Game-based learning helps me understand mathematical concepts better.	3.52	0.49
2. Using games in math classes makes lessons easier to remember.	3.48	0.51
3. Games help me apply what I have learned in real-life situations	3.44	0.53
4. Game-based learning makes mathematics more interesting to study.	3.56	0.47
5. Learning mathematics through games helps improve my problem-solving skills.	3.46	0.52
6. Game-based learning encourages me to think critically in solving math problems.	3.45	0.53
7. I believe that games are an effective tool for learning mathematics.	3.58	0.46
<b>B. Behavioral Attitude</b>		
8. I actively participate in math games during class.	3.36	0.58
9. I am motivated to learn when the teacher uses games in math lessons.	3.42	0.56
10. I put more effort into math lessons that include games.	3.34	0.60
11. I encourage my classmates to join math game activities.	3.28	0.62
12. I like to explore additional math games outside class to improve my skills.	3.24	0.65
13. I pay more attention when math lessons are taught using games.	3.38	0.57
14. I am willing to try new games that can help me learn mathematics.	3.41	0.55
<b>C. Affective Attitude</b>		
15. I enjoy learning mathematics when games are used in class.	3.55	0.48
16. I feel excited when playing math-related games.	3.53	0.50
17. Game-based learning reduces my anxiety when learning difficult math topics.	3.39	0.57
18. I find math lessons more fun and engaging when games are involved.	3.58	0.46
19. I feel more confident in learning math through games.	3.42	0.54
20. I prefer game-based activities over traditional math lessons.	3.50	0.49
<b>Overall</b>	<b>3.44</b>	<b>0.53</b>

*Legend:* (n = 120); 1-1.49 Strongly Disagree, 1.50-2.49 Disagree, 2.50-3.49 Agree, 3.50-4.00 Strongly Agree

The results of reliability testing using Cronbach's alpha were shown in Table 5. The Cronbach's Alpha values for each three factors shows excellent internal consistency, exceeding the commonly accepted threshold of 0.70. Cognitive Attitude ( $\alpha = 0.923$ ), Affective Attitude ( $\alpha = 0.912$ ), and Behavioral Attitude ( $\alpha = 0.904$ ). In addition, the overall reliability of

0.882 further confirms that the instrument is a highly reliable tool for measuring students' attitudes toward game-based learning in mathematics.

**Table 5**

*Results of Cronbach's Alpha*

Factor	Number of Items	Cronbach's Alpha
Cognitive Attitude	7	0.923
Affective Attitude	6	0.912
Behavioral Attitude	7	0.904
<b>Total</b>	<b>20</b>	<b>0.882</b>

Finally, the Principal Component Analysis, following Varimax rotation, effectively confirmed the anticipated theoretical framework of the attitude items. Results were shown as follows.

**Table 6**

*Rotated component matrix of Viramax rotation*

	Component		
	1	2	3
Cognitive Attitude Item 1	.755	.066	.258
Cognitive Attitude Item 2	.851	.024	.135
Cognitive Attitude Item 3	.778	.084	.161
Cognitive Attitude Item 4	.801	.141	.087
Cognitive Attitude Item 5	.825	.094	.119
Cognitive Attitude Item 6	.828	.046	.137
Cognitive Attitude Item 7	.840	-.042	.161
Affective Attitude Item 1	.106	.017	.831
Affective Attitude Item 2	.253	.034	.815
Affective Attitude Item 3	.058	-.005	.827
Affective Attitude Item 4	.226	.088	.765
Affective Attitude Item 5	.133	.022	.815
Affective Attitude Item 6	.208	-.037	.841
Behavioral Attitude Item 1	.058	.774	.047
Behavioral Attitude Item 2	.028	.843	.023
Behavioral Attitude Item 3	-.031	.816	-.006
Behavioral Attitude Item 4	.147	.759	-.052
Behavioral Attitude Item 5	.060	.774	.075
Behavioral Attitude Item 6	.010	.802	.126
Behavioral Attitude Item 7	.115	.794	-.090

Extraction Method: Principal Component Analysis  
 Rotation method: Varimax with Kaiser Normalization  
 Rotation converged in 5 iterations

After Varimax rotation, the factor loadings became clearer as it reveals three distinct and independent underlying dimensions of attitude. Component 1: Cognitive Attitude (7 items); Component 2: Behavioral Attitude (7 items); Component 3: Affective Attitude (6 items). All 20 items exhibited high factor loadings ranging from .755 to .851, indicating strong correlations with their respective factors.

## 5. Conclusion

With an overall mean of 3.44 (SD = 0.53), the pilot testing results showed that students' attitudes toward game-based learning in mathematics were generally positive. While behavioral attitudes showed slightly greater variation, indicating situational effects on engagement, the cognitive and affective dimensions displayed higher mean scores and less variability. Moreover, the findings suggest that the developed instrument (GBMAS) for measuring students' attitudes toward game-based learning in mathematics is a valid and reliable tool. The instrument revealed excellent content validity, internal consistency, and exploratory factor analysis proved the three anticipated dimensions: cognitive, affective, and behavioral attitudes. The instrument's strong psychometric qualities are further supported by the high factor loadings following Varimax rotation, indicating that it can successfully measure these distinct elements of student attitudes.

From a STEM education perspective, teachers can use the GBMAS as a diagnostic tool to determine students' attitudes, feelings, and engagement behaviors about game-based instruction in mathematics. The development of focused teaching techniques that improve motivation and conceptual understanding can be guided by these outcomes.

For curriculum designers, the instrument offers empirical evidence that promotes the inclusion of structured game-based activities in mathematics curriculum.

For policymakers and school administrators, the GBMAS provides a data-driven framework for evaluating innovative instructional programs that correspond with learner-centered and digitally assisted education reforms.

For researchers, the tool is recommended for use in academic studies, evaluations, and data collection processes to understand trends, the effectiveness of teaching methods, or other research objectives regarding students' attitude towards mathematics specifically in the context of Game-based Learning.

Finally, the study had a small sample size and was limited to just one institution. Thus, to further improve generalizability, future research can repeat the analysis with bigger and more varied student populations or employ the validated GBMAS in various educational situations. Validation over time and association with academic success could further support the scale's predictive validity.

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### **Institutional Review Board Statement**

The conduct of this study has been approved and given relative clearance by Northeastern College- Basic Education Center.

### **AI Declaration**

The author declares the use of Artificial Intelligence (AI) in writing this paper. In particular, the author used Quillbot in paraphrasing ideas and checking grammar. The author takes full responsibility in ensuring proper review and editing of contents generated using AI.

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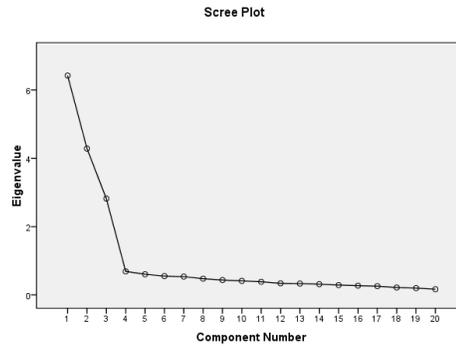
# Appendix

## Appendix A

Results of Exploratory Factor Analysis (EFA) using SPSS

**Communalities**

	Initial	Extraction
Cognitive Attitude Item 1	1.000	.641
Cognitive Attitude Item 2	1.000	.742
Cognitive Attitude Item 3	1.000	.639
Cognitive Attitude Item 4	1.000	.669
Cognitive Attitude Item 5	1.000	.704
Cognitive Attitude Item 6	1.000	.707
Cognitive Attitude Item 7	1.000	.734
Affective Attitude Item 1	1.000	.702
Affective Attitude Item 2	1.000	.730
Affective Attitude Item 3	1.000	.686
Affective Attitude Item 4	1.000	.643
Affective Attitude Item 5	1.000	.682
Affective Attitude Item 6	1.000	.751
Behavioral Attitude Item 1	1.000	.604
Behavioral Attitude Item 2	1.000	.711
Behavioral Attitude Item 3	1.000	.667
Behavioral Attitude Item 4	1.000	.600
Behavioral Attitude Item 5	1.000	.608
Behavioral Attitude Item 6	1.000	.659
Behavioral Attitude Item 7	1.000	.651



Extraction Method: Principal Component Analysis.

**Total Variance Explained**

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 %
1	6.424	32.121	32.121	6.424	32.121	32.121	4.846	24.229	24.229
2	4.285	21.425	53.546	4.285	21.425	53.546	4.478	22.391	46.620
3	2.822	14.108	67.654	2.822	14.108	67.654	4.207	21.034	67.654
4	.688	3.440	71.094						
5	.605	3.024	74.118						
6	.550	2.751	76.869						
7	.536	2.680	79.549						
8	.475	2.374	81.923						
9	.435	2.175	84.098						
10	.411	2.056	86.154						
11	.384	1.921	88.075						
12	.340	1.699	89.774						
13	.332	1.660	91.434						
14	.315	1.573	93.007						
15	.289	1.443	94.450						
16	.270	1.352	95.802						
17	.257	1.285	97.087						
18	.217	1.083	98.169						
19	.199	.997	99.166						
20	.167	.834	100.000						

Extraction Method: Principal Component Analysis.