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Achievement emotions for mathematics questionnaire in senior high school: Validity and reliability for Indonesian students

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Abstract

Achievement emotions are recognized as key factors influencing students' success in mathematics. However, no Achievement Emotions Questionnaire for Mathematics (AEQ-M) specifically tailored for Indonesian senior high school students has been developed. This study aims to translate the 68-item AEQ-M into Indonesian and validate its use for senior high school students in Indonesia, termed AEQ-M-SHS-I. A purposive cluster sampling method was used to select 198 tenth and eleventh-grade students in West Java, Indonesia. Data analysis included descriptive statistics, item analysis, and reliability testing. Structural, convergent, and discriminant validity were assessed using confirmatory factor analysis (CFA). All of data analyses were supported by SPSS 26.0 and AMOS 26.0. The Indonesian AEQ-M-SHS-I consists of ten factors and 68 items, all demonstrating good discriminant validity. CFA showed good structural model fit indices (e.g., X^2/df = 2.245, CFI = 0.937, TLI = 0.950, SRMR = 0.059, RMSEA = 0.079). Moreover, all of ten emotions in the AEQ-M-SHS-I had ideal convergent validity. Additionally, the tool exhibited high internal consistency (α = 0.868). These results indicate that the AEQ-M-SHS-I is a valid and reliable instrument for assessing achievement emotions in mathematics among Indonesian senior high school students.

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Keywords
Achievement emotions, Indonesia, mathematics, reliability, senior high school, validity

INTRODUCTION

Achievement emotions, defined as emotions directly associated with success or failure in academic tasks (Pekrun, 2019; Pekrun et al., 2023), are vital in educational settings. In mathematics education, these emotions profoundly affect students' motivation, engagement, and learning outcomes (Camacho-Morles et al., 2021; Schukajlow et al., 2023). Positive emotions like enjoyment and pride can boost interest in mathematics and encourage persistence in tackling challenging problems (Suparman et al., 2021). Conversely, negative emotions such as anxiety and frustration often impede performance and lead to avoidance behaviors (Putwain et al., 2021). Therefore, understanding and addressing achievement emotions is crucial for educators aiming to foster emotionally supportive environments that enhance both academic success and emotional well-being in mathematics.

Despite their importance, researches show that students frequently encounter emotional challenges in mathematics, particularly at the senior high school level (Gur et al., 2023; Suparman et al., 2021; Suparman et al., 2024). Gur et al. (2023) observed that senior high school students often experience heightened anxiety, frustration, and boredom during math activities, negatively affecting their performance and confidence. These emotions are often amplified by factors such as the subject's

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perceived difficulty, societal pressures to excel, and the competitive atmosphere of high school. Consequently, it becomes crucial to assess students' achievement emotions accurately to identify emotional barriers and implement effective interventions.

A significant challenge in the Indonesian context is the lack of reliable, culturally relevant instruments to measure achievement emotions specifically in mathematics. Although various achievement emotions questionnaires have been developed internationally (Peixoto et al., 2015; Pekrun et al., 2011; Pekrun et al., 2023; Raker et al., 2019; Suzuki & Tonegawa, 2022), only a few have been adapted to specific educational and cultural settings, such as Germany, China (Frenzel et al., 2007), Turkey (Calik & Aydin, 2019), Poland (Bieleke et al., 2023), and Mexico (Gómez et al., 2020; Moreira et al., 2019). However, in Indonesia, the Achievement Emotions Questionnaire–Mathematics (Bieleke et al., 2023; Moreira et al., 2019; Pekrun et al., 2011) has not been widely validated or tailored for senior high school students. This gap limits researchers' ability to explore the specific emotional dynamics of Indonesian students in mathematics, hindering efforts to collect meaningful data that could inform educational improvements (Suparman et al., 2024). Developing and validating an AEQ-M for the Indonesian context would greatly benefit educational researchers, especially those focusing on the psychology of mathematics education. Such a tool would offer critical insights into the emotional experiences of Indonesian senior high school students, creating a foundation for further studies in educational psychology and mathematics instruction. For Indonesian researchers, this instrument could enable a deeper understanding of how emotions influence cognitive processes and academic outcomes in mathematics, ultimately supporting better teaching practices and enhanced student engagement.

The recent study aims to create a Indonesian translation of the 68-item AEQ-M and AEQ-R developed by Bieleke et al. (2023) and Pekrun et al. (2023), and validate it in Indonesian senior high school students (AEQ-M-SHS-I, an AEQ-M for senior high schools in Indonesia). Particularly, the items of AEQ-M cover five positive emotions (e.g., enjoyment, pride, hope, contentment, relaxation) and five negative emotions (e.g., anxiety, shame, anger, hopelessness, boredom). Moreover, the AEQ-M-SHS-I measures three activities-related emotions, consisting of class-related emotions, homework-related emotions, and test-related emotions. This study is expected to provide the valid and reliable AEQ-M-SHS-I in capturing achievement emotions of Indonesian senior high school students in doing mathematics activities. Since students' achievement emotions became significant predictor for students' mathematics performance, the tool is urgently needed, specifically for Indonesian researchers in mathematics education, to present the profile of students' achievement emotions in mathematics.

The Control-Value Theory of Achievement Emotions

The Control-Value Theory (CVT) of achievement emotions, introduced by (Pekrun, 2006, 2024), provides a conceptual framework for understanding how emotions affect learning and performance. According to this theory, emotions are primarily influenced by two key factors: an individual's perceived control over a task and the subjective value assigned to that task and its outcomes (Pekrun, 2019, 2024). When a person feels they have control over an achievement-related activity and considers it meaningful, certain emotions arise that can either support or hinder their performance. CVT integrates cognitive appraisals of control and value with emotional responses, highlighting the role these emotions play in academic motivation and achievement (Lazarides & Raufelder, 2021). It also considers the interplay between individual traits and environmental influences, emphasizing the dynamic relationship between emotions and academic success.

Achievement emotions, defined as those linked to academic activities or outcomes such as studying or testing (Pekrun, 2016; Pekrun & Stephens, 2012), are triggered by perceptions of success, failure, or progress toward goals. These emotions are integral to cognitive and motivational processes in learners. Pekrun (2006) categorizes these emotions based on their object focus, differentiating between emotions

experienced during an activity (e.g., enjoyment or boredom) and those associated with future or past outcomes (e.g., pride or shame). Rather than being mere byproducts of academic activities, these emotions shape learning behaviors, drive motivation, and influence academic performance (Camacho-Morles et al., 2021; Pekrun & Linnenbrink-Garcia, 2012). Achievement emotions can be analyzed along three dimensions: valence, activation, and object focus (Pekrun et al., 2023). In terms of valence, emotions are either positive (e.g., enjoyment, pride, hope) or negative (e.g., anxiety, hopelessness, boredom). Activation refers to physiological arousal, distinguishing activating emotions (e.g., enjoyment, anxiety) from deactivating ones (e.g., boredom, hopelessness). Finally, object focus differentiates between emotions tied to activities and those related to outcomes, such as receiving feedback or grades (Pekrun & Linnenbrink-Garcia, 2012). This framework aids educators and researchers in understanding how emotions impact learning, enabling them to design strategies to enhance academic motivation and success, particularly in mathematics.

Achievement Emotions and Mathematics Performance

Achievement emotions directly affect students' academic performance, influencing how they engage with learning tasks. Research demonstrates that emotions like pride, enjoyment, and anxiety can either support or hinder learning (Schukajlow et al., 2023). Positive emotions enhance cognitive functions, such as memory and problem-solving, fostering better academic outcomes (Suparman et al., 2021). On the other hand, negative emotions disrupt learning by increasing stress and reducing focus, thereby lowering performance (Pekrun et al., 2017). Consequently, achievement emotions play a complex role in shaping how students' approach and perform in academic tasks. In mathematics, a subject often associated with strong emotional responses, achievement emotions are particularly significant (Suparman et al., 2024). The cognitive demands of mathematics frequently evoke intense feelings, which can influence performance. Positive emotions such as interest and enjoyment enhance engagement with challenging tasks, boosting performance. Conversely, negative emotions like anxiety impair cognitive processes, often leading to lower achievement. Thus, students' emotional states are critical determinants of their success in mathematics. Positive emotions—enjoyment, pride, hope, and relaxation—consistently improve mathematics performance (Juandi & Suparman, 2024). Enjoyment encourages active participation, leading to deeper learning and improved problem-solving skills. Pride, often rooted in previous successes, motivates students to pursue further achievement, creating a positive feedback loop. Hope and relaxation also contribute by fostering confidence and a calm approach to challenges. Together, these emotions create an environment conducive to learning.

In contrast, negative emotions—anxiety, hopelessness, shame, anger, and boredom—adversely affect performance (Putwain et al., 2021). Math anxiety, a prevalent negative emotion, disrupts working memory, complicating problem-solving. Hopelessness and shame, often linked to repeated failure, lead to disengagement and lowered expectations. Anger and frustration reduce focus and motivation, while boredom, stemming from disinterest, results in minimal effort. These emotions diminish both performance and the

Measurement of Achievement Emotions

The measurement of achievement emotions has been a focus of extensive research, with the Achievement Emotions Questionnaire (AEQ) developed by Pekrun et al. (2011) being a widely used tool. Rooted in the CVT framework, the AEQ evaluates a range of emotions tied to academic activities, such as enjoyment, pride, anxiety, and shame. This instrument has been instrumental in exploring how emotions influence motivation, learning strategies, and academic outcomes (Juandi & Suparman, 2024).

The AEQ has been adapted for various fields and cultural contexts, proving its versatility. In China, it has been customized for language learning, demonstrating strong reliability and validity (Tian et al.,

2023). Similarly, studies in Mexico, Spain, Germany, and Turkey have applied the AEQ to diverse subjects, uncovering cultural variations in achievement emotions (Calik & Aydin, 2019; Gómez et al., 2020; Moreira et al., 2019). These applications highlight the AEQ's effectiveness in capturing emotional dynamics across disciplines and educational systems.

In mathematics, the AEQ has been adapted to study subject-specific emotions in countries like Germany, Mexico, China, and Turkey. These adaptations measure key emotions such as math anxiety, pride, and enjoyment, validating the AEQ as a reliable tool for assessing emotions in mathematics education (Bieleke et al., 2023; Frenzel et al., 2007). These findings emphasize the importance of understanding achievement emotions in mathematics, where emotional experiences greatly influence performance and attitudes toward learning.

METHODS

Participants

The participants were 198 Indonesian students at public senior high schools in West Java selected by purposive sampling. They consisted of 55.05% girls aged 15 to 17 years (M = 16.23 year, SD = 2.13) and 44.95% boys aged 15 to 18 years (M = 16.89, SD = 1.74). Moreover, 51.52% students took courses focusing on the natural sciences (e.g., physics, chemistry, and biology), whereas 48.48% students took courses focusing on the social sciences (e.g., economics, sociology, and geography) but all of them were absolutely required to take mathematics as a fundamental course. Additionally, they were differentiated to be 38.89% tenth-grade students and 61.11% eleventh-grade students. Subsequently, 48.99% of them lived in the urban area and 51.01% of students lived in the rural area.

Instrument

The AEQ-M used in this study was specifically adapted and developed to measure the mathematics achievement emotions of senior high school students. The questionnaire was based on the work of Bieleke et al. (2022) and Pekrun et al. (2023) and consisted of 68 items measured on a 4-point Likert scale, ranging from 1 (strongly disagree) to 4 (strongly agree). Of these, 52 items were derived from Bieleke et al. (2022), covering seven categories of achievement emotions: enjoyment, anxiety, pride, shame, hopelessness, anger, and boredom. The remaining 16 items were adapted from Pekrun et al. (2023), focusing on three additional categories: hope, contentment, and relaxation. Following the framework of Pekrun (2016), the emotions were grouped into five positive categories (enjoyment, pride, hope, contentment, relaxation) and five negative ones (anxiety, anger, shame, hopelessness, boredom). The questionnaire was designed to assess students' emotional experiences during mathematics-related activities, such as attending classes, taking exams, and completing homework.

Procedure

The AEQ-M was initially translated into Indonesian by two graduate students fluent in English and Indonesian with expertise in mathematics education. The 68 items were adjusted to align with the Indonesian cultural and educational context. To ensure content validity, the translated questionnaire was reviewed by three experts specializing in educational psychology, and guidance and counselling. After revisions, the finalized Indonesian version was administered to senior high school students in West Java, Indonesia.

Statistical Analysis

Data analysis was performed using SPSS 26.0 and AMOS 26.0. Descriptive statistics were used to examine participant demographics (e.g., gender, major, age, grade) and their responses to each item. Item analysis involved calculating the correlation between each item and the total score, with a correlation threshold of $r \geq 0.6$ (Taylor, 1990). Participants were then divided into two groups—the top 27% (high scorers) and bottom 27% (low scorers)—based on total scores. An independent two-tailed t-test was

conducted to determine whether significant differences existed between the groups, with items showing significant differences deemed to have good discriminant validity (Vieira, 2017). Internal consistency was assessed using Cronbach's alpha, with values above 0.7 indicating acceptable reliability (Hair et al., 2019).

Confirmatory factor analysis (CFA) was conducted to evaluate the questionnaire's construct validity. Model fit was assessed using several indicators, including Chi-square/degree of freedom ratio (χ^2/df)–values below 5 were considered reasonable, Comparative Fit Index (CFI) and Tucker Lewis Index (TLI)–both indices needed to exceed 0.9 to indicate a good fit, Standardized Root Mean Square Residual (SRMR) and Root Mean Square Error of Approximation (RMSEA)–values below 0.08 were deemed acceptable (Almanasreh et al., 2019; Hu & Bentler, 1999), and factor loadings– items were required to have loadings greater than 0.40, given the study's sample size of approximately 200 public senior high school students (Hair et al., 2017). Convergent validity was assessed using the Average Variance Extracted (AVE) and Construct Reliability (CR). AVE values above 0.50 and CR values of at least 0.70 were considered acceptable (Fornell & Larcker, 1981). Discriminant validity was established by comparing the square root of each factor's AVE with its correlations to other factors. Higher AVE values indicated satisfactory discriminant validity (Butler & Dedrick, 2021).

RESULTS AND DISCUSSIONS

Descriptive Statistics

An overview regarding the characteristics of participants in this study, including gender, grade, age, major, and demography is provided in Table 1.

Table 1 <The Characteristics of Participants>

Characteristics	Number of Students	Percentage
Gender		
Male	89	44.95
Female	109	55.05
Grade		
Tenth-Grade	77	38.89
Eleventh-Grade	121	61.11
Age		
15 Years Old	36	18.18
16 Years Old	101	51.01
17 Years Old	57	28.79
18 Years Old	4	2.02
Major		
Social Science	96	48.48
Natural Science	102	51.52
Demography		
Urban	97	48.99
Rural	101	51.01

Meanwhile, the mean and standard deviation (SD) scores for each emotion and its items of the AEQ-M-SHS-I are presented in Table 2.

Table 2 <Mean and SD Scores for Each Item of the AEQ-M-SHS-I>

Items	Mean (SD)
Enjoyment	2.58 (0.87)
1. I look forward to mathematics classes every week	2.39 (0.83)
2. I enjoy attending mathematics classes	2.68 (0.81)
3. I find the topics discussed in mathematics class very interesting	2.72 (0.83)
4. I am happy because I can understand mathematics topics well	2.83 (0.82)
5. I smile happily at the teacher during mathematics lessons	2.85 (0.83)

Items	Mean (SD)
6. I am in a good mood when doing mathematics homework	2.41 (0.88)
7. I thoroughly enjoy doing mathematics homework	2.31 (0.83)
8. I am happy while taking mathematics tests	2.29 (0.88)
9. I smile with joy when the mathematics test goes well	2.76 (0.84)
Pride	2.86 (0.90)
10. I am proud of my knowledge in mathematics	2.75 (0.85)
11. I am proud of my contributions in mathematics class	2.64 (0.88)
12. I am proud of my work after completing mathematics homework	2.92 (0.91)
13. I am proud when I can do mathematics homework well	3.02 (0.93)
14. I am proud of myself after completing a mathematics test	2.89 (0.87)
15. I am proud when I can perform well on a mathematics test	2.92 (0.91)
Hope	2.59 (0.87)
16. I am optimistic about learning mathematics	2.60 (0.88)
17. I am confident I can master mathematics material	2.54 (0.85)
18. I am optimistic about completing mathematics homework	2.55 (0.85)
19. I choose not to give up on mathematics homework	2.60 (0.89)
20. I am confident the mathematics test will go well	2.64 (0.87)
21. I am optimistic about completing a mathematics test	2.59 (0.88)
Contentment	2.72 (0.92)
22. I am satisfied with my knowledge in mathematics	2.66 (0.90)
23. I am satisfied with my performance in mathematics class	2.62 (0.93)
24. I am satisfied with my work after completing mathematics homework	2.77 (0.92)
25. I am satisfied after being able to complete a mathematics test independently	2.83 (0.91)
Relaxation	2.52 (0.88)
26. I participate in mathematics lessons with ease	2.84 (0.80)
27. I express mathematical ideas in front of the class calmly	2.27 (0.84)
28. I do mathematics homework calmly	2.61 (0.86)
29. I do not feel burdened when solving difficult mathematics homework	2.40 (0.91)
30. I take mathematics tests calmly	2.62 (0.86)
31. I do not feel burdened when solving difficult mathematics tests	2.37 (0.91)
Anger	2.15 (0.92)
32. I am upset to the point that I want to leave mathematics class	2.20 (0.92)
33. I am upset because mathematics material is very difficult	2.42 (0.86)
34. I am upset because mathematics homework takes up most of my playtime	2.02 (0.79)
35. I want to throw my mathematics homework in the trash	1.94 (0.88)
36. I want to tear my mathematics test paper into pieces	1.96 (0.99)
37. I am upset because the teacher asks difficult questions during the mathematics test	2.37 (0.98)
Anxiety	2.41 (0.97)
38. I feel nauseous when thinking about mathematics class	2.16 (0.91)
39. I worry that mathematics material is too difficult	2.61 (0.95)
40. I choose to skip school because mathematics is frightening	1.84 (0.88)
41. I worry about my ability to fully understand mathematics material	2.47 (0.94)
42. I worry I won't complete mathematics homework on time	2.63 (0.90)
43. My heart races when I can't finish mathematics homework	2.54 (0.94)
44. I prefer not to do difficult mathematics homework	2.31 (0.96)
45. I feel tense and nervous when taking mathematics tests	2.51 (0.93)
46. I worry about getting a bad grade on a mathematics test	2.81 (0.97)
47. I worry about falling even before a mathematics test begins	2.59 (0.92)
48. I feel nauseous when thinking about an upcoming mathematics test	2.09 (0.91)
Shame	2.24 (0.93)
49. My face turns red when presenting ideas in mathematics class	2.08 (0.91)
50. I feel ashamed for not answering mathematics questions well	2.47 (0.96)
51. I am embarrassed about my lack of knowledge in mathematics	2.65 (0.92)

Items	Mean (SD)
52. I do not want to tell anyone when I do not understand mathematics homework	2.17 (0.84)
53. I avoid eye contact with classmates when discussing mathematics homework	2.06 (0.87)
54. My face turns red after taking a mathematics test	2.03 (0.89)
55. I do not want to talk about anything after completing a mathematics test	2.20 (0.91)
Hopelessness	2.28 (0.92)
56. I feel hopeless in mathematics class	2.16 (0.90)
57. I keep thinking I can't understand the mathematics material being taught	2.47 (0.92)
58. I would rather give up on mathematics homework	2.22 (0.88)
59. I no longer put effort into doing mathematics homework	2.14 (0.89)
60. I feel hopeless during mathematics tests	2.27 (0.89)
61. I keep thinking I will never get good grades in mathematics tests	2.44 (0.98)
Boredom	2.23 (0.95)
62. I find mathematics lessons boring	2.31 (0.93)
63. I do not focus when the teacher explains mathematics material	2.44 (0.93)
64. I am so bored that I do not want to learn mathematics anymore	2.08 (0.90)
65. I do not really care about the mathematics homework assigned	2.15 (0.97)
66. Mathematics homework bores me to death	2.17 (0.95)
67. Mathematics tests make me extremely bored	2.28 (0.95)
68. I do not really care about the mathematics tests assigned	2.22 0.99)

Item Analysis

The validity of individual items in the AEQ-M-SHS-I was assessed using item-to-total score correlation analysis (see Table 3). Pearson correlation results indicated a significant relationship between each item and the total score, with correlation coefficients (r) ranging from 0.579 to 0.786 ($p < 0.001$). Additionally, an independent sample t-test comparing high and low scoring groups revealed significant differences for all items ($p < 0.001$). These findings demonstrate that the AEQ-M-SHS-I items exhibit strong discriminatory power (see Table 3).

Table 3 <The Results of Item Analysis>

Items	*r*	*t*	Items	*r*	*t*
1	0.712**	13.269**	35	0.624**	9.732**
2	0.734**	12.902**	36	0.698**	9.767**
3	0.709**	13.349**	37	0.658**	12.803**
4	0.699**	13.068**	38	0.632**	9.986**
5	0.707**	11.729**	39	0.596**	10.698**
6	0.708**	12.492**	40	0.609**	8.801**
7	0.714**	12.500**	41	0.579**	10.641**
8	0.711**	14.286**	42	0.686**	9.953**
9	0.761**	11.166**	43	0.725**	14.707**
10	0.766**	12.350**	44	0.680**	14.174**
11	0.696**	13.982**	45	0.583**	13.694**
12	0.741**	12.297**	46	0.628**	9.054**
13	0.716**	11.858**	47	0.746**	10.350**
14	0.739**	11.471**	48	0.631**	11.942**
15	0.723**	11.731**	49	0.673**	9.534**
16	0.782**	12.012**	50	0.651**	13.341**
17	0.755**	16.442**	51	0.639**	13.249**
18	0.684**	13.522**	52	0.656**	10.549**
19	0.780**	12.944**	53	0.675**	9.435**
20	0.786**	16.653**	54	0.682**	9.921**
21	0.781**	16.501**	55	0.703**	10.339**
22	0.757**	15.666**	56	0.693**	11.730**
23	0.733**	14.864**	57	0.686**	12.714**

Items	*r*	*t*	Items	*r*	*t*
24	0.663**	15.136**	58	0.737**	10.176**
25	0.618**	10.786**	59	0.734**	11.730**
26	0.666**	9.1768**	60	0.646**	12.779**
27	0.678**	13.000**	61	0.725**	11.831**
28	0.648**	13.373**	62	0.722**	12.783**
29	0.741**	12.790**	63	0.669**	13.278**
30	0.638**	13.889**	64	0.752**	10.015**
31	0.619**	12.150**	65	0.775**	13.796**
32	0.636**	9.792**	66	0.761**	14.125**
33	0.601**	11.400**	67	0.751**	15.465**
34	0.606**	9.055**	68	0.737**	12.241**

** $p < 0.001$

Item analysis, a critical procedure for evaluating the quality and effectiveness of individual test items, ensures the instrument's overall validity and reliability (Lara-Bocanegra et al., 2025). The analysis of the AEQ-M-SHS-I items revealed significant correlations between individual item scores and the total test score, with Pearson's r values ranging from 0.579 to 0.786, all at a statistically significant level ($p < 0.001$). These strong correlations indicate that each item aligns well with the overall construct measured by the test, supporting the internal consistency of the scale (Valenti & Faraci, 2025). Furthermore, independent sample t-tests comparing the top and bottom groups of respondents confirmed significant differences in scores across all items ($p < 0.001$), highlighting the items' strong discriminatory power. This means that the items effectively differentiate between high and low performers, an essential quality for robust assessments. High-performing items, such as those with r values near 0.786, demonstrate exceptional alignment with the overall scale and contribute significantly to test validity (Olsson & Mattsson, 2024). Additionally, significant t-test results reinforce the ability of the instrument to rank individuals based on their ability or knowledge levels (Vieira, 2017). These findings show that the AEQ-M-SHS-I is a psychometrically sound instrument, with no items showing weak validity or discrimination.

Confirmatory Factor Analysis

A first-order confirmatory factor analysis (CFA) model with ten factors was constructed to evaluate the validity of the AEQ-M-SHS-I (see Figure 1). The fit indices confirmed that the model met statistical thresholds, including $X^2/df < 5$, CFI ≥ 0.9, TLI ≥ 0.9, SRMR < 0.08, and RMSEA < 0.08 (see Table 4). These results indicate that the model demonstrates a good fit, confirming the AEQ-M-SHS-I's construct validity.

Table 4 <The Fitting Indicators of the First-Order Ten-Factor Structural Model>

Model	10-Factor Model	
X^2	4,861.056	
df	2,165	
X^2/df	2.245	
CFI	0.937	
TLI	0.950	
SRMR	0.059	
RMSEA (90% CI)	0.79	(0.077 – 0.082)

Confirmatory factor analysis (CFA) of the AEQ-M-SHS-I was conducted to evaluate the validity of its ten-factor structure, and the results demonstrate strong construct validity. The model met widely accepted fit criteria, including a chi-square ratio (X^2/df) of 2.245, which is well below the threshold of 5, indicating an acceptable fit. Other key indicators, such as the Comparative Fit Index (CFI = 0.937) and

Tucker-Lewis Index (TLI = 0.950), exceeded the recommended cutoff of 0.90, further supporting the model's adequacy. Additionally, the Standardized Root Mean Square Residual (SRMR = 0.059) and Root Mean Square Error of Approximation (RMSEA = 0.079 with a 90% confidence interval of 0.077–0.082) fall within the acceptable ranges of less than 0.08, underscoring the model's suitability. These results collectively confirm that the AEQ-M-SHS-I has a robust factorial structure, aligning well with theoretical expectations (Hu & Bentler, 1999). The strong fit indices show that the test effectively measures its intended constructs and maintains internal consistency across factors. The use of a ten-factor structure allows for nuanced assessments of emotional constructs, ensuring that distinct dimensions of emotions are adequately captured. These findings align with best practices in scale validation as outlined by Kline (2015), reinforcing the AEQ-M-SHS-I as a psychometrically sound instrument. The CFA results highlight the scale's potential applicability in both research and practical educational settings.

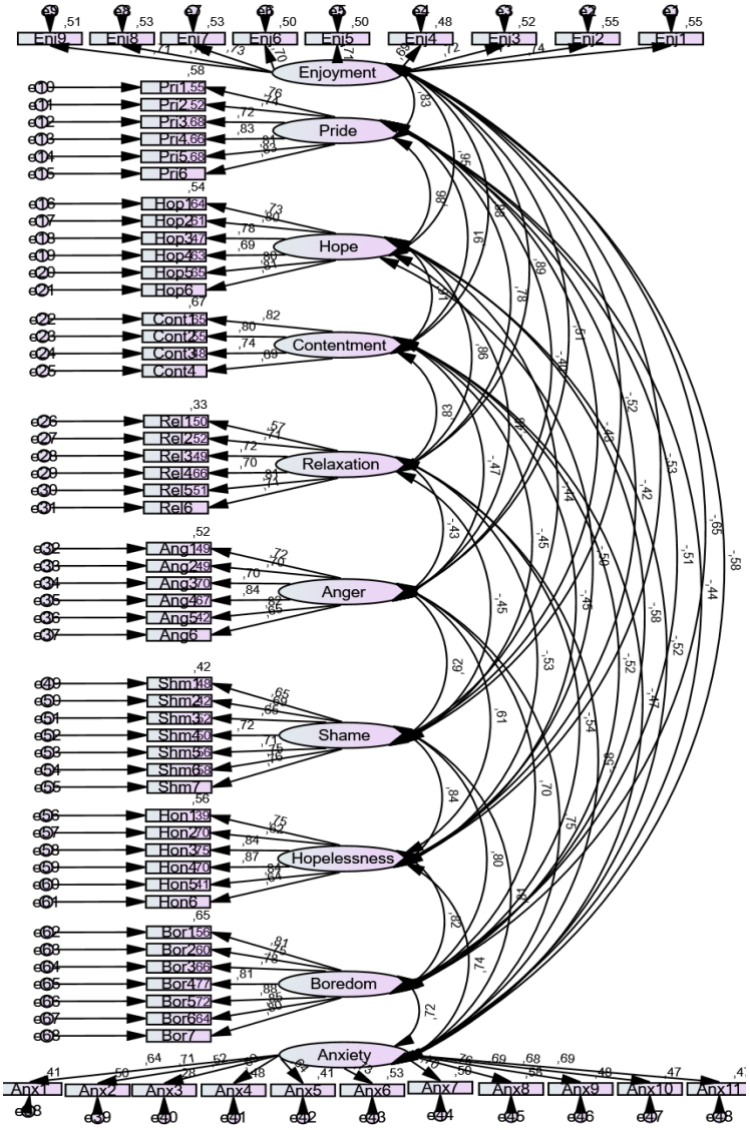

Figure 1 <First-Order Ten-Factor Structural Model>

Convergent and Discriminant Validity

The factor loadings for all items corresponding to the ten emotional dimensions—enjoyment, pride, hope, contentment, relaxation, anger, anxiety, shame, hopelessness, and boredom—exceeded 0.5, indicating strong representativeness of the items. Furthermore, all ten factors had Composite Reliability

(CR) values ranging from 0.773 to 0.993, exceeding the threshold of 0.7, and Average Variance Extracted (AVE) values between 0.659 and 0.929, surpassing the 0.5 benchmark (see Table 5). These results confirm the AEQ-M-SHS-I has excellent convergent validity.

Table 5 <Convergent Validity of the AEQ-M-SHS-I Scales>

Path	Factor Loading	AVE	CR
Enj1 < — Enjoyment	0.739	0.659	0.866
Enj2 < — Enjoyment	0.740		
Enj3 < — Enjoyment	0.721		
Enj4 < — Enjoyment	0.694		
Enj5 < — Enjoyment	0.708		
Enj6 < — Enjoyment	0.704		
Enj7 < — Enjoyment	0.729		
Enj8 < — Enjoyment	0.731		
Enj9 < — Enjoyment	0.712		
Pri1 < — Pride	0.762	0.866	0.993
Pri2 < — Pride	0.739		
Pri3 < — Pride	0.722		
Pri4 < — Pride	0.825		
Pri5 < — Pride	0.812		
Pri6 < — Pride	0.827		
Hop1 < — Hope	0.733	0.797	0.973
Hop2 < — Hope	0.803		
Hop3 < — Hope	0.779		
Hop4 < — Hope	0.686		
Hop5 < — Hope	0.796		
Hop6 < — Hope	0.805		
Cont1 < — Contentment	0.820	0.694	0.836
Cont2 < — Contentment	0.803		
Cont3 < — Contentment	0.744		
Cont4 < — Contentment	0.690		
Rel1 < — Relaxation	0.571	0.719	0.854
Rel2 < — Relaxation	0.705		
Rel3 < — Relaxation	0.720		
Rel4 < — Relaxation	0.703		
Rel5 < — Relaxation	0.811		
Rel6 < — Relaxation	0.711		
Ang1 < — Anger	0.722	0.701	0.773
Ang2 < — Anger	0.697		
Ang3 < — Anger	0.698		
Ang4 < — Anger	0.836		
Ang5 < — Anger	0.819		
Ang6 < — Anger	0.646		
Anx1 < — Anxiety	0.638	0.685	0.828
Anx2 < — Anxiety	0.710		
Anx3 < — Anxiety	0.524		
Anx4 < — Anxiety	0.689		
Anx5 < — Anxiety	0.643		
Anx6 < — Anxiety	0.727		
Anx7 < — Anxiety	0.704		

Path	Factor Loading	AVE	CR
Anx8 < — Anxiety	0.764		
Anx9 < — Anxiety	0.690		
Anx10 < — Anxiety	0.685		
Anx11 < — Anxiety	0.687		
Shm1 < — Shame	0.651	0.778	0.907
Shm2 < — Shame	0.692		
Shm3 < — Shame	0.650		
Shm4 < — Shame	0.719		
Shm5 < — Shame	0.705		
Shm6 < — Shame	0.746		
Shm7 < — Shame	0.760		
Hon1 < — Hopelessness	0.746	0.695	0.784
Hon2 < — Hopelessness	0.624		
Hon3 < — Hopelessness	0.839		
Hon4 < — Hopelessness	0.865		
Hon5 < — Hopelessness	0.839		
Hon6 < — Hopelessness	0.640		
Bor1 < — Boredom	0.807	0.929	0.973
Bor2 < — Boredom	0.750		
Bor3 < — Boredom	0.777		
Bor4 < — Boredom	0.813		
Bor5 < — Boredom	0.876		
Bor6 < — Boredom	0.848		
Bor7 < — Boredom	0.802		

The absolute correlation coefficients between factors were all below 0.5 and less than the square root of their respective AVE values. Significant correlations were observed among the ten emotions (see Table 6). These findings confirm that the AEQ-M-SHS-I exhibits strong discriminant validity, with clear differentiation among its factors.

Table 6 <Discriminant Validity of the AEQ-M-SHS-I Scales>

	1	2	3	4	5	6	7	8	9	10
1. Relaxation	0.419									
2. Anger	0.178*	0.401								
3. Contentment	0.337*	0.185*	0.394							
4. Shame	0.202*	0.272*	0.195*	0.478						
5. Hopelessness	0.217*	0.244*	0.177*	0.363*	0.395					
6. Hope	0.392*	0.213*	0.401*	0.216*	0.222*	0.497				
7. Boredom	0.277*	0.351*	0.261*	0.436*	0.410*	0.325*	0.629			
8. Anxiety	0.235*	0.293*	0.185*	0.347*	0.287*	0.228*	0.352*	0.385		
9. Pride	0.382*	0.192*	0.431*	0.226*	0.199*	0.457*	0.304*	0.204*	0.566	
10. Enjoyment	0.347*	0.195*	0.329*	0.216*	0.200*	0.402*	0.311*	0.217*	0.375*	0.359
AVE Square Root	0.647	0.633	0.628	0.691	0.628	0.705	0.793	0.618	0.752	0.599

* $p < 0.001$

The AEQ-M-SHS-I demonstrates robust convergent validity and discriminant validity, key indicators of a well-constructed instrument. Factor loadings for all items exceeded 0.5, confirming that the items strongly represent their corresponding emotional constructs, such as enjoyment, pride, hope, and others.

Composite Reliability (CR) values ranged from 0.773 to 0.993, surpassing the 0.7 threshold, and Average Variance Extracted (AVE) values ranged from 0.659 to 0.929, exceeding the minimum standard of 0.5. These results indicate excellent convergent validity, showing that the items effectively measure their intended latent constructs (Hair et al., 2011). Moreover, the correlation coefficients among the ten emotional factors were all below 0.5 and lower than the square root of their respective AVE values. This confirms ideal discriminant validity, meaning that the constructs are distinct and not overly correlated, reducing redundancy in measurement (Butler & Dedrick, 2021). Significant correlations among emotions like anger, hope, and relaxation reflect theoretical coherence while maintaining factor independence. Together, these findings show that the AEQ-M-SHS-I is capable of accurately measuring and differentiating between emotional constructs. These outcomes align with Fornell and Larcker's criteria for convergent and discriminant validity, which emphasize high AVE values and low inter-factor correlations for quality measurement tools (Fornell & Larcker, 1981; Voorhees et al., 2016). The results underscore the scale's utility in assessing a wide range of emotions with both precision and clarity.

Reliability Analysis

The reliability of the AEQ-M-SHS-I was assessed using Cronbach's alpha to determine internal consistency. The Cronbach's alpha coefficients for the ten dimensions ranged from 0.846 to 0.930, with an overall coefficient of 0.868 (see Table 7). These results indicate that the AEQ-M-SHS-I has high internal consistency and is a reliable instrument for measuring achievement emotions.

Table 7 <The Reliability of the AEQ-M-SHS-I Scales>

Emotions	**Cronbach α**
Enjoyment	0.906
Pride	0.902
Hope	0.894
Contentment	0.846
Relaxation	0.851
Anger	0.872
Anxiety	0.903
Shame	0.871
Hopelessness	0.886
Boredom	0.930
Total Score	0.868

The AEQ-M-SHS-I demonstrates strong reliability, as evidenced by both internal consistency and test-retest reliability analyses. Cronbach's alpha coefficients for the ten dimensions ranged from 0.846 to 0.930, with an overall alpha of 0.868, exceeding the commonly accepted threshold of 0.7 for high internal consistency. These results show that the items within each dimension are cohesively measuring their intended constructs, ensuring reliable responses across various administrations (Hair et al., 2019). These findings align with best practices in reliability analysis as outlined by Kline (2015), who emphasizes the importance of both internal consistency and stability over time for psychometric robustness. Together, these results validate the AEQ-M-SHS-I as a reliable tool for assessing emotional constructs.

Implications to the Mathematics Education

The developmental study of the AEQ-M-SHS-I offers significant theoretical implications for mathematics education in Indonesia. First, it highlights the critical role of culturally relevant validation processes in assessing achievement emotions, ensuring that emotional constructs align with the lived experiences of Indonesian students. By demonstrating reliability and validity within the Indonesian

context, the study supports the cross-cultural applicability of emotional frameworks in mathematics education. Moreover, it emphasizes the need to recognize emotional diversity, such as anxiety, enjoyment, and pride, which affect students' motivation and performance in mathematics. These findings reinforce the importance of integrating emotional dimensions into theoretical models of mathematics learning. Furthermore, they suggest that achievement emotions are not just individual traits but are shaped by societal and educational norms. This perspective urges a reevaluation of learning theories to incorporate emotional dynamics specific to cultural contexts. Additionally, the study contributes to the broader literature by expanding knowledge on how emotions interact with cognitive and behavioral aspects of learning. It also lays the foundation for future research into the mechanisms through which emotions influence mathematics achievement in Indonesia. Finally, the validated AEQ-M-SHS-I provides a robust tool for assessing emotional factors, offering theoretical clarity in understanding student engagement and resilience. This, in turn, supports the development of comprehensive theories that address both cognitive and affective domains of mathematics education.

The validated AEQ-M-SHS-I also presents crucial practical implications for improving mathematics education in Indonesia. Firstly, it enables teachers to identify and address students' emotional challenges, such as anxiety or hopelessness, which may hinder mathematical understanding. By using the questionnaire, educators can design targeted interventions that foster positive emotions, such as enjoyment and contentment. Moreover, the findings encourage schools to adopt teaching strategies that mitigate negative emotions while enhancing engagement and motivation. For example, incorporating collaborative and interactive learning activities may help reduce anxiety and increase enjoyment in mathematics. Additionally, the tool can guide the development of professional training programs for teachers, equipping them with skills to manage and support students' emotional well-being. It also suggests the inclusion of emotional assessment in regular classroom evaluations to monitor students' affective states alongside academic progress. Policymakers can leverage the findings to develop curriculum reforms that prioritize emotional resilience as a critical component of mathematics learning. Furthermore, the study emphasizes creating a supportive learning environment that addresses cultural nuances and reduces the stigma associated with negative emotions. By aligning educational practices with the emotional needs of students, schools can foster a more inclusive and effective learning atmosphere. Finally, the AEQ-M-SHS-I serves as a vital resource for continuous improvement, enabling stakeholders to measure and enhance the emotional aspects of mathematics education systematically.

Limitations and Suggestions

The developmental study of AEQ-M-SHS-I has several limitations that warrant attention. First, the sample size and diversity might not fully represent the broader population of Indonesian senior high school students, limiting the generalizability of the findings. Additionally, the study's cross-sectional design restricts its ability to capture changes in achievement emotions over time. The reliance on self-reported data could also introduce biases, as students may provide socially desirable responses rather than reflecting their true emotions. Another limitation lies in the focus on cognitive and behavioral components without sufficient exploration of external factors, such as socio-economic status or school infrastructure, which may influence achievement emotions. The study may have also overlooked the role of teacher-student relationships in shaping students' emotional experiences in mathematics. To demonstrate validity, it would be critically important to examine relations with external variables, such as students' mathematics achievement. Furthermore, the instrument's linguistic adaptation, while validated, may still carry subtle ambiguities that could affect respondents' interpretations. Lastly, the study does not address the interplay between achievement emotions and other subject areas, potentially limiting the scope of its conclusions.

Future studies should address these limitations to strengthen the understanding and application

of the AEQ-M-SHS-I in Indonesia. To enhance generalizability, researchers should expand the sample size and include students from diverse regions, socio-economic backgrounds, and educational contexts. Longitudinal studies are recommended to examine how achievement emotions evolve over time and their long-term effects on mathematics learning outcomes. To minimize response bias, incorporating triangulation methods, such as observational data and teacher assessments, can provide a more comprehensive understanding of students' emotional states. Researchers should also investigate the impact of external factors, such as family support and school resources, on students' achievement emotions in mathematics. Moreover, future studies could explore the role of teacher interventions and pedagogical practices in moderating negative emotions and enhancing positive ones. Refining the linguistic adaptation of the AEQ-M-SHS-I through iterative feedback from both students and language experts can improve clarity and accuracy. Lastly, expanding the application of the questionnaire to other subjects may reveal interdisciplinary emotional patterns, offering deeper insights into the holistic educational experience of Indonesian students.

CONCLUSION

The AEQ-M-SHS-I demonstrates strong psychometric properties, making it a valid and reliable tool for assessing achievement emotions among senior high school students in Indonesia. Item analysis revealed significant item-to-total correlations and excellent item discrimination, with *r* values ranging from 0.579 to 0.786 ($p < 0.001$). CFA established good construct validity, with fit indices (e.g., $X^2/df = 2.245$, CFI = 0.937, TLI = 0.950, SRMR = 0.059, RMSEA = 0.079) meeting statistical criteria. The ten-factor structure explained 68.404% of the variance, with factor loadings exceeding 0.5 for all items. The model demonstrated robust convergent validity, as all factors had CR values above 0.7 and AVE values above 0.5. Discriminant validity was also supported by AVE square roots exceeding inter-factor correlations. Reliability analysis showed high internal consistency, with Cronbach's alpha coefficients ranging from 0.846 to 0.930. These findings affirm the AEQ-M-SHS-I as a stable and comprehensive instrument, suitable for cross-sectional and longitudinal studies on achievement emotions in Indonesian educational settings.

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AUTHOR CONTRIBUTION STATEMENT

All of authors were involved in writing this article. Particularly, Suparman translated and re-designed the instrument, and administrated it to students and collected the data. Bambang Avip Priatna Martadiputra organized, analyzed, and interpreted the data using SPSS 26.0 and AMOS 26.0. Dadang Juandi and Turmudi reviewed and supervised this study overall.

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