International Journal of Evaluation and Research in Education (IJERE)
Vol. 13, No. 3, June 2024, pp. 1908~1916
ISSN: 2252-8822, DOI: 10.11591/ijere.v13i3.27718

An Indonesian-version of the short attitude toward mathematics inventory: a voice from pre-service chemistry teacher

Andrian Saputra, Lisa Tania
Department of Chemistry Education, Faculty of Teacher Training and Education, Universitas Lampung, Bandar Lampung, Indonesia

Article Info

Article history:

Received Jun 21, 2023
Revised Sep 6, 2023
Accepted Oct 10, 2023

Keywords:

Confirmatory factor analysis
Mathematics attitude
Pre-service chemistry teacher
Structured mean modelling
Survey research

ABSTRACT

This study aimed to examine the validity of the Indonesian version of the short attitude toward mathematics inventory (ATMI). The adapted inventory was also used for further analysis to explore mathematics attitude of pre-service chemistry teachers across gender. The original ATMI was translated into Bahasa and distributed to 328 participants via the online survey. After preliminary checking for multivariate outliers, all the data were used to analyze the construct validity of structural model using confirmatory factor analysis (CFA). Furthermore, multigroup analysis with structured mean modelling was conducted to explore the gender effect toward mathematics attitude. All item means, standard deviations and correlation matrix were also explored. The result found that the short form supported the four-factor solution as the original ATMI. Modification indices, standardized regression weight, and squared multiple correlations were used to determine which items to be removed or retained during analysis until standard criteria for model fit reached. This items deletion produced a shorter version of ATMI (19 items) with fairly good internal consistency, both for all items inventory (α=0.92) or for individual subscale (mean α=0.86). Moreover, the t-test on the latent mean value showed no significant difference of attitude toward mathematics between male and female.

Corresponding Author:

Andrian Saputra
Department of Chemistry Education, Faculty of Teacher Training and Education, Universitas Lampung
Jl. Prof. Dr. Sumantri Brojonegoro No. 1, 3514 Bandar Lampung, Lampung, Indonesia
Email: andriansaputra@fkip.unila.ac.id

1. INTRODUCTION

University-level chemistry course is considered as the most tough course for science students. How come, most of subject in university chemistry apply math-based approach to gain chemistry concept, such as physical chemistry, analytical chemistry, and statistical thermodynamics. which require experience and high-level math skills [1]. For example, in physical chemistry courses, students need to master advanced calculus such as integral and partial differential equations, operators, matrices, group theory, vectors, mathematical series [2]. Which is can being a barrier to student success in the course because the topic is not taught as standard mathematical courses in schools [3]. There are at least three things that need to be considered and improved in order to be successful in mathematics-based chemistry course including attitudes towards mathematics, prerequisite mathematical abilities and the ability to translate mathematical language into physical systems and/or otherwise [4].

Because of its significant role in students' success of studying chemistry at university, efforts to improve math attitudes and abilities have become one of the focuses of research in recent decades [5]–[12]. However, many researchers more focus on increasing mathematical achievement only, without changing students' mathematical mindset and confidence [13]. The mathematics attitudes can affect students' way of thinking in mathematics, the perceived importance of it, and willingness to put a lot of effort in improving their mathematics achievement [14]. Mathematics attitudes contributed to students' mathematical performance more than personality and cognitive abilities [15]. Moreover, a personal decision to take a large portion of mathematics and math-related subjects that they will study in the future is significantly influenced by how they perceive mathematics itself. Specifically, individuals with poor attitudes toward mathematics are less likely to choose university courses and careers that require the use of mathematical skills [16]. In line with that, student confidence is one of the most prominent reasons in deciding whether to take or not a higher level of mathematics besides evaluating the time demands of the higher levels of mathematics compared with other subjects [17]. Furthermore, mathematics teachers and career professionals revealed that the main factors causing students to decide not to take the higher levels of mathematics at senior secondary school were dominated by self-perception of ability, interest and liking for higher level mathematics, perceptions of the difficulty of the higher subject level, previous achievement in mathematics and its perceived usefulness [18]. Improving students mathematical knowledge, especially science students is very important, but building a positive attitude towards mathematics is work that cannot be ruled out. The two must go hand in hand.

An attitude is "a disposition to react favorably or unfavorably to a class of objects" [19]. Thus, attitude toward mathematics is an affective component described the positive, neutral, or negative feelings a person has about mathematics. Attitude toward mathematics as personal emotions, beliefs, and behavior related to mathematics [20]. A basic conception that is widely used as the basis for adapting mathematical attitudes is Neale's conception of attitude towards mathematics which is well known and widely understood in mathematics research. His definition of attitude toward mathematics is "a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activity, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless" [21]. In line with this definition, Tapia and Marsh [22] also had the similar formulation that attitude toward mathematics refers to one's feelings and emotions toward mathematics, which includes value, self-confidence, enjoyment, and motivation. From many definitions related to mathematics attitude, all of them are derived from the definition that attitude consists of three different components, namely cognitive, affective, and behavioral components. Thus, the measurement and development of instrument for attitudes toward mathematics have to consider the emotional response toward mathematics (affective), facts and beliefs about mathematics (cognitive), as well as observations and behavior of mathematics practices (behavior) [23].

Literature searching found a variety of instruments used to measure attitudes towards mathematics [16], [24]–[28]. Among the available instruments, The Fennema-Sherman mathematics attitudes scales (FSMAS) is the best known and the most widely used in related research [24]. This scale accommodates nine subscales, namely attitude, self-efficacy, anxiety, and value of mathematics. The other five subscales are gender; student's perception of their mother's interest in math; student's perception of their father's interest in math; student's perception of teacher's attitudes toward math; and the usefulness of mathematics as a domain. However, this instrument consists of 108 items which can take more time in filling the instrument so it has the potential to distract the respondent's focus. In addition, the instrument was standardized based on norms drawn from United States (US) which makes the existing scales might not be appropriate for the Indonesian people. Another instrument called the attitudes toward mathematics inventory (ATMI) developed by Tapia and Marsh [22] is one of the latest instruments, although this instrument has not received much attention for education researchers [29], [30]. The original form of ATMI consists of 49 items which are grouped into six dimensions, namely confidence, anxiety, value, enjoyment, motivation and parent/teacher expectations. Twelve items of which are reversed items. A field trial using the five-point Likert scale of the original ATMI was conducted on 544 high school mathematics students in Mexico City, of which 291 participants were male and the rest were female [25].

All the data was processed to understand the internal consistency and structural validity of the instrument. Item-to-total correlation and Cronbach alpha were used to decide if items should be retained or removed. One by one the items with the lowest item-to-total correlation were deleted to increase the coefficient of Cronbach alpha. This process was stopped until no further increase in the alpha value. The results showed that there were 9 items removed with an item-to-total correlation below 0.50, leaving 40 items as the final version of ATMI with a Cronbach alpha of the instrument reached 0.97. This alpha value confirmed that the instrument had a high degree of internal consistency. Factor analysis to the 40 items of the ATMI resulted in a four-factor solution, namely self-confidence (15 items), value (10 items), enjoyment (10 items) and motivation (5 items) which accounted for a total of 59.22% of variance [25], [31].

Although ATMI has a stable factor structure and strong psychometric properties, the use of this inventory to assess the mathematics attitude of school or university students is still rare compared to the famous Fennema-Sherman scale [22], [30]. Lim and Chapman [30] suggested to extend the use of ATMI to non-western samples with a shorter form to shorten the time for administration. The same thing was conveyed by Chamberlin and Powers who suggested that this inventory tested to the cross-cultural sample with different ages, levels of education and with a shorter version [29].

The main problem of this research is studies on the use of ATMI instruments in various Asian countries are still very rare, including in Indonesia. There is no information regarding the validation of the ATMI construct toward Indonesians sample. Therefore, the question is whether this short version of ATMI remains stable for non-western populations, especially Indonesian university students. The proposed solutions to examine the cross-cultural validity and internal consistency of the Indonesian version of the short ATMI by applying a set of statistical techniques, such as confirmatory factor analysis (CFA). Moreover, a validated instrument will be implemented to assess the mathematical attitudes of pre-service chemistry teacher across gender using latent mean analysis.

2. RESEARCH METHOD

2.1. Participants

The sample was 328 pre-service chemistry teachers, Faculty of Teacher Training and Education, University of Lampung, Indonesia consisting of 297 females and 31 males. With respect to the grade, 119 are first year students, 75 second year students, 76 third year students and 58 fourth year students. The number of samples used in this study match the recommended range of sample size ($200 \leq N \leq 400$) for a field test and usable surveys [23].

2.2. Research design and procedures

This survey research took approximately 4 months. At the initial stage, an assessment was carried out on students' prior knowledge about mathematical attitudes, attitude instruments, and the need for analysis of mathematical attitudes. Furthermore, a literature study was conducted regarding existing mathematical attitude instruments and their use in other countries. ATMI was first developed for western samples with native English language so that cross cultural adaptation and translation into Indonesian was carried out in collaboration with linguists. The ATMI adaptation is carried out by considering the suitability of the theoretical construct with the original ATMI and the concept relevance with Neale's definition of mathematics attitude. Because the research sample is a non-English spoken language, the ATMI back translation procedure was carried out with two active English translators and continued with verification of the suitability of items based on Neale's definition [21]. The items of adapted ATMI were written into a google form, codified into a five-point Likert scale, and distributed to samples through online meetings. the students were asked to join in the online meeting to be explained about the procedure for filling out the questionnaire and the students were asked to stay in the meeting until all students had finished filling out the questionnaire. This step is taken to ensure that students fill in correctly and avoid a functional filling out of the questionnaire.

2.3. Instrument

The instrument used in this study was a questionnaire on the attitude scale of pre-service chemistry teacher towards mathematics which was developed for the first time by Tapia [25]. The final version of the original ATMI consists of 40 statement items factored into 4 subscales, namely self-confidence (15 items), value (10 items), enjoyment (10 items), and motivation (5 items). Full item statements of original ATMI and the associated factors can be seen in supplementary information. The original ATMI has been tested to be constructively valid, meets the standard criteria of fit index and has a high level of internal consistency to be used in determining students' mathematical attitudes. The launching of ATMI was first tested on a sample of students with native spoken English and then some researchers used it to non-western sample [30], [32], [33]. Therefore, in the current study, the ATMI instrument was used to analyze mathematical attitudes for Indonesian college chemistry students.

2.4. Data analysis

The survey datasets were prepared for avoiding errors in data entry and multivariate outliers' detection using Mahalanobis distance. Moreover, the structural model of the original ATMI was drawn with the help of AMOS and the model was tested for validation of the construct against our clean data using CFA. During analysis, data reduction indicators are determined based on the smallest possible modification indices value to reach the minimum criteria of acceptable fit index. Recommended range of fit indices include $\chi 2/df<3$, TLI≥0.95, CFI≥0.95, NFI≥0.90, SRMR≤0.08, RMSEA≤0.06, RFI and GFI≥0.90, respectively [34]–[36]. Data regarding factor loading, variance, covariance, squared multiple correlations were extracted according to the proposed model. Furthermore, multigroup comparisons across gender, grade, and learning achievements were also carried out by first testing measurement invariance across groups including configurational invariance, metric invariance, scalar invariance, residual items (errors) variance–covariance invariance and factor variance–covariance invariance [37]. Chi-square, Gamma Hat, and McDonald noncentrality index (NCI) tests were used to identify the equivalence of the proposed model across groups. Latent mean difference and effect size analysis were also carried out to understand the gender effect on mathematics attitudes.

3. RESULTS AND DISCUSSION

Factor analysis is a powerful statistical technique widely used to determine psychometric properties of the scale. CFA techniques had been applied in this study to confirm the structure validity and the relationship between the structural factors of ATMI on cross-cultural sample i.e., Indonesian students. Prior to the structural factor analysis, the ATMI adaptation process was carried out by considering Neale's definition of attitude toward mathematics to ensure that cross-cultural adaptation and statistical justification of the inventory related to the theoretical framework. The use of Neale's definition is done by making a correspondence between the subscales and the definition as shown in Table 1. All item will be crosschecked for their suitability with Neale definition by approaching the keywords of the definition.

Table 1. Subscale of ATMI and the corresponding Neale's definition

Subscale of ATMI	Neale definition
Self confidence	A belief that one is good or bad at mathematics
Value	A belief that mathematics is useful or useless
Enjoyment	A liking or disliking of mathematics
Motivation	A tendency to engage in or avoid mathematical activity

3.1. Confirmatory factor analysis

The structural equation model is built by connecting endogenous and exogenous factors. Exogenous factors are questionnaire items while endogenous factors are latent factors that represent several questionnaire items. Each factor is connected by one-way arrows to describe the relationship between endogenous and exogenous factors, while each latent factor is then connected by two-way arrows that illustrate the relationship of covariances between latent factors. In the CFA analysis, the factors considered in the fit model have at least 3 items. This is because factors that only have less than 3 items are considered to be very weak or unstable; on the other hand, a factor consisting of 5 or more items with a loading value (0.50 or more) is preferred and indicates a solid factor.

The maximum likelihood estimation technique was applied in the CFA with retained items in the construct determined based on three indicators to prevent model misspecification described by Kamaruddin and Abeysekera [38]. Three main causes of model misspecification, namely errors in the analysis of standardized regression weights, squared multiple correlations, and modification indices [39]. Standardized regression weights play a role in determining the loading factor for each item, squared multiple correlations to determine the reliability of items, and modification indices to avoid items that might have the same meaning. Modification indices propose the possibility of adding or subtracting items to the model and predicting that the chi-square value of the model will decrease if the suggested parameters are added or decreased (a lower chi-square value indicates better model fit). In short, the modification indices can be used to better understand which items or relationships might lead to better or poorer fit of the model. Modification indices will lead researchers to choose which items should be deleted or retained in the model.

The results of the CFA support the four-factor model of the original ATMI, but with a much shorter version (19 items). Similar to the Tapia and Marsh structure of ATMI, the items statement in the short version is also accommodated in four subscales, namely self-confidence (6 items, α=0.90), value (5 items, =0.85), enjoyment (5 items, =0.89), and motivation (3 items, =0.82). All of the four dimensions exceeded the minimum reliability value for the acceptable range of internal consistency [40]. The full short form of inventory had a high internal consistency (α=0.92) although this value is slightly below the original ATMI (α=0.96). Moreover, the alpha value of this version was found to be similar to the short form of ATMI [30]. The difference between this short version and the original ATMI is found in the composition of the items statement for each subscale. The original ATMI includes positive and negative items for each subscale except the value subscale which only has positive items, while this short version only has negative statements on self-confidence (all items in this subscale are reversed items), the other subscales are positive statements. The proposed structural model of the short ATMI with factor loading, item intercepts and factor covariances is presented in Figure 1. The model is confirmed to have an acceptable fit to the data like $\chi 2/df=2.09$; TLI=0.94; CFI=0.95; NFI=0.91; SRMR=0.04; RMSEA=0.06; RFI=0.90, GFI=0.90.

Furthermore, verification of the short ATMI is continued by looking at the values of standardized regression weights and squared multiple correlations. The estimated value of standardized regression weights explains the relationship between the response variable (latent factor) and predictor (items). This value accounts the changed in standard deviations of variable and predictor. This means that the regression weights can be used to deduce regarding the cause-effect interactions between latent factor-items. The estimated values of standardized regression weights, or what is often referred to as factor loading, of this construct were more than 0.70 (ranging from 0.64 to 0.88) except three items which is slightly lower (~0.64). These scores showed a predictor variable have a quite strong impact on a dependent variable. This was also supported by squared multiple correlations with a value ranging from 0.41 to 0.78. The estimated values of standardized regression weights and squared multiple correlations were in the acceptable range suggested by Kamaruddin and Abeysekera [38], and reached the adequacy criteria of covariance structural model.

The construct model in Figure 1 also shows the relationship between factors described by factor covariance. Covariance value provides information that the factors are positively and significantly correlated with each other. In addition, CFA also generated subscale variance as: self-confidence (0.78), motivation (0.67), enjoyment (0.49), and value (0.22). Moreover, the full short version was accounted for 54% of variance which is slightly lower than original ATMI (59.22%). This indicates that self-confidence plays a key role in determining mathematical attitudes. Similar studies stated that self-confidence is a key affective variable in mathematics education research in the last 10 years. Furthermore, self-confidence has become one of the most important variables that determine students' mathematics achievement in recent years [41]–[43]. In the next discussion, we will discuss self-confidence in relation to the learning achievement of chemistry students.

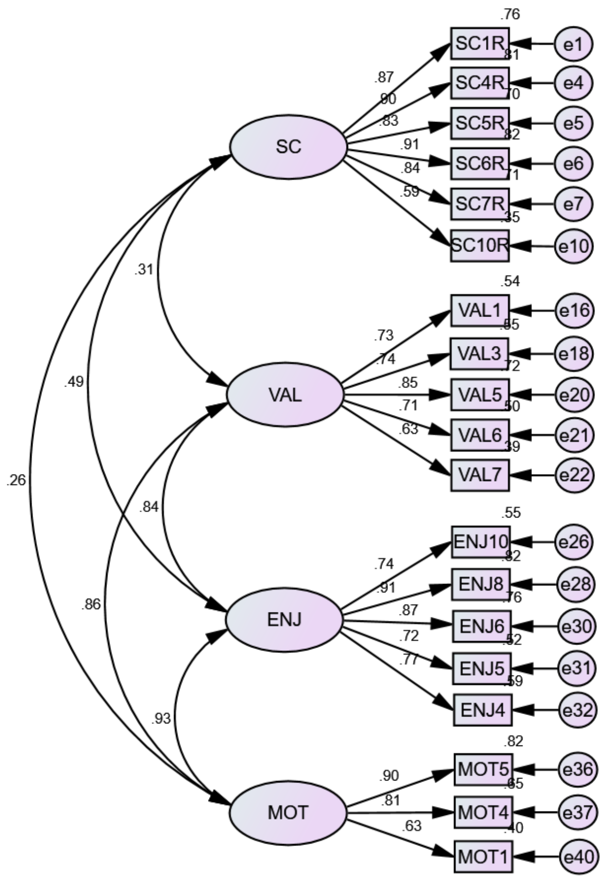

Figure 1. The structural model of the short ATMI

3.2. Descriptive analysis

From the descriptive analysis, it can be observed that generally participants tend to have relatively low levels of self-confidence in the context of interacting with mathematics (M=3.33-4.04, SE=0.054-0.068). All items of self-confidence subscale accommodated in the inventory were negative statements and most of students realized that they were not confident enough to face lectures that require mathematical reasoning.

Students feel that mathematics makes them uncomfortable and even most of them always feel quite depressed in mathematics-based lectures. Nevertheless, they realized that mathematics and learning mathematics is a valuable thing (M=3.82-4.49, SE=0.035-0.048) and one of the subjects that must be studied. Most of them agreed that mathematics is one of the most important subjects to learn because its usefulness in many ways to make life easy. Furthermore, they also felt quite enjoy (M=3.40-3.62, SE=0.048-0.060) in studying mathematics at university and showed a fairly good interest in mathematics although when compared to other courses/non-mathematics classes, they may be happier to be in it. Lastly, they had quite high motivation (M=2.98-3.48, SE=0.051-0.054) to learn mathematics because they believed that learning mathematics can help in their future work or professional life. Overall, participants have a fairly positive attitude towards mathematics and learning mathematics, although in this case their confidence is relatively low.

Learning chemistry concepts cannot be separated from mathematics. Numerous studies have reported that students' mathematical abilities have a strong correlation to the chemistry achievement [12], [44]–[46]. In general, the mathematical skills required for university chemistry can be categorized into basic mathematical skills such as the ability to use and manipulate fractions, decimals, exponents, percentages, one-variable equations, ratio and proportion required in the admission exams and introductory chemistry courses [47]–[49]. Meanwhile, more advance mathematics ability like understanding higher-order equations, trigonometry, and complex numbers are needed for the advanced level of chemistry course [12]. Good math skills and abilities will greatly support students' learning in chemistry and even, after graduate and entering the professional work, math skills also support their STEM career [50], [51].

However, one cannot rely solely on cognitive variables and ignore non-cognitive variables such as attitudes and beliefs. It has been proven that attitudes also play a vital role in determining students' success in chemistry [52]. In relation to non-cognitive variables, research conducted by Ma states that math ability and attitude toward mathematics strengthen each other reciprocally [53]. Many failures in mathematics and mathematics related subject are caused by students' belief that mathematics is an exceptionally difficult and tedious subject [54]. Additionally, unproductive belief of achieving in mathematics "becomes a self-fulfilling prophesy that results in high levels of failure and disinterest in mathematical related subjects" [55]. As a pre-service teacher, students build a positive attitude toward mathematics in order to teach the related field well, and that task must immediately begin at the university. Therefore, it is very important for all education stakeholders to focus on upgrading their self-confidence in learning mathematics, besides improving their ability and skills in mathematics [56].

3.3. Measurement invariance across gender

Before conducting multigroup comparisons analysis and its interpretations, it must be known in advance whether the data set is invariant or equivalent to be analyzed across two different groups. A set of measurement invariance i.e. configural invariance, metric invariance, scalar invariance, residual items (errors) variance–covariance invariance and factor variance–covariance invariance was conducted to the baseline model (Figure 1) as recommended by Cheung and Rensvold [37]. First of all, the configuration invariance test is applied to the baseline model across gender where none of the parameter is constrained. The results show that the model fit is acceptable across groups (χ^2/df=1.712; TLI=0.94; CFI=0.95; NFI=0.88; SRMR=0.096; RMSEA=0.047; RFI=0.86, GFI=0.88) by referring to the Hu and Bentler [35] combinational rules. Furthermore, the chi-square and degree of freedom values in the configurational invariance were extracted and used as the basic/reference values for the metric invariance. Other supporting data such as CFI, Gamma Hat, and McDonald's NCI values are also calculated to strengthen conclusions in measurement invariance [37]. The delta of these values is used as the basis for determining the equivalence/invariance of the model across groups [34], [37].

In the second stage, the model of metric invariance is constructed by constraining all factor loadings of the items. Evaluation of the invariance metric is carried out to ascertain whether the items were responded to in the same way by two groups. Furthermore, the delta of chi-square, degree of freedom, CFI, Gamma Hat, and McDonald NCI in the metric invariance model versus the configurational invariance model were calculated to determine whether there was a reduction in model fit as a result of adding loading constraints. The results show that the $\Delta\chi^2$=10.703 (with Δdf=15) indicates that there is no significant difference in model fit at $p<0.01$. This result is also supported by the values of ΔCFI=0.001, ΔGamma Hat=0.001, and ΔMcDonald's NCI=0.005 which indicated no substantial decrement of model fit due to the factor loadings constraint. The same treatment was also applied to scalar invariance, residual item (error) variance/covariance invariance, and factor variance/covariance invariance and value of the invariant indicators extracted after analysis. Measurement invariant and values regarding the invariant indicators were presented in supplementary information. All measurement invariance testing showed that there was no significant change in the fit of the baseline model at the 0.01 significance level and the values of CFI, Gamma Hat, and McDonald's NCI were less than or equal to 0.01, 0.001, and 0.02, respectively [34], [37].

Therefore, it can be confirmed that the proposed structural model of the short ATMI was invariant or equivalent across gender difference.

3.4. Attitude towards mathematics with gender perspectives

A cross-cultural validated of the short ATMI was applied to evaluate the mathematics attitudes of Indonesian pre-service chemistry teacher across gender. Latent mean difference was observed in the multiple group analysis by setting to zero for latent mean value of male and freely estimated for female group as deviations from male group. The negative latent mean value actually indicates that the mathematical attitude of women is slightly more negative than that of men, although gender did not show a significant effect except on motivational variable ($p<0.05$). Even so, gender effect was negligible based on effect size analysis. The detailed information regarding latent mean analysis was presented in Table 2. Although these findings are supported by some literature [57]–[61], further investigation of gender effects was discontinued because the relatively small number of males in the sample [62].

Table 2. Latent mean analysis for subscales

Variable	Male (n=32)		Female (n=297)		z score	d	p-value
	Latent mean	SD	Latent mean	SD			
Self confidence	0	1.029	0.08	0.872	-0.458	-0.08	NS
Value	0	0.412	-0.03	0.469	0.444	0.068	NS
Enjoyment	0	0.728	-0.17	0.693	1.390	0.24	NS
Motivation	0	0.812	-0.30	0.812	2.213	0.37	S

*NS=not significant, S=significant

4. CONCLUSION

This essay has discussed the structural validity and reliability of short ATMI on a sample of Indonesian students. Covariance structure analysis had proven the four-factor solution of mathematics attitude as the original ATMI. Selected items load significantly to the corresponding affective disposition of ATMI and meet the acceptable rank of structural fit index in CFA. This version has high internal consistency by accommodating approximately 54% of the variance as also showed by another short version of ATMI. A Structured mean analysis exhibited a better mathematics attitude of male than female. The findings from this study had a contribution for adding the literature on the short version of ATMI, especially for non-western countries. Therefore, the researcher suggests using the short ATMI as widely as possible in analyzing mathematical attitudes for non-western samples for future work. Further investigation is needed by comparing the socioeconomic characteristics of students and their school of origin. In the future, a study on how the impact of mathematical attitudes affects math anxiety and career in mathematics also needs to be implemented.

ACKNOWLEDGEMENTS

The authors would like to acknowledge to Universitas Lampung for funding this research with grant number 4941/UN26.13/PN/2023. Moreover, special thanks of gratitude to Salman Abdullah and Umar Ibadurrahman, for their support in completing this research.

REFERENCES

[1] J. F. Ogilvie and M. B. Monagan, "Teaching mathematics to chemistry students with symbolic computation," *Journal of Chemical Education*, vol. 84, no. 5, p. 889–896, May 2007, doi: 10.1021/ed084p889.
[2] R. G. Mortimer, *Mathematics for physical chemistry*. Elsevier, 2005.
[3] R. Neville, P. D. Shipman, N. E. Levinger, and A. T. Krummel, "ConfChem conference on mathematics in undergraduate chemistry instruction: Applied mathematics for chemistry majors," vol. 95, no. 8, pp. 1438–1439, Jul. 2018, doi: 10.1021/acs.jchemed.8b00107.
[4] L. A. Fox and G. H. Roehrig, "Nationwide survey of the undergraduate physical chemistry course," *Journal of Chemical Education*, vol. 92, no. 9, pp. 1456–1465, Jul. 2015, doi: 10.1021/acs.jchemed.5b00070.
[5] S. A. Angel and D. LaLonde, "Science success strategies: An interdisciplinary course for improving science and mathematics education," *Journal of Chemical Education*, vol. 75, no. 11, pp. 1437–1437, Nov. 1998, doi: 10.1021/ed075p1437.
[6] G. Nicoll and J. S. Francisco, "An investigation of the factors influencing student performance in physical chemistry," *Journal of Chemical Education*, vol. 78, no. 1, pp. 99–102, Jan. 2001, doi: 10.1021/ed078p99.
[7] M. E. Derrick and F. W. Derrick, "Predictors of success in physical chemistry," *Journal of Chemical Education*, vol. 79, no. 8, pp. 1013–1016, Aug. 2002, doi: 10.1021/ed079p1013.
[8] R. C. Turner and H. A. Lindsay, "Gender differences in cognitive and noncognitive factors related to achievement in organic chemistry," *Journal of Chemical Education*, vol. 80, no. 5, pp. 563–568, May 2003, doi: 10.1021/ed080p563.

[9] C. F. Bauer, "Beyond 'student attitudes': Chemistry self-concept inventory for assessment of the affective component of student learning," *Journal of Chemical Education*, vol. 82, no. 12, pp. 1864–1870, Dec. 2005, doi: 10.1021/ed082p1864.

[10] S. E. Lewis, J. L. Shaw, J. O. Heitz, and G. H. Webster, "Attitude counts: self-concept and success in general chemistry," *Journal of Chemical Education*, vol. 86, no. 6, pp. 744–749, Jun. 2009, doi: 10.1021/ed086p744.

[11] X. Xu and J. E. Lewis, "Refinement of a chemistry attitude measure for college students," *Journal of Chemical Education*, vol. 88, no. 5, pp. 561–568, May 2011, doi: 10.1021/ed900071q.

[12] P. Vincent-Ruz, K. Binning, C. D. Schunn, and J. Grabowski, "The effect of math sat on women's chemistry competency beliefs," *Chemistry Education Research and Practice*, vol. 19, no. 1, pp. 342–351, Nov. 2017, 10.1039/C7RP00137A.

[13] K. Singh, M. Granville, and S. Dika, "Mathematics and science achievement: Effects of motivation, interest, and academic engagement," *The Journal of Educational Research*, vol. 95, no. 6, pp. 323–332, Jul. 2002, doi: 10.1080/00220670209596607.

[14] G. Ramirez, S. T. Shaw, and E. A. Maloney, "Math anxiety: Past research, promising interventions, and a new interpretation framework," *Educational Psychologist*, vol. 53, no. 3, pp. 145–164, Apr. 2018, doi: 10.1080/00461520.2018.1447384.

[15] A. A. Lipnevich, F. Preckel, and S. Krumm, "Mathematics attitudes and their unique contribution to achievement: Going over and above cognitive ability and personality," *Learning and Individual Differences*, vol. 47, pp. 70–79, Apr. 2016, doi: 10.1016/j.lindif.2015.12.027.

[16] L. R. Aiken, "Attitudes toward mathematics," *Review of Educational Research*, vol. 40, no. 4, pp. 551–596, 1970, doi: 10.3102/00346543040004551.

[17] S. Gordon and J. Nicholas, "Students' conceptions of mathematics bridging courses," *Journal of Further and Higher Education*, vol. 37, no. 1, pp. 109–125, Jan. 2013, doi: 10.1080/0309877x.2011.644779.

[18] G. McPhan, W. Morony, J. Pegg, R. Cooksey, and T. Lynch, "Maths? Why not?" Canberra: Department of Education, Employment and Workplace Relations, 2008.

[19] I. Sarnoff, "Psychoanalytic theory and social attitudes," *Public Opinion Quarterly*, vol. 24, no. 2, pp. 251–279, Jan. 1960, doi: 10.1086/266948

[20] C. Primi, A. Bacherini, C. Beccari, and M. A. Donati, "Assessing math attitude through the attitude toward mathematics inventory – short form in introductory statistics course students," *Studies in Educational Evaluation*, vol. 64, p. 100838, Mar. 2020, doi: 10.1016/j.stueduc.2020.100838.

[21] D. C. Neale, "The role of attitudes in learning mathematics.," *The Arithmetic Teacher*, vol. 16, no. 8, pp. 631–641, Jan. 1969.

[22] M. Tapia and G. E. Marsh, "An instrument to measure mathematics attitudes," *Academic Exchange Quarterly*, vol. 8, no. 2, pp. 16–21, 2004.

[23] R. S. Asempapa and G. P. Brooks, "Factor analysis and psychometric evaluation of the mathematical modeling attitude scale for teachers of mathematics," *Journal of Mathematics Teacher Education*, vol. 25, no. 2, pp. 131–161, Nov. 2020, doi: 10.1007/s10857-020-09482-0.

[24] E. Fennema and J. A. Sherman, "Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males," *Journal for Research in Mathematics Education*, vol. 7, no. 5, pp. 324–326, Nov. 1976, doi: 10.2307/748467.

[25] M. Tapia, "The attitudes toward mathematics instrument," in *Annual Meeting of the Mid-South Educational Research Association*, 1996, pp. 1–21.

[26] A. L. White, J. Way, B. Perry, and B. Southwell, "Mathematical attitudes, beliefs and achievement in primary pre-service mathematics teacher education," *Mathematics Teacher Education and Development*, vol. 7, pp. 33–52, 2006.

[27] R. Pierce, K. Stacey, and A. Barkatsas, "A scale for monitoring students' attitudes to learning mathematics with technology," *Computers & Education*, vol. 48, no. 2, pp. 285–300, Feb. 2007, doi: 10.1016/j.compedu.2005.01.006.

[28] B. Pepin, "Pupils' attitudes towards mathematics: A comparative study of Norwegian and English secondary students," *ZDM*, vol. 43, no. 4, pp. 535–546, Feb. 2011, doi: 10.1007/s11858-011-0314-9.

[29] S. A. Chamberlin and R. A. Powers, "Assessing affect after mathematical problem solving tasks: Validating the Chamberlin affective instrument for mathematical problem solving," *Gifted Education International*, vol. 29, no. 1, pp. 69–85, Jan. 2013, doi: 10.1177/0261429412440652.

[30] S. Y. Lim and E. Chapman, "Development of a short form of the attitudes toward mathematics inventory," *Educational Studies in Mathematics*, vol. 82, no. 1, pp. 145–164, Jun. 2012, doi: 10.1007/s10649-012-9414-x.

[31] M. R. Mack, C. A. Stanich, and L. M. Goldman, "Math self-beliefs relate to achievement in introductory chemistry courses," in *It's just math: Research on students' understanding*, Washington, DC: ACS Symposium Series, 2019, pp. 81–104. doi: 10.1021/bk-2019-1316.ch006.

[32] A. Soni and S. Kumari, "The role of parental math anxiety and math attitude in their children's math achievement," *International Journal of Science and Mathematics Education*, vol. 15, no. 2, pp. 331–347, Oct. 2015, doi: 10.1007/s10763-015-9687-5.

[33] S. H. Lin and Y.-C. Huang, "Development and application of a Chinese version of the short attitudes toward mathematics inventory," *International Journal of Science and Mathematics Education*, vol. 14, no. 1, pp. 193–216, Jul. 2014, doi: 10.1007/s10763-014-9563-8.

[34] R. B. Kline, "Software review: Software programs for structural equation modeling: Amos, EQS, and LISREL," *Journal of Psychoeducational Assessment*, vol. 16, no. 4, pp. 343–364, Dec. 1998, doi: 10.1177/073428299801600407.

[35] L. Hu and P. M. Bentler, "Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives," *Structural Equation Modeling: A Multidisciplinary Journal*, vol. 6, no. 1, pp. 1–55, Jan. 1999, doi: 10.1080/10705519909540118.

[36] J. F. Hair, W. C. Black, B. J. Babin, and R. E. Anderson, *Multivariate data analysis*, 7th ed. Upper Saddle River, NJ: Prentice-Hall, 2010.

[37] G. W. Cheung and R. B. Rensvold, "Evaluating goodness-of-fit indexes for testing measurement invariance," *Structural Equation Modeling: A Multidisciplinary Journal*, vol. 9, no. 2, pp. 233–255, Apr. 2002, doi: 10.1207/s15328007sem0902_5.

[38] K. Kamaruddin and I. Abeysekera, *Intellectual capital and public sector performance*. Bingley, UK: Emerald Group Publishing, 2013.

[39] B. M. Byrne, "Structural equation modeling with AMOS, EQS, and LISREL: Comparative approaches to testing for the factorial validity of a measuring instrument," *International Journal of Testing*, vol. 1, no. 1, p. 55, 2001, doi: 10.1207/s15327574ijt0101_4.

[40] J. Nunnally and I. H. Bernstein, *Psychometric theory*. McGraw-Hill Humanities/Social Sciences/Languages, 1994.

[41] P. Kloosterman, "Self-confidence and motivation in mathematics," *Journal of Educational Psychology*, vol. 80, no. 3, pp. 345–351, 1988.

[42] M. R. Meyer and E. Fennema, "Gender differences in the relationships between affective variables and mathematical achievement," in *Annual Meeting of the American Educational Research Association*, San Francisco, CA, 1986.

[43] L. H. Reyes, "Affective variables and mathematics education," *The Elementary School Journal*, vol. 84, no. 5, pp. 558–581, May 1984, doi: 10.1086/461384.

[44] C. I. Cooper and P. T. Pearson, "A genetically optimized predictive system for success in general chemistry using a diagnostic algebra test," *Journal of Science Education and Technology*, vol. 21, no. 1, pp. 197–205, Feb. 2012, doi: 10.1007/s10956-011-9318-z.
[45] S. E. Lewis and J. E. Lewis, "Predicting at-risk students in general chemistry: Comparing formal thought to a general achievement measure," *Chemistry Education Research & Practice*, vol. 8, no. 1, pp. 32–51, 2007, doi: 10.1039/b6rp90018f.
[46] H. E. Spencer, "Mathematical SAT test scores and college chemistry grades," *Journal of Chemical Education*, vol. 73, no. 12, pp. 1150–1153, Dec. 1996, doi: 10.1021/ed073p1150.
[47] R. T. Denny, "The mathematics skill test (MAST) for chemistry," *Journal of Chemical Education*, vol. 48, no. 12, pp. 845–846, Dec. 1971, doi: 10.1021/ed048p845.
[48] R. L. Weisman, "A mathematics readiness test for prospective chemistry students," *Journal of Chemical Education*, vol. 58, no. 7, p. 564, Jul. 1981, doi: 10.1021/ed058p564.
[49] D. Gabel and R. D. Sherwood, "Analyzing difficulties with mole-concept tasks by using familiar analog tasks," *Journal of Research in Science Teaching*, vol. 21, no. 8, pp. 843–851, Nov. 1984, doi: 10.1002/tea.3660210808.
[50] N. E. Betz and G. Hackett, "The relationship of mathematics self-efficacy expectations to the selection of science-based college majors," *Journal of Vocational Behavior*, vol. 23, no. 3, pp. 329–345, Dec. 1983, doi: 10.1016/0001-8791(83)90046-5.
[51] R. T. Warne, G. Sonnert, and P. M. Sadler, "The relationship between advanced placement mathematics courses and students' STEM career interest," *Educational Researcher*, vol. 48, no. 2, pp. 101–111, Mar. 2019, doi: 10.3102/0013189x19825811.
[52] B. Ferrell, M. M. Phillips, and J. Barbera, "Connecting achievement motivation to performance in general chemistry," *Chemistry Education Research and Practice*, vol. 17, no. 4, pp. 1054–1066, 2016, doi: 10.1039/c6rp00148c.
[53] X. Ma, "Reciprocal relationships between attitude toward mathematics and achievement in mathematics," *The Journal of Educational Research*, vol. 90, no. 4, pp. 221–229, Mar. 1997, doi: 10.1080/00220671.1997.10544576.
[54] M. Brown, P. Brown, and T. Bibby, "'I would rather die': Reasons given by 16-year-olds for not continuing their study of mathematics," *Research in Mathematics Education*, vol. 10, no. 1, pp. 3–18, Mar. 2008, doi: 10.1080/14794800801915814.
[55] J. Gutbezahl, *How negative expectancies and attitudes undermine females' Math confidence and performance: A review of the literature*. University of Massachusetts at Amherst. Department of Psychology, Jan. 1995.
[56] Y. L. Tsao, "Attitudes and beliefs toward mathematics for elementary preservice teachers," *US-China Education Review*, vol. 4, no. 9, pp. 616-626, 2014.
[57] X. Ma and N. Kishor, "Assessing the relationship between attitude toward mathematics and achievement in mathematics: A meta-analysis," *Journal for Research in Mathematics Education*, vol. 28, no. 1, p. 26, Jan. 1997, doi: 10.2307/749662.
[58] F. Pajares and L. Graham, "Self-efficacy, motivation constructs, and mathematics performance of entering middle school students," *Contemporary Educational Psychology*, vol. 24, no. 2, pp. 124–139, Apr. 1999, doi: 10.1006/ceps.1998.0991.
[59] M. Nicolaidou, and G. Philippou, "Attitudes towards mathematics, self-efficacy and achievement in problem solving," *European Research in Mathematics Education III. Pisa: University of Pisa*, pp. 1–11, 2003.
[60] C. M. Vale and G. C. Leder, "Student Views of computer-based mathematics in the middle years: does gender make a difference?" *Educational Studies in Mathematics*, vol. 56, no. 3, pp. 287–312, 2004, doi: 10.1023/b:educ.0000040411.94890.56.
[61] L. Mohamed and H. Waheed, "Secondary students' attitude towards mathematics in a selected school of Maldives," *International Journal of humanities and social science*. vol. 1, no. 15, pp. 277–281, 2011.
[62] M. Townsend and K. Wilton, "Evaluating change in attitude towards mathematics using the 'then-now' procedure in a cooperative learning programme," *British Journal of Educational Psychology*, vol. 73, no. 4, pp. 473–487, Dec. 2003, doi: 10.1348/000709903322591190.

BIOGRAPHIES OF AUTHOR

Andrian Saputra is an Assistant Professor of Chemistry Education at the Faculty of Teacher Training and Education, Universitas Lampung. He was joint in the university in 2016 after completed his master degree at the Department of Chemical Science, Universitas Gadjah Mada, Indonesia. His research interest are computer-based learning, visualization and simulation in chemical education, psychometric analysis in educational context, chemistry teaching and learning. He can be contacted at email: andriansaputra@fkip.unila.ac.id.

Lisa Tania is Head of Chemistry Education Department at the Faculty of Teacher Training and Education, Universitas Lampung. She was appointed as a physical chemistry lecturer in the department in 2008. Her research interest are chemistry teaching and learning, computer-based learning, structural equation modelling. She can be contacted at email: lisa.tania@fkip.unila.ac.id.