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Implementation of Maximum Likelihood Estimation (MLE) in the Assessment of Pro-Environmental Tools Measurement Models for Engineering Students

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***Abstract*—The criterion validity test is used to compare the research construct with other tools that have been declared valid and reliable by correlating. In this study, data was obtained by distributing questionnaires and drawing conclusions by concluding the answers from the research subjects. The samples in this study were students of the Faculty of Engineering, Universitas Negeri Makassar, amounting to 200 research subjects. The researcher will collect the data by distributing questionnaires directly to respondents and through a google form with three research constructs. This is done to meet the requirements of the number of respondents who recommend conducting research whose data analysis uses the Maximum Likelihood Estimation (MLE). The IBM AMOS program was used to analyze Confirmatory Factor Analysis (CFA). The Goodness of Fit test (CMIN/DF, GFI, RMSEA, CFI, PNFI) shows that the proposed model is fit and can be continued for further analysis. Convergent validity (loading factor) constructs on the get a value of > 0.7 with a probability value of (p < 0.05), which means that the validity of the indicator has good reliability. Convergent validity gets a value > 0.7 with a probability value (p < 0.05) which means the indicator validity has good reliability. The average variance extract (AVE) value obtained is > 0.5, which means that the indicators in the developed model are proven to measure variable constructs. From the results of the research conducted, the reliability and validation values of the tools are consistent and reliable; from these results, the tools can be used repeatedly in research. A test is said to have high reliability if it provides data with consistent (fixed) results even though it is given at different times to the same subjects.**

***Keywords*— Confirmatory factor analysis (CFA); environmental education; reliability and validity; sustainable environment.**

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I. INTRODUCTION

In dealing with the challenges for environmental sustainability today, education and information are needed regarding various ecological problems and how to prevent and overcome them [1]. Implementing environmental education is one of the keys that the government hopes to prepare the community with knowledge, behavior, values, and attitudes that always care about the environment so that various environmental problems around us can be resolved. Therefore, the implementation of environmental education learning begins to be given in school, especially in education in schools, as a provision in the community [2].

Environmental factors strongly influence human life. Vice versa, the environment can be affected by human activities and behavior. The interdependence of life between humans and their environment places humans as the main subjects who take advantage of natural resources to support their survival [3]. Human position as subjects in using natural resources sometimes makes them forget themselves because they are driven by a desire to fulfill their needs. The development process is often carried out only to pursue economic growth without considering environmental sustainability, causing environmental damage. Humans must have high environmental care behavior because humans have a direct sociological and biological relationship with the environment in which they are located, from humans born until they die [4], [5]. However, viewed from the human side, the environment is passive, while the active is humans. So that the quality of the environment is very dependent on the

quality of humans; unfortunately, humans often forget that a poor-quality climate will affect the quality of their lives [6].

Experts have concluded that technical and environmental aspects do not cause various environmental problems but more than that, namely by social factors (human behavior) [7], [8]. Many foreign researchers who come to Indonesia to implement a waste management system that has been successfully applied in their country to be also implemented in Indonesia, but it does not work. The researchers duplicated the waste management methods of developed countries for Indonesia without paying attention to social aspects, including workers' skill level and community environmental education, thus causing the unsuccessful implementation of the system to repeat itself as in previous cases [9]. Therefore, evaluating social aspects, "environmental education" is essential in designing an excellent environmental management system.

The United Nations (UN) declared the importance of environmental education at the Human Environment (UNCHE) conference in Stockholm in 1972. In developed countries such as Japan, formal environmental education has been introduced in all schools throughout Japan. By the Ministry of Education, Science, Sports, and Culture since 1991 to increase public environmental awareness. Even in 2006, the fundamental law of education (from the United Nations) updated the definition of "aims of education" in law number 2, namely "To build a corporative attitude to esteem life and nature, and to preserve the environment." However, experts reveal that environmental education is not the only determining factor in people's environmental behavior, which is stated in several studies that people are more likely to recycle if they are concerned for the environment [10]–[12]. Individuals will be consistent if he has a positive attitude towards environmental problems where family, friends, neighbors, or colleagues can influence positive environmental behavior [13], [14]. The ecological concern is defeated by laziness or lack of interest in protecting the environment [15]. Neighbors' actions can strongly influence recycling behavior among household members [16], [17]. Actions, attitudes, and motivations for recycling are more biased towards individuals than communities [18]. Social, cultural, and structural influence on the behavior of household waste recycling [19]. A study conducted by Kuhlemeier et al. [20] stated that among junior high school students, it was found that the relationship between environmental education and environmental behavior was weak but had a strong relationship with attitude. Like the results of this study, Bradley et al. also found a significant relationship between environmental education and attitudes in junior high school students [21].

A person's level of knowledge is needed as a basis for behavior, both in the household environment, living environment, and workplace. Likewise, knowledge of behavior related to the environment is required in behavior related to the environment. The level of knowledge that a person has regarding friendly behavior or care for the environment does not necessarily encourage the person to behave in an environmentally friendly manner. However, the knowledge factor regarding environmental care behavior must be pursued by everyone. Correct knowledge about environmentally friendly behavior is the main component of internal factors that can encourage changes in a person's attitude to be closer to the environment [11], [12]. The minimal level of understanding about the atmosphere causes a lack of awareness of the domain.

In the environmental context, the cohesion of space with all objects, forces, and circumstances, including humans with all behavior, where humans are located, affects their welfare, safety, and other living bodies. Knowledge of one's environment is vital for household, neighborhood, and workplace conduct. Likewise, knowledge of behavior related to the environment is required in behavior related to the environment. Environmental knowledge that a person has regarding friendly behavior or care for the environment does not necessarily encourage that person to behave in an environmentally friendly manner. However, the knowledge factor regarding environmental care behavior must be pursued by everyone. Correct knowledge about environmentally friendly behavior is the main component of internal factors that can encourage changes in a person's attitude to be closer to the environment. Knowledge becomes the basis for forming beliefs and becomes a material consideration for determining attitudes, while knowledge is a collection of information recorded in a person.

The attitude of caring for the environment is not only determined by the knowledge possessed [22]. Not a few people know, but they are still not environmentally friendly. Environmental issues are now increasingly being discussed. Development that aims to develop Indonesian people cannot be separated from the goal so that life between fellow humans and the natural environment can balance. This is not easy to realize, considering that people are not fully aware of the importance of caring for the environment. The sources that cause environmental problems are human activities that, in their actions, do not care about the balance and harmony of the atmosphere. Humans always try to fulfill their needs and desires beyond the environment's ability to support life. Activities in the form of overexploitation disrupt the balance and harmony of the atmosphere. In addition to the development process that often results in environmental degradation, consumptive behavior and human lifestyles also cause ecological problems. Damage to natural resources is mainly caused by human activities, such as air pollution, water pollution, soil pollution, and forest damage [23], [24].

Based on the results of a study by the Intergovernmental Panel on Climate Change (IPCC) in 2007, in addition to natural factors, human activities are also the leading cause of increasing concentrations of greenhouse gases in the earth's atmosphere, which in turn contributes to global warming and climate change [25]. Human activities include transportation, energy use, forest burning, and animal husbandry. Human behavior is intended to meet the needs of life. The link between human activities and environmental problems is not as simple as whether an activity can be carried out. However, it is hoped that everyone can be held responsible for the ecological damage it causes. The interaction between humans and their territory is not simple but complex because many influencing elements are in the background. The influence of one component will propagate to other factors so that its impact on humans often cannot be immediately seen and felt. The behavior of people who care about the environment is inseparable from environmental knowledge and attitudes about various things related to the environment. A person's

understanding of something will indirectly affect his attitudes and behavior towards the environment [26].

Based on a study conducted in Makassar, the community still surrenders its full responsibility to the government regarding waste management/household [27]. In addition, in terms of saving energy and water, people tend to waste and leave the lights on during the day and let the water flow and be wasted without being used. People ignore the relationship between waste management behavior, water use behavior, energy-saving behavior contributing to carbon emissions, healthy living behavior, and fuel use behavior towards their environment. This study aims to examine the validity and reliability of the measurement model on each exogenous and endogenous construct to ensure that the instrument (questionnaire) we developed was effective at measuring symptoms and producing valid data.

II. Materials and Method

A. Materials

The materials in this research are in the form of research instruments used to obtain data from the field or research sources. The scale often used in preparing the questionnaire is the ordinal scale or the Likert scale. Quantitative data processing and analysis were used in this study. The data were collected through the distribution of questionnaires, and conclusions were drawn from the responses of the respondents. This instrument was designed to transform quantitative data to analyze it using statistical methods. The details of the items can be seen in Table 1.

TABLE I
Research Instrument

Variables	Indicators
Pro-Environmental Behavior	I believe I can do garbage sorting (B1)
	I believe I can comply with the rules (B2)
	I believe I can reduce waste production (B3)
	I believe I can reuse consumables (B4)
	I believe I can care more about environmental issues (B5)
Environmental Knowledge	Waste production increases due to increasing population (K1)
	If people do not care about the environment, there will be a danger to living things (K2)
	Waste segregation will help protect the environment (K3)
	The quality of the environment will increase if the community does waste sorting (K4)
	Waste segregation can help reduce environmental pollution (K5)
	Waste management is carried out entirely by the local government (K6)
Habits	I throw garbage everywhere (H1)
	I throw garbage into rivers and seas (H2)
	Littering litter is normal because everyone does it (H3)
	In the neighborhood where I live, garbage piles up everywhere (H4)
	Scattered garbage has become a common thing (H5)

In making the questionnaire, the researchers used a Likert scale, and the scoring was odd between 1 to 5 categories. The pro-environmental behavior scale has five items on a categorical scale (1 "disagree" to 5 "strongly agree"). The environmental knowledge scale has six items on a categorical scale (1 "disagree" to 5 "strongly agree"). The community habit scale has five items on a categorical scale (1 "disagree" to 5 "strongly agree").

B. Method

1) Research approach: In this investigation, a quantitative methodology was employed. As a foundation for analysis, this method depends more on numerical values in the form of scores. The rating was derived from a survey. This technique is utilized in big and small populations; however, the data analyzed are gathered from population samples to determine relative events, distributions, and correlations between variables [28]. In this instance, the objective of the survey is to collect the behavior, beliefs, values, demographics, attitudes, views, habits, wants, and other data required for research [29]. Using the survey's data, facts, or information, the condition of each variable under study can be characterized such that the influence of one variable on another can be determined.

2) Population and Sample: The population taken in the study were all students of the Faculty of Engineering, Universitas Negeri Makassar, South Sulawesi, which amounted to about 3889 students. Regarding the minimal sample size within SEM analysis, Hair et al. state that if in the model analyzed there are 5 (five) constructs or less where each construct is measured at least by 3 (three) indicators, a minimum sample size of between 100 – 300 observations is required [30]. This is done to achieve the requirements for the number of respondents who recommend conducting research whose data analysis uses the Structural Equation Modeling (SEM) model with Maximum Likelihood Estimation (MLE). The number of samples that the authors took was 200 samples with the purposive sampling technique in the study. This number of pieces is generally accepted as a representative sample in SEM analysis.

3) Procedures: The data collection method that the researcher will do is by distributing questionnaires directly to respondents. The sampling technique using purposive sampling is to take samples from students who are respondents in this study. In this study, the questionnaire was made after obtaining the appropriate indicators based on previous research. After receiving the proper hands, the questionnaire was selected and adapted to this research. The researchers' initial questionnaire results were then made into

a pilot study to obtain a final questionnaire that the respondents could understand.

The pilot study aims to determine the accuracy of the research instruments previously used by previous researchers from the related literature [31]. This pilot study was conducted to determine whether the respondents understood the questions to enable the respondent can answer the question correctly. After carrying out the pilot study, the questionnaire that was not understood was corrected based on the suggestions from the respondents. The revision results were re-tested to not give rise to the impression of ambiguity among the respondents. The questionnaire results from the last improvement will then be distributed again to all data collection samples. The questionnaires in the study were distributed to respondents via Google Form.

4) Data Analysis: This research scale is an interval scale based on the measurement scale. The interval scale is a scale that results from measurements in which it is assumed that there are the same units of measurement. The measurement scale is an agreement used to determine the short interval length in the research measuring instrument. With a measurement scale, the value of the variables measured by specific tools can be expressed in numbers so that the results obtained will be more accurate, efficient, and communicative [32].

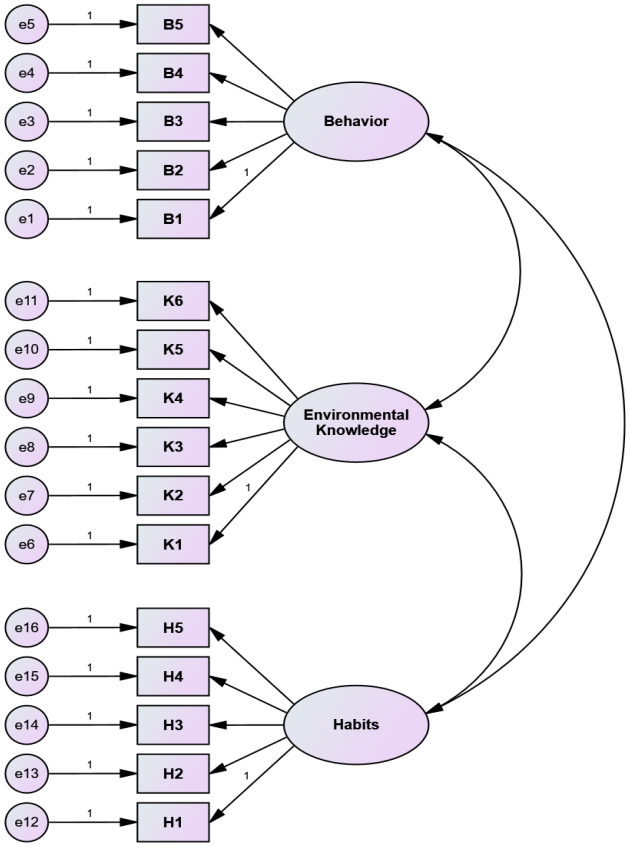

Fig. 2 Confirmatory Factor Analysis Research Design

The data analysis technique used in this research is confirmatory factor analysis (CFA). Confirmatory factor analysis is an analysis that aims to find several indicator variables that are not directly measured based on the theoretical basis [33]–[35]. The CFA analysis will be processed using the IBM AMOS 23 Program.

III. Result and Discussion

A. Respondents' Characteristics

From the type and research method used, the categories of respondent characteristics in the study are gender, respondent's age, and length of analysis of respondent analysis. In this case, the sample (respondent) is a student of the Faculty of Engineering at Universitas Negeri Makassar. The details of the characteristics of the respondents are presented in Table 1.

TABLE II
Demographic Characteristics of Respondents (N=200)

Category	Freq.	Percent
Gender		
Man	135	67.50%
Woman	65	32.50%
Age		
< 20 years	22	11.00%
21 years	53	26.50%
22 years	68	34.00%
23 years	25	12.50%
> 24 years	32	16.00%
Length of study (semesters)		
One year (1-2 semesters)	25	12.50%
Two years (3-4 semesters)	49	24.50%
Three years (5-6 semesters)	59	29.50%
Four years (7-8 semesters)	31	15.50%
> 5 years (>8 semesters)	36	18.00%
Department		
Family welfare education	22	11.00%
Electrical engineering education	28	14.00%
Electronic engineering education	29	14.50%
Mechanical engineering education	26	13.00%
Automotive engineering education	27	13.50%
Civil engineering and planning education	26	13.00%
Informatics and computer engineering	42	21.00%

In the study, respondents were dominated by male (67.50%) and female (32.50%) genders. The gender imbalance of the respondents was because, generally, students studying at the Faculty of Engineering were dominated by the male gender. The age of the respondents at the time of sampling was the majority was 22 years old (34.00%), and the lowest was under 20 years (11.00%). Generally, the age for entering college is between 17 – 18 years, but some respondents have just entered college at the age of 20 in the undergraduate program. Most respondents' study length is in the third year or 5 – 6 (29.50%). From the length of time, a person is in college, it is expected that more knowledge and information can be obtained from studying at the university. Most respondents in the study are Informatics and Computer Engineering (21.00%). This department is one of the favorite majors in the engineering faculty. The number of students accepted is almost two times that of students from other majors.

B. The Goodness of Fit (GOF)

The goodness of fit of a statistical model denotes how well the model corresponds to a set of observations. The goodness of fit measure summarizes the difference between observed and expected model values. The goodness of fit (GOF) criteria that are often presented in publications are Chi-Square (CMIN/DF), Root Mean Square Error of Approximation (RMSEA), Parsimony Normed Fit Indices (PNFI), and Comparative Fit Index (CFI) [36]–[38]. The results of the model fit size follow (Table 3).

TABLE III
ESTIMATE GOODNESS OF FIT (GOF)

Criteria	Threshold	Value	Sources
CMIN/DF	≤ 5.000	0.784	[30], [34], [39]
GFI	≥ 0.900	0.956	[30], [40]
RMSEA	≤ 0.080	0.011	[30]
CFI	≥ 0.900	0.978	[41]
PNFI	≥ 0.500	0.532	[42]

Table 2 shows the Goodness of Fit analysis which shows all the criteria for obtaining good results (fit). The proposed model can be analyzed at the next stage with these results.

C. Convergent Validity (Loading Factor)

Measurement of the indicator validity as a measure of the variable can be seen from the outer loading of each indicator. An indicator is said to have good reliability if the outer loading value for each indicator is > 0.70 (in research in undeveloped fields, it can use 0.5 - 0.6). If using the standard value of Convergent Validity > 0.70, then the loading value below 0.70 is removed from the model [30], [43].

TABLE IV
ESTIMATE LOADING FACTOR

			Prob. (p)	Loading Factor
Knowledge	→	K1	0.018	0.717
Knowledge	→	K2	0.002	0.752
Knowledge	→	K3	0.004	0.764
Knowledge	→	K4	0.011	0.758
Knowledge	→	K5	0.000	0.763
Knowledge	→	K6	0.005	0.785
Habits	→	H1	0.001	0.725
Habits	→	H2	0.016	0.805
Habits	→	H3	0.005	0.828
Habits	→	H4	0.001	0.753
Habits	→	H5	0.013	0.766
Behavior	→	B1	0.006	0.757
Behavior	→	B2	0.000	0.734
Behavior	→	B3	0.007	0.784
Behavior	→	B4	0.005	0.755
Behavior	→	B5	0.012	0.767

From the results of the measurement of the validity of the indicator (loading factor) in Table 4, it shows that the indicators on the knowledge, habits, and behavior variables get a value of > 0.7 with a probability value of ($p < 0.05$), which means that the validity of the indicator has good reliability.

D. Composite Reliability (CR)

Two methods, namely Cronbach's alpha and composite reliability, can be used for the SEM reliability test: Cronbach's alpha and composite reliability. Cronbach's alpha measures the lower limit of a construct's reliability value, whereas composite reliability measures the construct's actual reliability value. When estimating the internal consistency of a construct, composite reliability is deemed superior. The formula for calculating the value of composite reliability is as follows:

$$CR = \frac{(\Sigma\ Loading\ Factor)}{(\Sigma\ Loading\ Factor)\ +\ \Sigma\ Ej} \quad (1)$$

$$\Sigma\ Ej = 1 - (Loading\ Factor) \quad (2)$$

The value on composite reliability can be used to test the reliability value of each indicator on a variable. Hair et al. [44] stated that the composite reliability value should be > 0.70 even though the value of 0.60 is still acceptable. A construct can have a high-reliability value if the composite reliability value is > 0.70. Reliability relates to the accuracy and precision of the measurement. Reliability testing was conducted to test whether the data obtained from the research instrument showed adequate internal consistency.

TABLE V
ESTIMATE COMPOSITE RELIABILITY (CR)

Variables	Composite Reliability (CR)
Pro-Environmental Behavior	0.863
Environmental Knowledge	0.838
Habits	0.797

By looking at the composite reliability value of the indicators that measure the constructs, it can be concluded that all constructs have good reliability (CR > 0.7), which means the instrument is proven to have accuracy, consistency, and accuracy.

E. Average Variance Extracted (AVE)

Average Variance Extract (AVE) explains the average variance or discriminant extracted from each indicator to determine each item's potential to exchange measurements with others. The stipulation that a more significant value shows that the generated indicators have accurately represented the underlying construct [45]. The equation to get the Average Variance Extract value is:

$$AVE = \frac{(\Sigma\ SLoading\ Factor)^2}{(\Sigma\ Loading\ Factor)^2\ +\ \Sigma\ Ej} \quad (3)$$

Fornell and Larker [46] explain that a latent construct has satisfactory discriminant validity if it has an AVE value more significant than the quadratic correlation of the latent construct with other latent constructs. The recommended minimum AVE value is 0.5. The AVE results can be seen in the following Table 6.

The AVE value obtained is > 0.5. Thus, it can be said that the indicators in the developed model are proven to measure the targeted latent construct and do not measure the other latent constructs. Various factors cause environmental

degradation, including the low level of knowledge about the environment and the low level of education. Therefore, they are slow to receive information that is useful for themselves. In addition, people's habits of arbitrarily throwing garbage anywhere are challenging to change, and they do not care about the polluted and dirty environment.

TABLE VI
ESTIMATE AVERAGE VARIANCE EXTRACT (AVE)

Variables	Average Variance Extract
Pro-Environmental Behavior	0.841
Environmental Knowledge	0.822
Habits	0.771

Education is one of the factors so that people understand the impact of significant damage caused by their indifference and indifference to the environment. Environmental education is essential in improving and preserving the environment in realizing a sustainable healthy life [47]. Environmental education aims to make individuals and communities understand nature's complex nature, and the environment is built from various interactions, including physical, biological, economic, and cultural aspects [47]–[49]. Environmental education is the first step to changing attitudes and behavior carried out by all parties and all elements of society to increase knowledge, skills, and awareness of environmental values, which will later be able to move the community to play a role in environmental conservation and safety efforts to protect the environment—interests of current and future generations. Environmental education is essential for sustainable living, so it must be applied in the community. Because education will certainly affect people's mindset about their environment, it is unfortunate that most people have low education. Thus, due to ignorance about the effects of environmental pollution, people are not concerned with their environment.

Low awareness will undoubtedly have a significant effect on health. Diseases such as Acute Respiratory Infections, diarrhea, and dengue fever are the primary diseases that occur due to an environment that is not well maintained, one of which is a dirty environment and the accumulation of garbage in river flows. The accumulation of existing waste will cause environmental pollution. Especially watersheds piled up with trash will harm organisms, populations, and ecosystems. Such as aesthetic disturbances (smell, taste, sight), disturbance to animal and plant life, and human health itself. Irregular or inappropriate waste disposal has become a habit in our society, which ultimately causes discomfort for them and damages the existing environmental ecosystem.

To increase cleanliness awareness, it is necessary to pay attention to factors that affect community hygiene. The first factor is the habits and behavior of the community itself regarding cleanliness. It can be simple habits, such as not throwing trash anywhere and constantly washing hands in various activities. Good behavior and traditions must be instilled early, especially in the family and school environments. Therefore, parents and schools need to instill positive habits in their children. The next factor is the culture in the surrounding community. The culture in a society in a specific area will affect the behavior and habits taught to everyone. Therefore, to increase awareness about hygiene and health, it is necessary to have good cooperation from the government, academics, implementers, and the community itself.

IV. CONCLUSION

The researchers recommend using modeling-based reliability coefficients as an alternative technique for identifying psychometric properties of measurements other than the alpha coefficient, which has been widely used. One of the factors contributing to the high suitability of the model and the data is the reliability of the measurement. Therefore, using reliability coefficients following the developed model is highly recommended. A reliability coefficient is more appropriate than other reliability coefficients if the coefficient can represent a model that fits the data. The use of reliability in the measurement model shows that the instrument used as a measuring tool in collecting primary research data is obtained with reliable results and can be used repeatedly. In future research, measurement models that have been measured through CFA can then be submitted for theory testing through SEM measurements. In the Structural Equation Model (SEM), the researcher aims to develop a model that fits the data obtained.

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