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among secondary school students: Confirmatory factor
analysis (CFA)**

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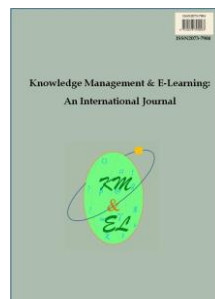
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Instrument validation of e-waste management awareness among secondary school students: Confirmatory factor analysis (CFA)

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Abstract: This study was conducted to validate the measurement model of the awareness of e-waste management among secondary school students. The

study's respondents consisted of 1,000 students from Malaysian secondary schools, who were selected using a simple random sampling technique based on their school level. The constructs studied were knowledge, attitude, and the practice of e-waste management. The data were analysed descriptively to determine the reliability value of Cronbach's alpha, whilst confirmatory factor analysis (CFA) was used to obtain a three-factor solution using SPSS 22 and AMOS 20. The analysis revealed that the Cronbach's alpha value was above 0.70, indicating a high classification level. The CFA analysis of the measurement model showed that the three-factor solution was compatible and acceptable based on the recommended indicators. Thus, the 29-item measurement model developed was appropriate to measure the awareness of e-waste management among secondary school students.

Keywords: Awareness; Knowledge; Attitude; Practice; Management; E-waste; Secondary school

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1. Introduction

E-waste, or electronic waste, refers to discarded electrical and electronic equipment, such as computers, mobile phones, household appliances, and printers, that are no longer in use or have been damaged. The rapid advancement of technology and increasing reliance on electronic devices have led to a global surge in e-waste production, estimated at 50 million tonnes annually, as reported by the Department of Environment (2020). Alarming, hazardous metals in e-waste account for 70% of the toxic substances found in landfill sites, posing significant threats to both the environment and human health. Among these electronic devices, smartphones contain numerous valuable materials, including precious metals such as gold, silver, and copper, yet improper disposal practices continue to exacerbate environmental concerns.

Efforts to manage e-waste are multifaceted, encompassing efficient collection systems, stringent regulations, and public awareness initiatives. In Malaysia, e-waste is regulated under the Environmental Quality (Scheduled Waste) Regulations 2005 and the Environmental Quality Act 1974, which classify e-waste as scheduled waste due to its toxic components, such as mercury, lead, cadmium, and bromine. Improper disposal of these hazardous substances can contaminate soil and water sources, threatening ecosystems and public health (Farghali et al., 2021). The government has emphasized the importance of recovery and recycling programs to extract valuable materials and mitigate the environmental impacts of e-waste. Despite these efforts, the rising e-waste volume underscores the urgent need for more innovative, collaborative, and efficient management strategies.

Numerous studies have examined the significance of e-waste management, focusing on awareness initiatives, recycling technologies, and legislative frameworks. Zameran et al. (2022) highlighted the increasing prevalence of electronic devices, particularly among teenagers, driven by rapid technological advancements. Meanwhile, Mihaela et al. (2020) emphasized the role of platforms like social media in disseminating information on e-waste awareness. However, existing literature often centres on general awareness campaigns or technological innovations without addressing persistent gaps in consumer behaviour, policy implementation, and stakeholder collaboration. Specifically, many studies fail to integrate comprehensive analyses of how localized e-waste management practices align with global sustainability goals or how to address the systemic barriers preventing effective e-waste recycling (Kang et al., 2020).

This study seeks to address these gaps by focusing on instrument validation of e-waste management awareness among secondary school students in Malaysia. Unlike prior

studies that primarily highlight the importance of e-waste management, this research adopts a holistic approach, integrating perspectives from industry stakeholders, policymakers, and the community to propose actionable strategies for achieving a circular economy. By leveraging insights from both local and global contexts, this paper offers a nuanced understanding of e-waste challenges and practical solutions that can be scaled or adapted for other regions.

2. Awareness of e-waste management

Electronic waste is a recently developed environmental threat. E-waste refers to electrical equipment or tools that are no longer in use or have reached the end of their useful life. (Wang et al., 2017). Dinggai et al. (2019) defined e-waste as damaged or discarded electrical equipment or electronic tools, for example, personal computers, TVs, radios, refrigerators, washing machines, air conditioners, printers, and mobile phones. This includes not only sizable electrical and electronic tools, but also diminutive tools made of obsolete micromaterials (Department of Environment, 2021). This e-waste equipment is made of iron and steel for cases and frames, non-ferrous metals like copper for wires, aluminium and glass for computer screens and window displays, electronic components, and other materials like rubber, wood, ceramics, and textiles (Kiddee et al., 2013).

The existence of precious metals in e-waste equipment indicates that it can still be recycled to recover the raw materials. Simultaneously, this step can reduce the costs associated with purchasing raw materials to manufacture new products. Although some of these materials contain precious materials, others can contain environmentally hazardous substances, such as mercury, lead, and arsenic. Therefore, if this e-waste is not properly managed, toxic substances can be released into the environment, potentially endangering human health and polluting the environment. Even good environmental management has a direct impact on the sustainability of nature (Tuntivivat et al., 2018). In Malaysia, the Department of Environment designates e-waste as a scheduled substance under the code SW110, according to the Environmental Quality Regulations (Scheduled Waste) 2005 and the Environmental Quality Act 1974. The SW110 Code classifies e-waste materials into four categories.

- ‘*Direct re-use*’ refers to whole electrical or electronic goods (including components) that can be reused and function similarly to the original.
- ‘*Recycling*’ refers to electrical and electronic goods that can be recycled or processed into their original materials after separating the components.
- ‘*Recovery*’ means that the electrical and electronic goods are modified to be used in other goods with different functions and values.
- ‘*Disposal*’ means that electrical and electronic items should be disposed of.

E-waste management involves various levels of the community, such as the government and NGOs, as well as acts or laws governing e-waste in Malaysia. The parties involved in e-waste management include the government, which acts as an authority, consumers, contractors, e-waste collectors, and recyclers. The Department of Environment (DOE), encompassed by the Ministry of Natural Resources and Environment, is the responsible governmental body that develops and implements e-waste laws and policies. Furthermore, at a local level, it establishes a collection system and tracks recycling targets. Consumers (household residents) play a role in separating e-waste from other household

waste and must ensure that e-waste collection is only done by authorised contractors or collectors. Contractors or e-waste collectors must ensure that e-waste is collected using appropriate transportation that is licenced by the DOE and that it is delivered to a licensed e-waste recovery facility.

The recycler's role is to ensure that the e-waste recycling process is carried out as efficiently as possible, minimising the production of waste, which should be disposed of in a licensed landfill. Recyclers must also control the pollution generated by the e-waste recovery or recycling process. Malaysia's DOE is in charge of e-waste collection and recycling and has set up a system for every household. To begin, the public can send their e-waste, which is limited to mobile phones, batteries and accessories, computers and accessories, and television sets, to the e-waste collection centre at the address listed on the DOE website. Solid waste concession companies or local authorities are responsible for managing e-waste collection centres.

E-waste necessitates a management system that is complex and distinct from regular solid waste. There are two main reasons why electronic waste needs to be managed systematically. The first reason is that electronic waste contains dangerous chemicals that can harm human health and the environment. The second reason is due to the rapid increase in the amount of electronic waste. The number of existing landfills is limited and unsuitable for the disposal of electronic waste (Ali, 2025). According to Norazli et al. (2015), the management of user-friendly e-waste is one of the solutions. E-waste management in countries such as Austria, Germany, France, and Belgium focuses on educating consumers and developing electrical and electronic materials that are easily disposed of. This concept, known as Extended Producer Response (EPR), requires that all electronic products on the market be free of toxic compounds, such as lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBBs), and polybrominated diphenyl (Norazli et al, 2015). In China, the government encourages the reuse of e-waste as a raw material that can change shape. The e-waste management process is designed to comply with solid waste management laws while also minimising environmental impact.

The term EPR is also used in situations involving hazardous e-waste. Osibanjo & Nnorom (2007) and Schluep et al. (2011) assert that e-waste management is inadequate in African communities. This e-waste is only managed informally, such as in the backyard, and electronic items are openly burned. Rafiza & Helyawati (2017) conducted a quantitative study to determine the level of awareness, understanding, and practice of e-waste disposal based on the educational perspective of students and lecturers at the Selangor International Islamic University College (KUIS). The study's findings revealed a relationship between awareness, understanding, and practice of electronic waste disposal, as well as a relationship between all three of these constructs and the level of education of KUIS students and lecturers. In general, KUIS students and lecturers have a good understanding of electronic waste. However, the practice level of e-waste disposal remains extremely low among respondents.

Awareness of e-waste management is crucial for addressing the environmental and health challenges posed by improper disposal practices. Public understanding and responsible behaviours significantly influence the success of e-waste recycling and disposal programs. Various studies have explored the level of awareness and knowledge about e-waste management in different contexts, providing insights into public attitudes and practices. For example, Mahat et al. (2019) investigated e-waste disposal awareness among the Malaysian community, revealing a moderate understanding of e-waste management practices. Their study emphasized the role of educational campaigns in

fostering environmentally responsible disposal behaviours. Similarly, Subhaprada and Kalyani (2017) examined awareness among medical students in India, reporting a general lack of knowledge about proper e-waste management and advocating for targeted awareness programs within educational institutions.

In an urban context, Kwatra et al. (2014) analysed public awareness in Delhi, India, finding that while many people were aware of the environmental impact of e-waste, only a small percentage actively participated in recycling programs. Table 1 highlights the need for more accessible e-waste collection systems and stricter enforcement of regulations.

Table 1

Summary of previous studies on e-waste awareness

Study	Focus	Findings	Implications
Mahat et al. (2019)	Awareness of e-waste disposal among the Malaysian community	Moderate understanding of e-waste management; educational campaigns are vital for fostering responsible behaviours.	Public campaigns are necessary to improve disposal practices in households.
Subhaprada & Kalyani (2017)	E-waste awareness among medical students in India	Students had limited knowledge of e-waste management but were receptive to awareness initiatives.	Awareness programs targeting specific groups can improve e-waste handling.
Kwatra et al. (2014)	Public knowledge of e-waste in Delhi, India	Awareness of environmental impacts was high, but participation in recycling programs was low.	Accessibility of recycling systems and stricter regulations can enhance participation.
Rafiza & Helyawati (2017)	E-waste awareness, understanding, and practice among students and lecturers in Malaysia	Good understanding but low levels of disposal practice among respondents.	Bridging awareness and practical implementation through education is essential.
Osibanjo & Nnorom (2007); Schluep et al. (2011)	E-waste management practices in African communities	Informal handling, such as backyard burning, dominates e-waste management, causing severe environmental harm.	Transitioning to formal systems and educating communities is urgent.

Despite these valuable contributions, gaps remain in addressing how demographic factors, socioeconomic conditions, and regional policies shape e-waste management awareness. Furthermore, there is limited research on integrating technology, such as social media platforms, to enhance public awareness and participation. This study aims to fill these gaps by raising awareness about e-waste management among high school students is critical for instilling environmental responsibility. Students need to comprehend the hazardous chemicals contained in e-waste and the importance of recycling to mitigate its environmental damage (Mahat et al., 2019). Furthermore, community participation, awareness of the importance of e-waste management, and prudent technology usage are emphasised. Students can facilitate a constructive impact on the long-term sustainability of the planet by cultivating more effective attitudes and behaviours through education, social consciousness, and sustainability-driven innovation.

3. Dimensions and indicators of e-waste management awareness

3.1. Dimensions and indicators of e-waste management awareness

E-waste management awareness is a multi-dimensional concept encompassing various aspects of knowledge, attitudes, behaviours, access to facilities, education, legislative understanding, and the use of technology. Knowledge forms the foundation of awareness, focusing on understanding what constitutes e-waste, its hazardous components (e.g., lead, mercury, cadmium), and the environmental impact of improper disposal. It also involves familiarity with available recycling programs and relevant regulations, such as Malaysia's SW110 Code for e-waste classification. Alongside knowledge, attitudes reflect individuals' perceptions and values toward e-waste management, such as their belief in the importance of recycling and their concern for environmental sustainability. Positive attitudes often translate into a willingness to adopt eco-friendly practices and support initiatives aimed at reducing e-waste.

Building on knowledge and attitudes, behaviours encompass the actual practices individuals engage in to manage e-waste responsibly. These include separating e-waste from general household waste, participating in recycling programs, and ensuring proper disposal through authorized collection centres or recyclers. However, effective behaviours depend on access to facilities, such as proximity to licensed e-waste collection centres and awareness of local recycling services. Convenient access to these resources plays a critical role in enabling individuals to act on their awareness and intentions. Similarly, education serves as a powerful driver in shaping awareness, with both formal and informal approaches proving effective. School curricula, community workshops, and social media campaigns can raise awareness and instil responsible behaviours, particularly among younger generations.

Another key dimension is legislative awareness, which involves understanding laws and policies related to e-waste management, such as the Environmental Quality Act 1974 or Extended Producer Responsibility (EPR) frameworks. Awareness of these regulations and their associated penalties encourages compliance and responsible disposal practices. Finally, technology usage has emerged as an essential factor in promoting e-waste awareness. Digital tools like mobile apps and websites help users locate recycling centres, while social media campaigns amplify public engagement and participation in e-waste initiatives. Together, these dimensions and their indicators provide a comprehensive framework for assessing and improving e-waste management awareness, ensuring a more sustainable approach to addressing the challenges posed by electronic waste.

E-waste management awareness can be evaluated through various dimensions that encompass knowledge, attitudes, behaviours, and enabling factors. Table 2 is a structured framework outlining key dimensions and their associated indicators.

4. Method

4.1. Study design

The research design was quantitative by using a questionnaire to validate the e-waste management awareness among high school students in Malaysia.

Table 2

Structured framework outlining key dimensions and their associated indicators

Dimension	Description	Indicators
Knowledge	Understanding the concept of e-waste, its environmental impact, and proper disposal methods.	- Awareness of what constitutes e-waste (e.g., damaged electronics, obsolete devices). - Knowledge of hazardous materials in e-waste (e.g., lead, mercury, cadmium). - Familiarity with recycling programs and e-waste regulations (e.g., SW110 Code in Malaysia).
Attitudes	Perceptions and values related to e-waste management and environmental sustainability.	- Belief in the importance of recycling and proper disposal of e-waste. - Concern about the environmental and health impacts of improper e-waste management. - Willingness to adopt eco-friendly practices and support recycling initiatives.
Behaviours	Actual practices related to e-waste management and recycling.	- Frequency of separating e-waste from regular household waste. - Participation in recycling programs or e-waste collection drives. - Proper disposal of e-waste through authorized collection centres or recyclers.
Access to facilities	Availability and accessibility of e-waste disposal and recycling facilities.	- Proximity to licensed e-waste collection centres or drop-off points. - Awareness of local recycling programs or e-waste recovery services. - Use of convenient options for e-waste disposal (e.g., community drives, pick-up services).
Influence of education	Role of formal and informal education in shaping e-waste awareness.	- Inclusion of e-waste topics in school curricula or community workshops. - Engagement in awareness campaigns through educational programs or social media.
Legislative awareness	Understanding of laws, regulations, and policies governing e-waste management.	- Familiarity with specific e-waste management laws (e.g., EPR, Environmental Quality Act 1974). - Awareness of penalties for improper e-waste disposal.
Technology usage	Role of digital tools and platforms in disseminating information and encouraging recycling.	- Utilization of mobile apps or websites to locate recycling centres. - Participation in social media campaigns promoting e-waste awareness.

4.2. Population and samples of the study

The study population included 2,037,433 secondary school students from Malaysia (Ministry of Education, 2020). Krejcie & Morgan's table (1970) was used to determine sample selection, with a suggested sample size of 384 people. However, this study included 1000 students who were chosen using a simple random sampling method, which involved assigning random numbers to the population and selecting participants without bias to ensure equal representation. This approach aligns with recommendations by Comrey & Lee (1992), who stated that a sample size of 1,000 or more is ideal for performing factor analysis. The questionnaire also collected demographic data, including the students' age range, which corresponded to the five levels of education in Malaysian secondary schools. Form 1 for 13-year-olds through Form 5 for 17-year-olds, where students sit for the SPM examination. Table 3 shows the distribution of the study sample, with the secondary school students separated by school level.

4.3. Methods of data analysis

A reliability test was performed on each construct, with the reliability value exceeding 0.7. Confirmatory factor analysis was performed to determine construct validity. This was conducted on the measurement model based on the hypothesised factors using analysis of moment structure (AMOS 18). The programme used a maximum likelihood estimation to

generate estimates in a full-fledged measurement model. The appropriateness index was used to ensure that the measurement model was appropriate, with the following parameters checked: (i) the minimum value of differences between the observed data and the hypothesised model divided by the number of degrees of freedom (CMIN/*df*); (ii) the comparative fit index (CFI); (iii) the Tucker Lewis index (TLI); (iv) the incremental fit index (IFI); and (v) the root mean square error of approximation (RMSEA). Arbuckle (1997), Hair et al. (2006), and Arbuckle & Wothke (1999) provide the following statements for the various index values.

- A CMIN/*df* value between 1 and 5 is considered an acceptable fit between the model and the data.
- CFI, IFI, and TLI indices close to 1.00 indicate a good fit between the model and the data.
- An RMSEA index of .08 or less indicates a reasonable and acceptable estimation error.
- If the model does not match, the following checks are performed: examination of the load factor of each item, which should exceed the recommended value based on the number of samples. The load factor describes the relationship between the latent construct (latent variable) and the item or indicator (Hair et al., 2006; Kline, 2005); examination of the residual standard, with values between 2.58 to 4.00 retained or dropped, while values greater than 4.00 are dropped; examination of the index modification to improve the model (Hair et al., 2006; Byrne, 2010; Kline, 2005). To strengthen the constructs in the model, central validity and discriminant validity tests were performed.

Central validity was based on a construct reliability of 0.70 or higher (Hair et al., 2006). Central validity was also evaluated based on research on the coefficients of each item with a significant load and the average variance extracted for a latent variable (Hair et al., 2006; Anderson & Gerbing, 1988; Fornell & Larcker, 1981). Meanwhile, the discriminant validity was assessed by comparing the squared correlations between the two constructs with the average of the respective variants. If the mean of the quoted variance exceeds the squared correlation, then discriminant validity is achieved (Hair et al., 2006). In this study, CFA was used to examine the construct validity of the research instrument.

Table 3
Background of respondents based on the school level

Form	Frequency	Percentage
Form 1	200	25
Form 2	200	25
Form 3	200	25
Form 4	200	25
Form 5	200	25
Total	1,000	100

4.4. Instruments

This study used a questionnaire as a research instrument, which is divided into four parts: part A, B, C, and D (Table 4). Part A contains demographic information about the

respondents, while parts B, C, and D contain information on the study's construct, which includes knowledge, attitudes, and practices related to e-waste management. Table 5 shows the constructs, items, and statements of this study in detail.

Table 4

Information on the respondent questionnaire

Part	Description	Detail/construct	No. of items	Source of item
A	Respondent background	Gender	2	Created based on the requirements for research
		Tiers	6	
		Clan	6	
		Middle school (State)	16	
		Location	2	
B	Knowledge of e-waste management		12	Built with custom and refers to the study of Akhtar et al. (2014), Echegaray and Hansstein (2017), Okoye and Odoh (2014) and Sivathanu (2016)
C	Attitude of e-waste management		12	Built with custom and refers to the study of Afroz et al. (2013), Akhtar et al. (2014) and Echegaray and Hansstein (2017)
D	Practices of e-waste management		12	Built with custom and refers to the study of Akhtar et al. (2014), Echegaray and Hansstein (2017), Ho et al. (2015), Okoye and Odoh (2014) and Sivathanu (2016)

Table 5

Constructs, items, and statements

Construct	Item	Statement
Knowledge of e-waste management	B1	E-waste poses a serious threat to the environment
	B2	Uncontrolled disposal of e-waste causes air pollution
	B3	Uncontrolled disposal of e-waste will cause water pollution
	B4	Uncontrolled disposal of e-waste will cause soil pollution
	B5	Malaysia has laws relating to e-waste management
	B6	An e-waste recycling program exists in Malaysia
	B7	The toxic effects of e-waste will cause respiratory diseases such as asthma/fatigue
	B8	The toxic effects of e-waste will cause skin diseases
	B9	Practicing e-waste recycling can generate side income
	B10	An effective way to dispose of e-waste is through recycling practices
	B11	An effective way to dispose of e-waste is through reuse practices
	B12	An efficient way to dispose of e-waste is to repair damaged equipment
Attitude of e-waste management	C1	I feel that recycling old electrical/electronic equipment is good for the environment
	C2	I feel e-waste is trash that needs to be removed
	C3	I think it is quite difficult to carry out e-waste removal*
	C4	I am worried that many damaged electrical/electronic equipment will not be repaired
	C5	I feel that recycling old electrical/electronic equipment is good for my health and that of my family
	C6	I am willing to share e-waste information on social media.
	C7	I'm trying to get more information about e-waste disposal
	C8	I try to dispose of e-waste according to the correct method
	C9	I'm happy if e-waste can generate my side income
	C10	I am happy if e-waste can generate income for my family
Practices of e-waste management	C11	I like repairing damaged electrical/electronic equipment rather than buying new equipment
	C12	I feel that recycling e-waste can save money
	D1	I am reviewing electrical/electronic equipment that can still be used
	D2	I practice proper e-waste disposal practices
	D3	I dispose of e-waste using the correct method

D4	I store e-waste at home*
D5	I send damaged electrical/electronic equipment to be repaired
D6	I participate in activities/campaigns related to e-waste disposal
D7	I learned about the laws regarding e-waste
D8	I encourage my family members to get involved in e-waste disposal activities
D9	I repair damaged electrical/electronic equipment rather than buying new equipment
D10	I bought old electrical/electronic equipment (second hand) but it can still be used
D11	I sell e-waste to generate side income
D12	I buy new electrical/electronic equipment because it is cheaper than repairing damaged equipment*

Note. Items marked with an asterisk (*) indicate reverse-coded statements to control for response bias

4.5. Instrument's reliability

Table 6 shows the reliability of elements for knowledge, attitude, and practice of e-waste management using Cronbach's alpha value, which measures the constructs' internal consistency. According to Babbie (1992), Cronbach's alpha values are classified based on the reliability index classification, with values of 0.90 – 1.00 being extremely high, 0.70 – 0.89 being high, 0.30 – 0.69 being medium, and 0.00 – 0.30 being low. The analysis showed Cronbach's alpha values for high and extremely high classifications, as they were greater than 0.80. The reliability of this research instrument was deemed to be high based on Babbie's (1992) classification.

Table 6
Reliability of the research questionnaire

Construct	No. of items	Cronbach's alpha value
Knowledge of e-waste management	12	0.817
Attitude of e-waste management	12	0.791
Practices of e-waste management	12	0.857

5. Study findings

5.1. Respondents' background

Table 7 displays the background of the respondents discussed, including gender, level, race, secondary school (state), and location. Out of a total of 1,000 respondents, 371 were male (37.1%) and 629 were female (62.9%). This clearly shows that there were more female respondents than male respondents. Next, the category by race shows that Malay was the highest, with 596 respondents (59.6%), followed by Chinese with 151 respondents (15.1%). Sarawak Bumiputera accounted for 131 respondents (13.1%). There were 67 Indian respondents (6.7%). According to the analysis, only 34 respondents (3.4%) identified as Sabah Bumiputera. Indigenous and other races had fewer respondents than other races, with only 11 (1.1%) from the indigenous and 10 (1.0%) from other races. In terms of secondary school categories by state, Selangor had the most respondents, with 320 (32.0%). There were 198 respondents from Sarawak (19.8%). Meanwhile, Perak had 167 people (16.7%), followed by Johor with 126 (12.6%). The number of respondents from Pahang state secondary schools was 65 (6.5%). Respondents from secondary schools in the state of Sabah followed, totalling 48 (4.8%). Kelantan had 27 respondents (2.7%), followed by

Terengganu secondary schools, which had 16 respondents (1.6%). Out of 1000 respondents, only 14 are from Kedah state secondary schools, accounting for 1.4%. Melaka secondary schools had only six respondents (0.6%), followed by Negeri Sembilan secondary schools, which had only four respondents (0.4%). The Federal Territory of Labuan had the fewest number of respondents, with only three (0.3%), while the high schools in the states of Perlis, Penang, and the Federal Territory of Kuala Lumpur had the same number of respondents, with only two (0.2%) each. Finally, the analysis was based on location. The majority of respondents, 604 (60.4%), live in cities. Meanwhile, 396 respondents were from rural areas (39.6%).

Table 7
Respondent profile

Respondents' background		Frequency	Percentage
Gender	Male	371	37.1
	Female	629	62.9
	Total	1,000	100
Race	Malay	596	59.6
	Chinese	151	15.1
	India	67	6.7
	Sarawak Bumiputera	131	13.1
	Sabah Bumiputera	34	3.4
	Other	10	1
	Indigenous (Orang Asal / Asli)	11	1.1
	Total	1,000	100
	Johor	126	12.6
	Kedah	14	1.4
State	Kelantan	27	2.7
	Melaka	6	0.6
	Negeri Sembilan	4	0.4
	Pahang	65	6.5
	Perak	167	16.7
	Perlis	2	0.2
	Pulau Pinang	2	0.2
	Sabah	48	4.8
	Sarawak	198	19.8
	Selangor	320	32
	Terengganu	16	1.6
	Wilayah Persekutuan Kuala Lumpur	2	0.2
	Wilayah Persekutuan Labuan	3	0.3
	Total	1,000	100
	Urban	604	60.4
Location	Rural	396	39.6
	Total	1,000	100

5.2. Exploratory factor analysis (EFA) of e-waste management for the knowledge construct

The results of the EFA of the e-waste management knowledge measurement tool explain the anti-image correlation analysis procedure, demonstrating that the correlation coefficient is greater than 0.5. This implies that the factor analysis can continue. The Kaiser-Meyer-Olkin (KMO) sampling adequacy measure was 0.831. Bartlett's test of

sphericity was significant, with a Chi-square value of 3,515.548 at 66 degrees of freedom (see Table 8).

Table 8

Appropriateness test of using factor analysis and consistency of KMO items and Bartlett's test on e-waste management for the knowledge construct

Kaiser-Meyer-Olkin	Measure of sampling adequacy	0.831
	Approx. Chi-Square Sphericity	3515.548
Bartlett's test of sphericity	<i>df</i>	66
	Sig.	0.000

The researcher conducted factor analysis, with the number of factors to be extracted limited to three, as specified in the questionnaire. Table 9 shows the component matrix with varimax rotation. The varimax rotation method was used because it reduces the number of complex constructs while increasing the expected results. The findings revealed that items B1, B2, B3, B4, B7, and B8 were removed because their “*anti-image correlation matrix*” values were less than 0.5. The values of B1, B2, B3, B4, B7, and B8 belong to component 1 (environment); B10, B9, B11, and B12 are accumulated in component 2 (social); and B5 and B6 belong to group 3 (economics).

Table 9

Component matrix with varimax rotation of e-waste management for the knowledge construct

Item	Component		
	Environment (A)	Social (S)	Economy (E)
B1	0.669		
B2	0.769		
B3	0.774		
B4	0.792		
B7	0.623		
B8	0.639		
B10		0.751	
B9		0.744	
B11		0.724	
B12		0.669	
B5			0.849
B6			0.785

5.3. Exploratory factor analysis (EFA) of e-waste management for attitude construct

The results of the EFA of the e-waste management attitude measurement tool explains the anti-image correlation analysis procedure, demonstrating that the correlation coefficient is greater than 0.5. This implies that the factor analysis can continue. The Kaiser-Meyer-Olkin (KMO) sampling adequacy measure was 0.803. Bartlett's test of sphericity was significant, with a Chi-square value of 3322.457 at 66 degrees of freedom (see Table 10).

Table 10

Suitability test using factor analysis and item uniformity of KMO and Barlett's test on e-waste management for attitude construct

Kaiser-Meyer-Olkin	Measure of sampling adequacy	0.803
	Approx. Chi-Square Sphericity	3322.457
Bartlett's test of sphericity	<i>df</i>	66
	Sig.	0.000

The researcher conducted factor analysis, with the number of factors to be extracted limited to three, as specified in the questionnaire. Table 11 shows the component matrix with varimax rotation. The varimax rotation method was used because it reduces the number of complex constructs while increasing the expected results. The result showed that C1 items were dropped because they had an “*anti-image correlation matrix*” value of less than 0.5. While the values of C10, C9, C1, C12, and C5 belong to component 1, which is the environment; C7, C6, and C8 are piled up in component 2, which is social; and C2, C3 and C4 belong to group 3, which is economic.

Table 11

Suitability test using factor analysis and item uniformity of KMO and Barlett's test on e-waste management for attitude construct

Item	Component		
	Environment (A)	Social (S)	Economy (E)
C10	0.792		
C9	0.772		
C1	0.655		
C12	0.621		
C5	0.618		
C7		0.831	
C6		0.805	
C8		0.688	
C11			
C2			0.746
C3			0.607
C4			0.574

5.4. Exploratory factor analysis (EFA) of e-waste management for practice construct

The results of the EFA of the e-waste management for practice measurement tool explain the anti-image correlation analysis procedure by demonstrating that the correlation coefficient value is greater than 0.5. This implies that the factor analysis can continue. The KMO sampling adequacy measure was 0.880. Bartlett's test of sphericity was significant, yielding a Chi-square value of 4,100.702 at 66 degrees of freedom (see Table 12).

Table 12

Suitability test for the use of factor analysis and consistency of KMO items and Barlett's test on e-waste management for attitude construct

Kaiser-Meyer-Olkin	Measure of sampling adequacy	0.880
	Approx. Chi-Square Sphericity	4100.702
Bartlett's test of sphericity	<i>df</i>	66
	Sig.	0.000

The researcher conducted factor analysis, with the number of factors to be extracted limited to three, as specified in the questionnaire. Table 13 shows the component matrix with varimax rotation. The varimax rotation method was used because it reduces the number of complex constructs while increasing the expected results. The result showed that D4 items were dropped because they had an “*anti-image correlation matrix*” value of less than 0.5. While the values D1, D2, and D3 belong to component 1, which is the environment; D5, D6, D7, and D8 are accumulated in component 2, which is social; and D9, D10, D11, and D12 belong to group 3, which is economic.

Table 13

Component matrix with varimax rotation of e-waste management for practice construct

Item	Component		
	Environment (A)	Social (S)	Economy (E)
D1	0.678		
D2	0.756		
D3	0.714		
D5		0.723	
D6		0.703	
D7		0.793	
D8		0.731	
D9			0.764
D10			0.577
D11			0.640
D12			0.765

5.5. Confirmatory factor analysis (CFA) for constructs of knowledge, attitude and practice of e-waste management

Following EFA for group items for the climate change knowledge construct, AMOS 20 software was used to determine the first and second level CFA models of climate change knowledge. Fig. 1 and Fig. 2 show the first stage CFA model of the climate change knowledge construct, which has achieved good fit accuracy. Fig. 3 is the second level CFA model, with this model being a combination of all the dimensions of the climate change knowledge construct maintained in the first level analysis.

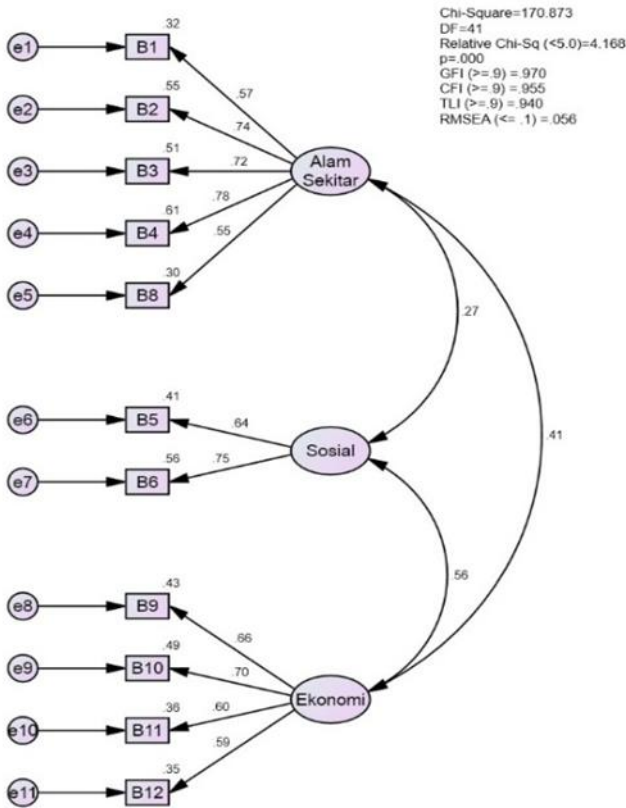


Fig. 1. First-stage confirmatory factor analysis model of e-waste management knowledge

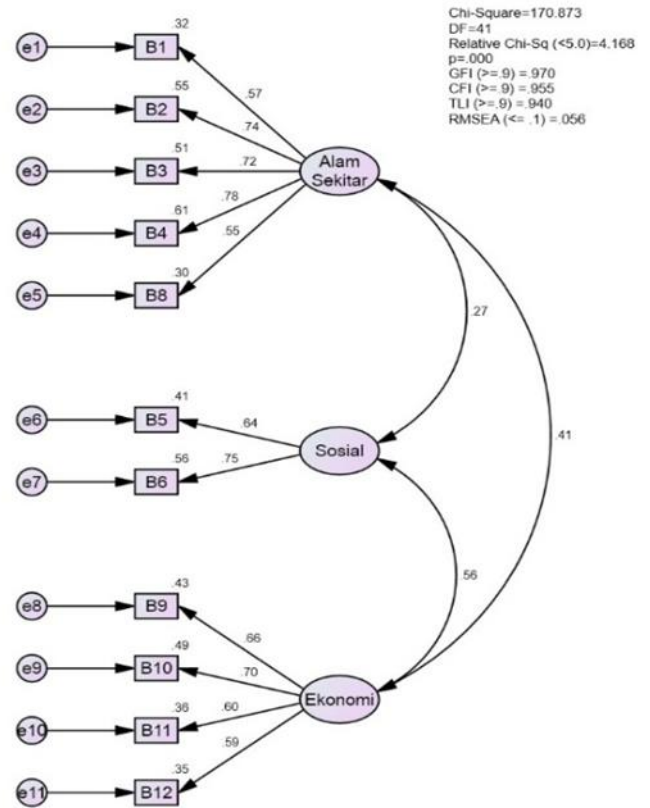


Fig. 2. First-stage confirmatory factor analysis of e-waste management attitude

The factor analysis model of the second level of e-waste management awareness verification, as displayed in Fig. 4, shows that the model formed has a good level of fit based on the set indicators (CMIN = 556.496, DF = 377, CMIN/DF = 4.739, $p = .000$, GFI = .933, CFI = .956, TLI = .914, and RMSEA = .017). The items and factor analysis model of the second level of e-waste management awareness can be used to measure and construct a structured equation model for high school students, following the conditions set by Hair et al. (2006), Anderson & Gerbing (1988), and Fornell & Larcker (1981).

6. Discussion and implications

The findings of this study highlight the successful validation of a measurement model for e-waste management awareness, encompassing the constructs of knowledge, attitude, and practice. The high reliability and strong fit indices of the model underscore its robustness and utility in assessing awareness among secondary school students. This questionnaire can serve as a valuable tool for future research, enabling the exploration of e-waste awareness in diverse contexts and demographic groups.

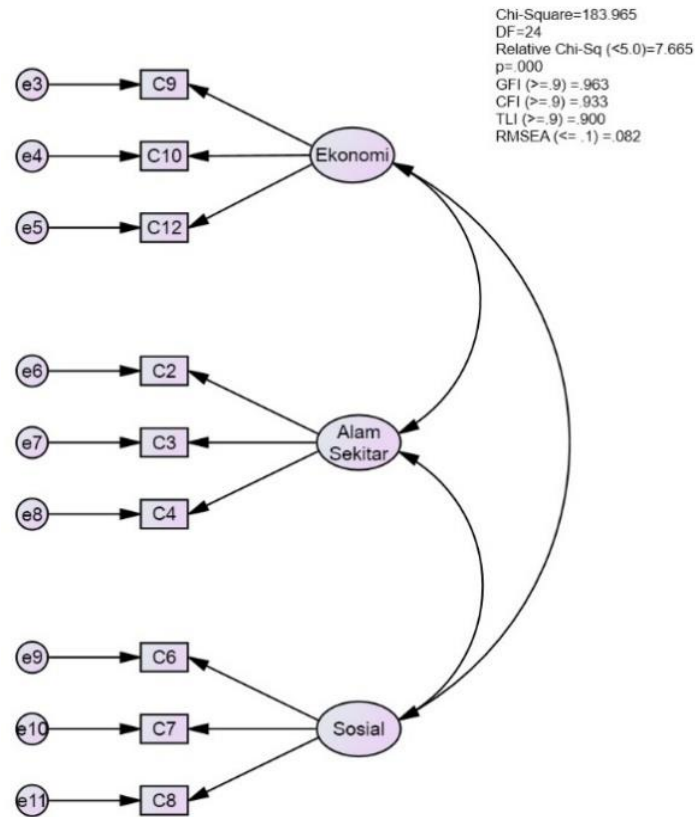


Fig. 3. Second-level confirmatory factor analysis of e-waste management practice

While the study provides critical insights, the results also suggest the need to consider possible differences in e-waste awareness across various demographic factors, such as location, age, or gender. For instance, the analysis revealed that urban respondents constituted the majority of the sample (60.4%), which may have influenced the findings, as urban students often have greater access to recycling facilities and environmental education programs compared to their rural counterparts. Future research could investigate how these location-based differences impact knowledge, attitudes, and practices related to e-waste.

Similarly, gender differences may play a role in shaping e-waste awareness. In this study, female respondents outnumbered males, potentially indicating varying levels of engagement or interest in environmental issues. Understanding gender-specific perspectives could guide the development of tailored awareness campaigns that resonate with both male and female students.

Age is another critical factor, particularly in the context of secondary education, where students progress through formative developmental stages. Differences in awareness between younger students (Form 1 and 2) and older students (Form 4 and 5) could reflect variations in exposure to environmental education, maturity levels, or societal responsibilities. Future studies should examine how age influences the adoption of

sustainable e-waste practices and whether interventions should be adapted for different age groups.

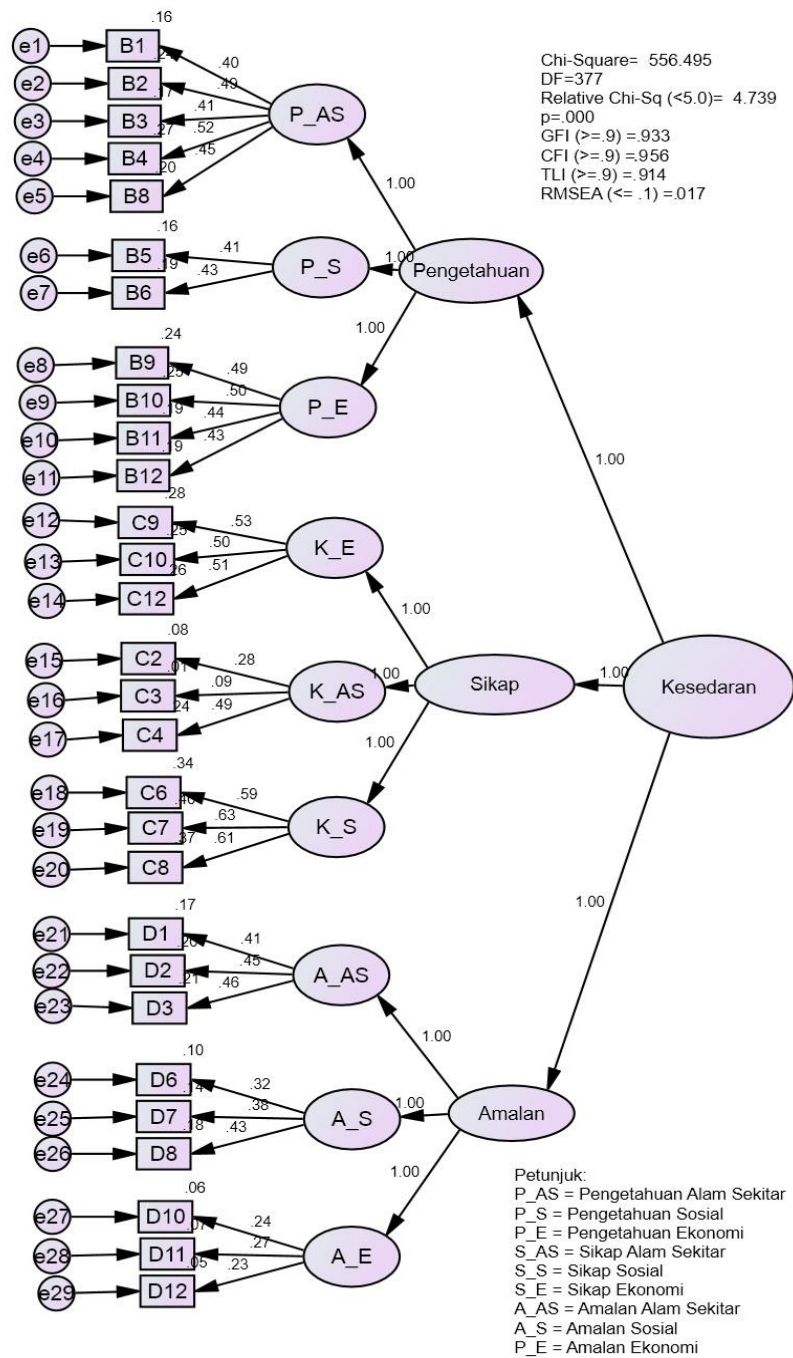


Fig. 4. Factor analysis model for second rank validation of e-waste management awareness

The validated questionnaire provides a foundation for future research to explore these demographic variations more comprehensively. Expanding the sample to include respondents from a broader range of locations, socioeconomic backgrounds, and educational systems could yield more generalizable insights. Additionally, longitudinal studies tracking changes in awareness over time would help identify the most effective interventions for fostering sustainable behaviours.

From a practical standpoint, educators and policymakers should consider these demographic factors when designing awareness campaigns and educational programs. For example, rural areas may benefit from initiatives that address the lack of access to recycling facilities, while urban areas could focus on enhancing participation in existing programs. Gender-sensitive approaches and age-appropriate educational materials could further enhance the effectiveness of these efforts.

Ultimately, this study contributes to a deeper understanding of e-waste management awareness and provides a strong basis for future investigations. By addressing the demographic variations in awareness and practice, future research can play a pivotal role in advancing sustainable e-waste management and fostering a more environmentally responsible society.

7. Conclusion

The results of EFA and CFA showed that central validity and discriminant validity can be achieved in this study. The EFA results revealed that three constructs of waste management awareness were generated: knowledge, attitude, and practice, with each component being economic, social, and environmental. Furthermore, as a result of this analysis, 33 of the initial 36 items constructed by the researcher obtained a good fit index, while the remaining three items were dropped. Correspondence values of CMIN = 556.496, DF = 377, CMIN/DF = 4.739, $p = .000$, GFI = .933, CFI = .956, TLI = .914, and RMSEA = .017 met the specified conditions. Overall, the model of e-waste management awareness that was generated from the CFA process can be used to measure the levels of knowledge, attitude, and practice of e-waste management among high school students. The instrument development of e-waste management awareness through the CFA model among secondary school students is a critical step in measuring the knowledge that affects their understanding of the issues related to e-waste management. With a better understanding, schools can design more targeted and effective educational interventions, ensuring a scientific approach to raising awareness and responsibility for e-waste management among high school students.

Author Statement

The authors declare that there is no conflict of interest.

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