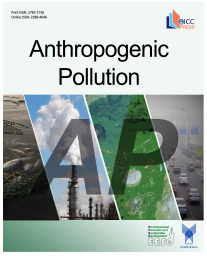

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Identification and prioritization of effective approaches for public education and participation in household waste management (A case study: Tehran, Iran)

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Abstract:

This study aimed to identify and prioritize effective methods to increase public education and participation in household waste management in Tehran (capital of Iran) as a pilot city. First, baseline data were gathered through a library research process, and then 33 waste management experts were employed as a panel to complete a researcher-made questionnaire on a Likert scale. Statistical tests and factor analysis were used to analyze the data and determine the relationships between the components. According to the results, among the determined 27 items of identifying and developing educational approaches for public participation in waste management, the item "environmental literacy" ranked first with an average score of 4.52, and the item "individual training" ranked lowest with an average score of 3.91. The final model includes five levels of factors influencing environmental education and promoting public participation. Normed Fit Index (NFI = 0.96), Relative Fit Index (RFI = 0.96), and Comparative Fit Index (CFI = 0.98) indicated that the proposed model had a good fit. The Goodness of Fit Index (GFI = 0.91) and the Adjusted Goodness of Fit Index (AGFI = 0.89) also confirmed the goodness of fit of the model. Effective municipal waste management requires active participation of citizens, which can be achieved by providing environmental education.

Keywords: Household waste management; Environmental literacy; Public participation; Tehran

1. Introduction

Waste management or waste disposal is one of the most serious environmental and health issues in the world today (Alikhan et al., 2021).. The explosion of human population and the industrialization of metropolises are the main factors in the production of abundant waste (**Hemmati2019**). Over 3.5 million tons of waste are daily generated in the world, and Iranians produce 40 thousand tons of waste daily with an average of 700 grams per capita, which is twice the world standard (Azimizadeh et al., 2024). Reportedly, the largest portion of waste generated in a community is household waste, accounting for a significant volume (Ebrahimi, 2016). Hence, municipal waste management, which is considered a subset of urban management, is essential and inevitable (Asgari, 2020). Waste management is a set of coherent and coordinated regulations to control the production, storage or collection, transportation, processing and disposal of waste, in accordance with the best health, economic, aesthetic principles and other environmental and general desirable requirements (Odonkor, 2020). The waste management system that emerged in industrialized countries in the 1930s is now able to recycle 50 to 80% of waste in countries such as Switzerland and Germany. Furthermore, half a century of efforts in the United States have increased waste recycling rates to 56% from about 6% (Moosavi, 2019). This

is despite statistics showing the less than ideal recycling situation in the household waste sector in Iran. The average per capita waste generated in Tehran (the capital of Iran) is 900 grams per person per day (Farajollahi, 2018).

In Iran, and especially in Tehran, despite the fact that the municipality has designed numerous waste management programs and allocated relatively large costs, little progress has been made in the field of waste management. Obviously, optimal waste management, which improves the quality of life, requires public participation in this field. However, citizen participation requires prerequisites that should be taken into consideration (Ansari, 2019). In this regard, one of the main tools in attracting public participation is behavior change through education and culture. The main challenges in this way are the lack of public awareness about sanitation and urban environment preservation and the misconception about waste. In fact, a large part of society believes that waste is a disposable material that should be removed from the home and living environment as quickly as possible. This misconception causes citizens not to value waste and not to show a great desire to implement management programs (Afzali, 2017). Waste management with the aim of reducing negative environmental impacts should be given more attention than ever before to manage waste at source and establish the necessary conditions for recycling (Ganji, 2016). However, this goal requires careful planning, practical measures, and basic prerequisites for proper and desirable management (Torkashvand, 2019).

It is important to note that all waste management training programs provided by Tehran Municipality to citizens are the same and there is no difference between different regions. In a way, there is no difference between the teaching methods in urban areas that enjoy a superior economic and social status and weaker areas. However, given the vastness of Tehran in terms of geographical and demographic size, it seems necessary to review and redesign the method of providing environmental education in a way that is appropriate for each urban area. Accordingly, the purpose of the present study was to identify the most effective and best approaches for transferring waste management teachings to Tehran citizens to maximize public participation.

1.1 Theoretical foundations

Environmental protection is one of the main tasks of the present and future because the environment, as a limited phenomenon, must be preserved not only for today's generation but also for the survival of future generations (Afzali, 2017). Protecting the environment and ensuring its sustainable and comprehensive development is, on the one hand, the most serious challenge facing the global community, and paying attention to it is equivalent to the possibility of a better and more desirable life for humans on Earth (Dehcheshmeh, 2020). In addition to imposing heavy costs on governments, improper waste management puts human health and hygiene at risk due to the hazardous nature of some types of waste (Mashidi, 2017). Pollution, even in small amounts, causes changes in the state of the environment (atmosphere, hydrosphere, and lithosphere), and the introduction of waste into the natural cycle (such as leachate infiltration from landfills into groundwater aquifers and other cases) certainly causes serious damage to the environment, especially urban spaces (Hashemi, 2019).

Waste management education is considered one of the most essential pillars of sustainable development (Adzawala, 2019). Formal environmental education has continued to develop and its goals have become more practical since 1977. The Sustainable Development Goals (SDGs) were developed for a better future at the Paris Conference (2015). The new UN agenda includes 17 SDGs with 169 associated targets that are interconnected and inseparable. In paragraph 25 of this agenda, all member states have committed to providing appropriate, inclusive and equitable quality education at all levels, early childhood, primary, secondary, tertiary, technical and vocational training (Kumar, 2016).

In the new SDGs (2030), there are five goals related to waste and its various aspects that are completely focused on the concepts of waste management. In essence, waste education encompasses several goals of sustainable development. One of the new approaches to waste management is the hierarchy framework (Figure 1).

In the waste management hierarchy process, multiple stakeholders are involved in implementing comprehensive waste

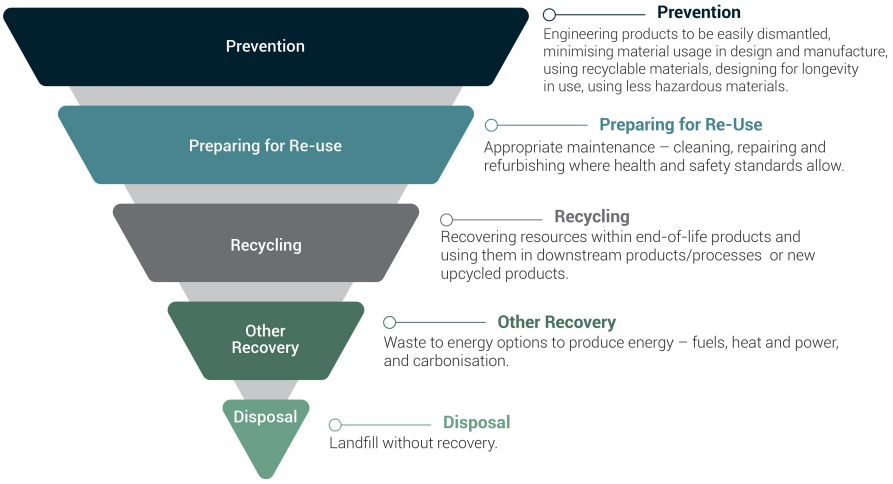

Figure 1. Understanding the waste hierarchy (Bahmanpour and Salajegheh, 2021).

management. At the first levels of this hierarchy, the central role belongs to the public, the private sector, and businesses. Moving from the higher levels of this hierarchy, the role of governments increases and the need for greater government intervention is felt (Fataei and Safavian, 2017). The higher levels of this hierarchy require comprehensive public participation, especially in the waste separation and segregation stage (surveys show that public participation in this area is currently weak), and the role of governments and municipalities gradually increases at the lower levels of this hierarchy. The functioning of each stage of this chain is subject to cultural and economic variables. At higher levels of this hierarchy, especially the stages of collection, processing and recycling, the role of relations governing the waste market, transparency and economic variables, as well as government support policies (processing and recycling stages) increases (Safavian et al., 2015). In this process, the level of profitability or benefit gradually decreases from higher to lower levels of this hierarchy, and the final disposal of waste has the least benefit in this chain and requires comprehensive government intervention and support.

The goal of environmental waste management is to minimize the adverse environmental impacts of waste and maximize the recovery of resources, including material and energy (Maleki and Sadeghi, 2022; toloun et al., 2025). The main priority in environmental waste management is to reduce waste generation and segregation and to place their recyclable parts in the appropriate path of the material recovery and recycling cycle. In addition, the second priority is to use management methods such as incineration, sanitary landfill and treatment (Fataei et al., 2022).

Research has proven that educating citizens on waste management can have positive effects, such as improving local cleanliness, reducing dumpster diving activity, reducing environmental pollution, and increasing resident satisfaction (Farahani, 2018). Despite the clarity of the legal duties of executive bodies, the current situation of waste management in Iran is not desirable, because experience has proven that the lack of public participation stops any plan and program and makes its implementation difficult (Gholami, 2019). This is despite the fact that 90% of citizens in Germany voluntarily participate in waste source separation schemes. The willingness to participate in waste source separation in Turkey is estimated at around 80% (Torkashvand, 2019). Therefore, one cannot hope for the performance of waste management until citizens' participation in the waste management process is attracted. One of the most important factors in attracting public participation is educational programs and increasing citizens' awareness in the field of waste management. Education means investing in individuals to enable them to perform better and make better use of their natural abilities (Mashidi, 2017). Public education in the field of waste management is considered a part of environmental education and can be carried out in two ways: formal education in schools, high schools and universities, and informal education. Informal education can be provided both face-to-face and using educational technologies (posters, billboards, and banners) and mass media (radio, television, internet, and newspapers) (Tavakolinia, 2017). Education is considered a tool for social transformation and development and the most effective factor in changing the behavior, insight, and attitude of human resources. The goal of environmental education is to create sensitivity, commitment, and responsibility in individuals towards physical, economic, social, political, and environmental events and changes and their impact on the biosphere (Jalilzadeh, 2018). The municipality is responsible for civic education in this area to create culture and educate citizens as much and as effectively as possible, in order to achieve the goals of protecting natural resources and preventing environmental pollution as an effective factor (Arora, 2015).

Participation in broad terms is defined as a process through which an individual plays a major role in the political, economic, and social life of his or her country and helps society achieve its goals (Dehcheshmeh, 2020). Participation is the conscious and spontaneous participation of individuals in the development plan of any society. Public participation in urban services is realized when urban residents transform from people who merely live in a place called a city to citizens (Rahmanpoor, 2019). A citizen who benefits from all of the above can achieve development participation, that is, participation in an integrated, comprehensive, dynamic, motivated, and involved social process in all stages of urban service development (Tavakolinia, 2017).

Karimi (2015) studied the role of environmental education of local communities on the environmental performance of citizens in Kalaleh city (Iran). The research results showed that environmental education of citizens had a positive effect on waste management, efficient water consumption, pollution reduction, green space, optimal energy consumption, and environmental protection. Ganji (2016) showed that improving the professional knowledge of teachers, trainers, and other individuals related to waste management in the municipality was significantly effective in increasing the effectiveness of educational methods. Alipour (2016) examined the impact of face-to-face training on citizen behavior regarding waste management in Isfahan (Iran) and concluded that municipal training has played a significant role in creating initial awareness among the general public in recent years. However, since 20% of people were disposing of their separated waste outside of the municipal principles and rules, it was evident that a culture of waste management had not been properly institutionalized. Kumar (2016) investigated the impact of a waste management training intervention on the knowledge, attitudes and practices of teaching hospital staff in Pakistan and concluded that the 18-month training course had a significant impact on human resource performance. Tavakolinia (2017) analyzed the factors affecting citizens' motivation to participate in waste management in an urban area in Tehran, which included individual characteristics, intention to participate, and possibility of participation. The results showed that factors such as accountability, citizen education and motivation, advertising, conditions and facilities, and laws and regulations had a positive and significant impact on attracting public participation. Jalilzadeh (2018) identified and ranked the factors affecting the management of construction and civil engineering waste in urban areas of Karaj city

(Iran). In this study, three criteria were identified: technical, economic, and managerial facilities, type and amount of waste produced, and environmental factors. Based on the results obtained, areas in the city center had the least potential for optimal management of construction waste, and the highest desirability for waste management was in the northern areas of the city.

2. Materials and methods

This research was of an applied type. The data were collected in two ways: library and field. In the first step, raw data were prepared through in-depth survey, review of theoretical foundations, and review of research background. In the second step, a researcher-made questionnaire was developed to obtain expert opinions.

Since the aim of this research was to achieve effective methods and techniques in environmental education, the statistical population included experts who had sufficient knowledge and experience in environmental education, especially the issue of urban waste. Therefore, the citizens were not asked so that the research data would not be general and trial-and-error and would be closer to the truth.

The statistical population of the study included experts in the field of waste management in Tehran, who were qualified with the following characteristics:

• Educational degree and specialized knowledge in the field of waste

• At least 10 years of effective work experience

• Authorship (article, book, research report) in the field of waste management

Accordingly, 33 experts were identified. In order to increase the accuracy of the data, a sample size proportional to the population was considered based on the purposive sampling method. The questionnaire consisted of 54 items (questions, q) designed based on a 5-point Likert scale (Not important at all, Of little importance, Of average importance, very important, absolutely essential). Therefore, expert opinions were sought on the effectiveness of the identified aspects and methods in waste management. The face validity of the questionnaire was reviewed and confirmed by two faculty members. Content validity was assessed using Content Validity Ratio (CVR) and Content Validity Index (CVI). Following the guidelines by Waltz and Bausell for determining the CVI (Equation (1)), experts were instructed to rate the relevance, clarity, simplicity and ambiguity of each item based on a 4-point Likert scale. The experts determined the relevance of each item in their opinion from 1: "not relevant", 2: "need to change a lot", 3: "need to change little", to 4: "completely relevant". The clarity of the item was determined from 1: "ambiguous", 2: " need to change a lot", 3: " need to change little", to 4: "clear". The simplicity of the item was also determined in order from 1: "incomprehensible", 2: " need to change a lot", 3: " need to change little", to 4: "very simple". The ambiguity of the item was also determined in order from 1: "doubtful", 2: " need to change a lot", 3: " need to change little", to 4: "meaning is clear".

$$\mathrm{CVI} = \frac{\sum \text{Number of answers 3 or 4}}{\text{Total number of experts}} \qquad (1)$$

The minimum acceptable value for CVI was equal to 0.79, and an item with CVI less than 0.79 was excluded (Hosseini et al., 2024).

In order to examine the responses of waste management experts to the specified items, first Kendall's coefficient of concordance (aka Kendall's W) was calculated to measure the degree of agreement among raters. This coefficient actually indicates that raters who ranked multiple categories based on their importance used similar criteria to judge the importance of each category and agreed with each other in this regard.

For panels with more than ten members, even small W values are considered significant. Therefore, in addition to this coefficient, the criteria for removing items in each period until the complete stop of polling according to the descriptive data table would be two criteria, the mean value and the standard deviation of each item. The items that scored less than the average (score 3) was eliminated in each period until a consensus was reached.

Second-order factor analysis method and LISREL statistical software were used to investigate the fitness of factor analysis and extracted factors and provide the final model of factors affecting waste management. The goal of exploratory factor analysis is to summarize a large number of observable variables into a smaller number of latent factors. If there is no correlation between the variables, factor analysis is unable to summarize the variables and therefore factor analysis is not appropriate for those variables. Bartlett's Test of Sphericity also examines the existence of a correlation pattern between items, and the null hypothesis of this test is the correlation matrix, meaning that establishing the null hypothesis means that there is no correlation between the variables.

3. Results

In this study, a total of four Delphi rounds were conducted. Due to the detailed nature of the results, only the results of the final round were presented in this section. The findings indicated that the calculated W (0.058) on 33 panel members with degrees of freedom (df) of 26 and an error level of less than 0.01 was significant in the fourth round, which was due to the very small increase in the coefficient in the fourth round, i.e. 0.001, compared to the previous Delphi round (W = 0.057). The results of the experts' answers to the measured items are presented in Table 1.

According to the results (Table 1), item q7 (Environmental literacy) ranked first with an average score of 4.52, and the second place was jointly assigned to items q13 (Social belonging) and q10 (Environmental attitudes, insights, and behavior) with an average score of 4.46. In addition, item q4 (Individual training) had the lowest rank with an average score of 3.91 in this round. Overall, all 27 items related to identifying and developing training methods and techniques for public participation in waste management in the Delphi panel scored above the average ($\bar{X} = 3$), so none of them were excluded.

After extracting the most important components from the experts' perspective using the Delphi method, an exploratory factor analysis (EFA) was conducted to determine a suitable

Table 1. Descriptive data related to the experts' responses in the final round to the items on identifying and developing training methods and techniques for public participation in waste management.

Codes	Items	Mean	Standard deviation	Standard error	Lowest score	Highest score
q1	Advertisements (radio, television and other media) are effective in promoting public participation in waste management.	4.33	0.65	0.11	3	5
q2	Holding competitions, games, and scientific excursions (adults, children) is effective in promoting public participation in waste management.	4.15	0.76	0.13	3	5
q3	Holding exhibitions, conferences, and workshops (in person and virtual) is effective in promoting public participation in waste management.	4.03	0.73	0.13	3	5
q4	Individual training is effective in promoting public participation in waste management.	3.91	0.63	0.11	3	5
q5	Group training is effective in promoting public participation in waste management.	4.21	0.7	0.12	3	5
q6	Virtual education is effective in promoting public participation in waste management.	4.03	0.77	0.13	3	5
q7	Environmental literacy is effective in promoting public participation in waste management.	4.52	0.51	0.09	4	5
q8	Access to educational facilities is effective in promoting public participation in waste management.	4.18	0.68	0.12	3	5
q9	Social trust is effective in promoting public participation in waste management.	4.42	0.66	0.12	3	5
q10	Environmental attitudes, insights, and behavior are effective in promoting public participation in waste management.	4.46	0.62	0.11	3	5
q11	Social capital (establishing relationships with others and social networks) is effective in promoting public participation in waste management.	4.21	0.7	0.12	3	5
q12	Satisfaction with municipal services is effective in promoting public participation in waste management.	4.42	0.71	0.12	3	5
q13	A sense of social belonging is effective in promoting public participation in waste management.	4.46	0.51	0.09	4	5
q14	Compliance with the consumption pattern (reduction of waste generation) is effective in promoting public participation in waste management.	4.3	0.68	0.12	3	5
q15	Public education and student education are effective in promoting public participation in waste management.	4.24	0.61	0.11	3	5
q16	Public and private culture is effective in promoting public participation in waste management.	4.21	0.7	0.12	3	5
q17	Education to modify consumption patterns is effective in promoting public participation in waste management.	4.18	0.68	0.12	3	5
q18	Reducing per capita consumption is effective in promoting public participation in waste management.	4.24	0.71	0.12	3	5
q19	Social well-being is effective in promoting public participation in waste management.	4.18	0.68	0.12	3	5
q20	Municipal incentive measures are effective in promoting public participation in waste management.	4.27	0.63	0.11	3	5
q21	Job creation and the establishment of centers for purchasing recyclable waste are effective in promoting public participation in waste management.	4.09	0.72	0.13	3	5
q22	Waste source separation is effective in promoting public participation in waste management.	4	0.71	0.12	3	5
q23	Access to waste separation bins is effective in promoting public participation in waste management.	4.21	0.7	0.12	3	5
q24	Urban cleaning is effective in promoting public participation in waste management.	4.24	0.61	0.1	3	5
q25	The status of street litter bins is effective in promoting public participation in waste management.	4.12	0.7	0.12	3	5
q26	Mechanized waste transport vehicles are effective in promoting public participation in waste management.	4	0.79	0.14	3	5
q27	The presence of recycling booths is effective in promoting public participation in waste management.	4.03	0.77	0.13	3	5

model for public participation in waste management. In general, 27 variables were entered into the model in the EFA. Eigenvalues were used to determine the number of extracted factors, such that factors with eigenvalues greater than 1 were extracted. In addition, principal component analysis (PCA) with orthogonal rotation (varimax method) was used to extract factors. It is worth mentioning that to determine the appropriate type of rotation, diagonal rotation was first performed, and given that the correlation between the factors was greater than 0.32, orthogonal rotation was used. In order to ensure sampling adequacy and non-zero correlation matrix, the results of Kaiser-Meyer-Olkin (KMO) test and Bartlett's sphericity test are given in Table 2.

According to the obtained results (Table 2), since the value of the KMO statistic for the present analysis was 0.940 and the value of this criterion was greater than the threshold value of 0.6, the sample size was adequate for the current analysis. In the present analysis, the results of the Bartlett's test of sphericity statistic were significant with a value of 3939.16 and a degree of freedom of 351 at the $P<0.01$ level, indicating that there was a significant correlation between the items and that the items were suitable for EFA.

In the present analysis, there were 27 observable variables, which were the same as the questionnaire items. After conducting EFA, 27 latent factors were calculated, of which 5 of the first specific factors showed values greater than 1. The initial characteristics of the five extracted factors, including eigenvalues, percent variance, and cumulative proportion of variance explained before and after Varimax rotation, are reported in Table 3.

According to the results (Table 3), the Varimax rotation showed five factors with eigenvalues higher than one, which indicated that the first factor with an eigenvalue of 4.12 alone explained about 15.25 percent of the variance. Next in order, the second factor with an eigenvalue of 3.21 was able to explain about 11.87 percent of the variance. The third factor with an eigenvalue of 2.81 could predict about 10.4 percent of the variance. The fourth factor with an eigenvalue of 2.45 explained about 9.08 percent of the variance. Finally, the findings indicated that these five factors together were able to explain nearly 55.12 percent of the total variance of the main variables. This amount of variance explained was acceptable and appropriate.

The unrotated factor loadings matrix contained general factors, and it was possible to see factors with positive and negative loadings, thus making the interpretation of the factors difficult. Therefore, after rotating the factors using the Varimax method, in addition to the above matrix showing the eigenvalues and explained variance, another matrix was presented in which the factor loadings of the items in each extracted factor were reported. Table 4 presents the coefficients of the rotated factor loading matrix of the 27-item set using the Varimax method.

In general, it could be concluded that about 55.12 percent of the variance in the components of identifying and developing methods and techniques for public participation in waste management in Tehran was explained by the five factors mentioned. In addition, all 27 items showed factor loadings greater than 0.3. Therefore, none of the items were excluded. Considering the formation of five subscales of identifying and developing teaching methods and techniques as a result of exploratory factor analysis, their correlation coefficients with each other and the total score of the scale were calcu-

Table 2. Results of sampling adequacy test and non-zero correlation matrix.

Tests	**Statistical features**	
Kaiser-Meyer-Olkin	Sampling adequacy	0.940
Bartlett's test of sphericity	Chi-square approximation	3939.16
	Degrees of Freedom	351
	Probability of error	0.000

Table 3. Initial statistical characteristics of the five extracted factors before and after Varimax rotation to determine the appropriate model for public participation in waste management.

Principle factors	**Initial eigenvalues before rotation**			**Sum of the squared component loadings after rotation**		
	Eigenvalues	**Percent variance**	**Cumulative proportion of variance explained**	**Eigenvalues**	**Percent variance**	**Cumulative proportion of variance explained**
First factor	10.09	37.38	37.38	4.12	15.25	15.25
Second factor	1.45	5.36	42.74	3.21	11.87	27.12
Third factor	1.19	4.4	47.14	2.81	10.4	37.51
Fourth factor	1.13	4.19	51.33	2.45	9.08	46.59
Fifth factor	1.02	3.79	55.12	2.3	8.53	55.12

Table 4. Exploratory factor matrix, rotated factor loadings of the 27-item set on the extracted factors.

Codes	Items	First factor	Second factor	Third factor	Fourth factor	Fifth factor
q1	Advertisements (radio, television and other media)					0.49
q2	Holding competitions, games, and scientific excursions (adults, children)					0.56
q3	Holding exhibitions, conferences, and workshops (in person and virtual)					0.7
q4	Individual training		0.44			
q5	Group training		0.51			
q6	Virtual education					0.6
q7	Environmental literacy		0.68			
q8	Access to educational facilities		0.59			
q9	Social trust			0.69		
q10	Environmental attitudes, insights, and behavior		0.56			
q11	Social capital (establishing relationships with others and social networks)		0.45			
q12	Satisfaction with municipal services			0.65		
q13	A sense of social belonging			0.48		
q14	Compliance with the consumption pattern (reduction of waste generation)		0.41			
q15	Public education and student education	0.54				
q16	Public and private culture building	0.59				
q17	Education to modify consumption patterns				0.52	
q18	Reducing per capita consumption				0.73	
q19	Social well-being				0.63	
q20	Municipal incentive measures			0.58		
q21	Job creation and the establishment of centers for purchasing recyclable waste	0.59				
q22	Waste source separation	0.52				
q23	Access to waste separation bins	0.74				
q24	Urban cleaning				0.44	
q25	The status of street litter bins			0.44		
q26	Mechanized waste transport vehicles	0.64				
q27	The presence of recycling booths	0.69				

Table 5. Correlation matrix between factors of the appropriate model for public participation in waste management and its total score.

Variables	1	2	3	4	5	6
First factor	-					
Second factor	0.7**	-				
Third factor	0.65**	0.69**	-			
Fourth factor	0.65**	0.61**	0.6**	-		
Fifth factor	0.6**	0.64**	0.56**	0.52**	-	
First factor	0.88**	0.89**	0.83**	0.79**	0.77**	-

**P<0.01

lated. Table 5 shows the correlation matrix of the subscales with each other and the total score of the scale.

The results obtained from the correlation coefficients (Table 5) revealed that the relationship of all five factors with each other and also with the total score of the scale showed positive and significant coefficients at the level of P<0.01. Moreover, the highest correlation coefficient was between the total score of the scale and the subscale of the second factor (r = 0.89), and the lowest correlation coefficient was between the fourth factor and the third and fifth factors (r = 0.52).

The results showed that all standardized factor loadings were greater than 0.4. The correlation between the latent variables (dimensions of each of the main constructs) and the observable variables was acceptable as well. In addition, the t-value for all items was significant at the level of error of less than 0.05 (t-value>1.96), indicating the significance of the correlations of the observable variables. Therefore,

Table 6. Results of second-order factor analysis of waste management using the bootstrap method.

Latent variables		Path analysis			Bootstrap confidence intervals	
Second order	First order	Path coefficient	t-value	Significance level	Lower limit	Upper limit
Waste management	First factor	0.92	12.34	<0.001	0.893	0.945
	Second factor	0.96	9.90	<0.001	0.939	0.989
	Third factor	0.91	9.78	<0.001	0.878	0.936
	Fourth factor	0.89	12.76	<0.001	0.861	0.918
	Fifth factor	0.86	10.13	<0.001	0.834	0.902

there was no need to exclude any of the research items and the construct was determined to be desirable. The results obtained are shown in figure 2.

Table 6 reports the results of the second-order factor analysis of waste management using the bootstrap method. The values presented in the "path coefficient" column are actually the standardized regression weights of the model, highlighting the importance of each item in constructing its corresponding factor and the importance of each factor in constructing the general factor.

Based on the results, the path coefficients between all factors and waste management were positive and significant at an error level of less than 0.01 ($p<0.01$). The significance of the path coefficients (t-value<2.58, $p<0.01$) and bootstrap confidence intervals indicated the accuracy of the second-order relationships of the model at a 99% confidence interval. Therefore, all five factors from the EFA were effective in waste management. Finally, several valid indicators were used to examine the fit of the research model, the results of which are presented in Table 7.

4. Discussion

The goal of environmental education is to create sensitivity, commitment, and responsibility in individuals towards physical, economic, social, political, and environmental events and changes and their impact on the biosphere (Jalilzadeh, 2018).

Given that the principles and structure of waste education programs, which are specific to citizens, are consistent and identical in all areas of Tehran Municipality, therefore, according to the results of this study, it was determined that this process needed to be revised.

The results showed that the most important factor in educating and encouraging public participation in municipal waste management was "environmental literacy." Education promotes social cohesion and strengthens a sense of social belonging. Providing public education and increasing the level of citizen culture and participation will gradually reduce waste production and resource consumption, and on

Table 7. Fit indices of the waste management model according to experts.

Indices	Acceptable values	Calculated values
Chi-Square/Df	Good <3 Acceptable <5	1.95
RMSEA	Good <0.08 Weak >0.1	0.05
NFI	>0.9	0.96
RFI	>0.9	0.96
IFI	>0.9	0.98
CFI	>0.9	0.98
RMR	<0.8	0.03
GFI	>0.9	0.91
AGFI	>0.8	0.89

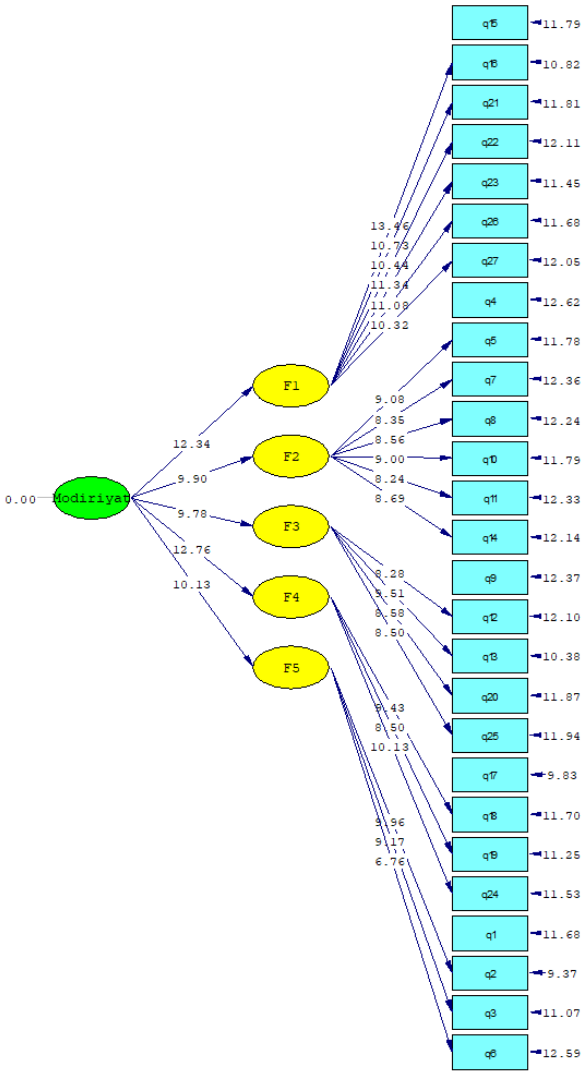

Figure 2. Second-order confirmatory factor analysis diagram for waste management in the significance state of coefficients (t-value).

the other hand, the amount of waste source separation will increase, thus reducing costs (Ebekozien et al., 2024).

The statistical population of the study included not only experts in the field of urban waste education, but also citizens of Tehran. Therefore, the results extracted from the study included both technical and sociological aspects.

The final proposed model of the current research is presented in figure 3. As can be seen, five factors were effective in improving citizens' environmental education, and as the level of knowledge increased, the level of citizen participation in household waste management increased. In addition, factors affecting environmental education that led to increased public participation in the issue of waste management were classified into five levels.

The relative chi-square value was 1.95, which was within the appropriate range. Since the chi-square-based fit indices are not very reliable, more reliable indices were used to validate the model, including the Normed Fit Index (NFI) with a value of 0.96, the Relative Fit Index (RFI) with a value of 0.96, and the Comparative Fit Index (CFI) with a value of 0.98. The values greater than 0.90 of these three indices demonstrated that the proposed model had a good fit. Therefore, the model was appropriate for the data and the hypothesized model adequately described the sample data. The Goodness of Fit Index (GFI = 0.91) and the Adjusted Goodness of Fit Index (AGFI = 0.89) also confirmed the goodness of fit of the model. In addition, the root mean square error of approximation (RMSEA), which is of particular importance in the field of model fit indices and criteria, was estimated as well. This index analyzes the level of probable error in the population and raises the question of how well a model with unknown parameters and optimal values chosen for it is determined to be optimal and consistent with the population covariance matrix (if any). Therefore, to make this index sensitive to the number of estimated parameters in a complete model, values less than 0.08 indicate good fit and values greater than 0.08 indicate possible errors in population estimation. The RMSEA value was obtained as 0.05. Therefore, it could be concluded that the model had a good fit and was appropriate to the mentioned data. Overall, it could be said that the calculations performed indicated an adequate fit for the final model.

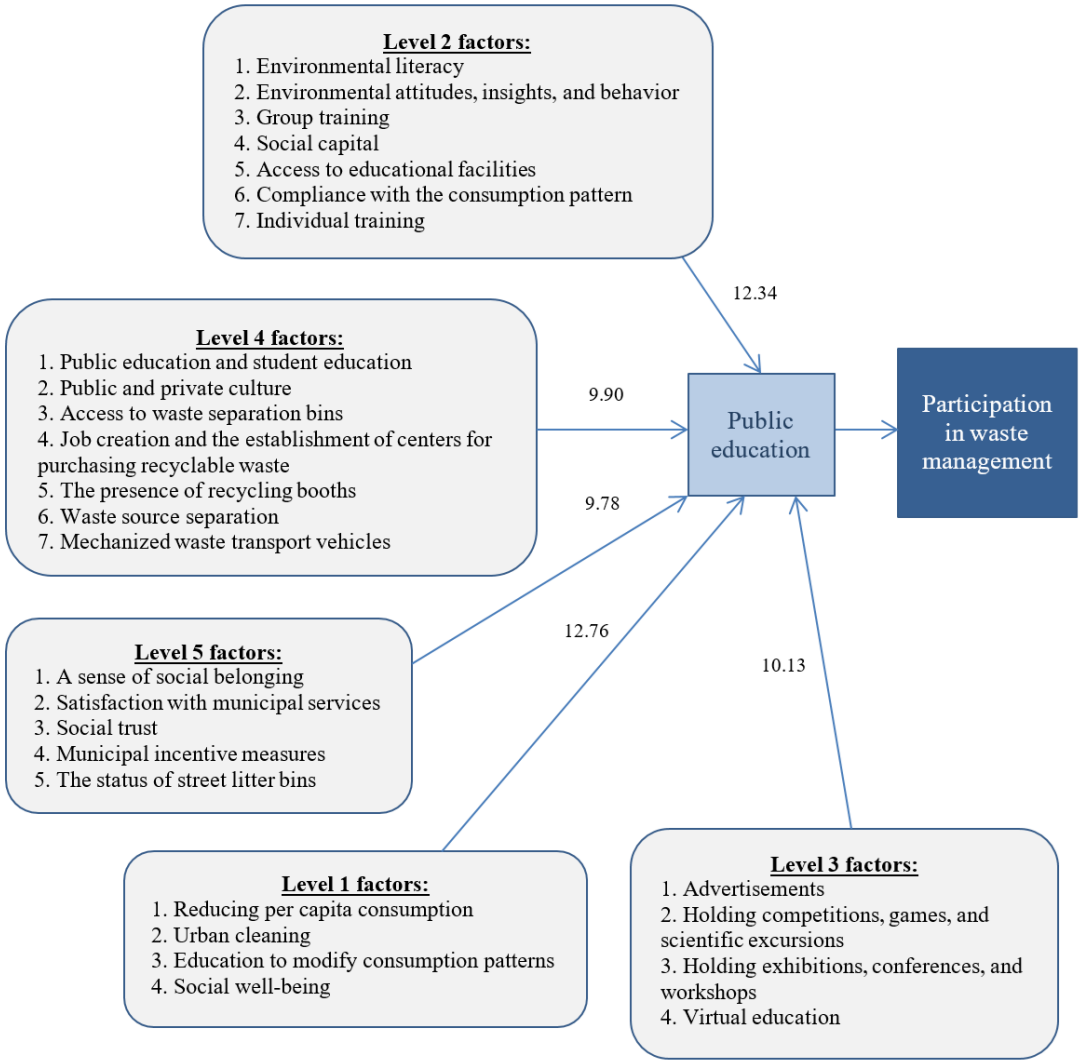

Figure 3. The final model of the research.

5. Conclusion

Effective municipal waste management and planning requires the participation and presence of citizens. This goal can be achieved by providing environmental education. To this end, the municipality and other relevant organizations should be required to implement regulations and guidelines based on social realities. Accordingly, improving the level of environmental literacy will increase the motivation of citizens, thus increasing their insight and, naturally, their responsible behavior. Instilling a sense of social belonging will promote social trust. On the other hand, satisfaction with the urban services provided by the responsible organizations can pave the way for greater public participation. It is obvious that continuous improvement in this field requires the use of a network of effective strategies that were mentioned in this research.
The innovation of this research was the use of the opinions of educational experts in the field of waste who, on the one hand, had a history of cooperation with the Tehran Municipality and, on the other hand, were also considered citizens of Tehran. Furthermore, the use of advanced statistical methods for modeling was another advantage of this research. It should be noted that the main focus of the research was solely on the issue of waste and no other environmental aspects were considered.

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Authors Contributions
Conceptualization: Hooman Bahmanpour; Data curation: Esmat al-Sadat Hashemi; Investigation: Hooman Bahmanpour; Methodology: Amir Hesam Hassani and Hooman Bahmanpour; Resources: Esmat al-Sadat Hashemi; Validation: Amir Hooman Hemmasi; Writing-original draft: Esmat al-Sadat Hashemi; Writing–review and editing: Hooman Bahmanpour and Amir Hooman Hemmasi

Availability of Data and Materials
All data generated or analysed during this study are available from the corresponding author upon reasonable request.

Conflict of Interests
The Authors declare that there is no conflict of interest.

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