Educational game technology applications to increase knowledge about sorting and processing household waste among Mecca Indonesian High School Students

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Abstract. Saudi Arabia has the largest waste generation in the Middle East region. One of the contributors to waste generation in Saudi Arabia is Indonesian migrant households and schools. Recently, Mecca Indonesian High School students have not been educated about household waste management. The aim of the research was to determine the effectiveness of a health education program on household waste management in increasing knowledge of household waste management for students at Indonesia High School, Mecca. The research methodology uses a quasi-experimental method, pre-post-test design. Education is provided in two forms, i.e. classroom-based education followed by website application-based education in the form of edugames. Class health education about waste management is provided in the form of presentations assisted by media and discussions. Website application-based education in the form of edugames. 50 Mecca Indonesian High School students who were willing to be interviewed, 41 students were willing to be interviewed, and 35 students were willing to take part in the educational program. A knowledge assessment was carried out before and after the health education program with 10 questions. Knowledge scores before and after education were analyzed using the dependent t-test. Most of the participants were male students, aged between 16-17 years and had an ideal BMI. Health education in class about waste management was proven to be effective in increasing participants' knowledge about sorting and processing household waste ($p<0.00$). In education using the edugame application, most of the participants have mastered level 1 knowledge about waste. Health education programs about waste management in the form of classroom education and edugame applications have proven effective in increasing knowledge about waste sorting and processing.

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1 Introduction

Students awareness of the importance of maintaining a clean and healthy environment is still low. Many children, teenagers and even adults are still used to throwing rubbish anywhere[1]. Caring for a healthy environment is an attitude and action that always strives to prevent environmental pollution and damage, and develops efforts to improve environmental quality due to environmental damage that has already occurred. This character is needed to minimize environmental problems and their direct impact on health problems, especially due to increasing waste generation[2]. With the existence of a character education policy in schools, this awareness should be realized. Through character education in schools, students can be taught to be accustomed to maintaining health and preserving the environment starting from waste management[3].

Waste that is not managed properly will cause various environmental and health problems. Human behavior in waste management is not only related to environmental quality but also to health levels. Piles of garbage in random places are a source of infectious diseases, causing unpleasant odors and air pollution. Piles of garbage are a source of air pollution and a source of disease transmission [4]. Health and environmental health experts have developed various methods to overcome the problem of household waste, including the 3R method (reuse, reduce, recycle) to overcome the problem of inorganic waste [5]. While the ecoenzyme technique is used to overcome the accumulation of organic waste, in reality many high school students do not know about household waste management methods. Indonesian migrant teenagers in Saudi Arabia were born with Indonesian customs but live and grow up in Saudi Arabia, which is the largest producer of household waste in the world [6]. The environmental conditions of the place of residence in Saudi Arabia influence the formation of a character that cares about waste and the environment in Indonesian migrant teenagers in Saudi Arabia. Indonesian teenagers in Saudi Arabia attend schools organized by Indonesian citizens or representatives of the Indonesian government or organized by the Saudi Arabian government [7]. Educational services provided by the community or representatives of the Indonesian government in Saudi Arabia include the Mecca Indonesian School (SIM), which educates more than 400 students from elementary to high school level with less than 30 teachers[8].

Healthy and clean living habits starting with concern for household waste need to be instilled from an early age. Character teaching in high school regarding awareness of the dangers of waste, waste management and its impact on environmental health by school teachers at the Mecca Indonesian School is of course minimal due to a lack of resources[9]. Special strategies are needed so that character education for environmental care and waste management in young high school students at SIM is successful[10]. In basic theory, character development and life habits always start from providing information and instilling values [11]as presented in Figure 1.

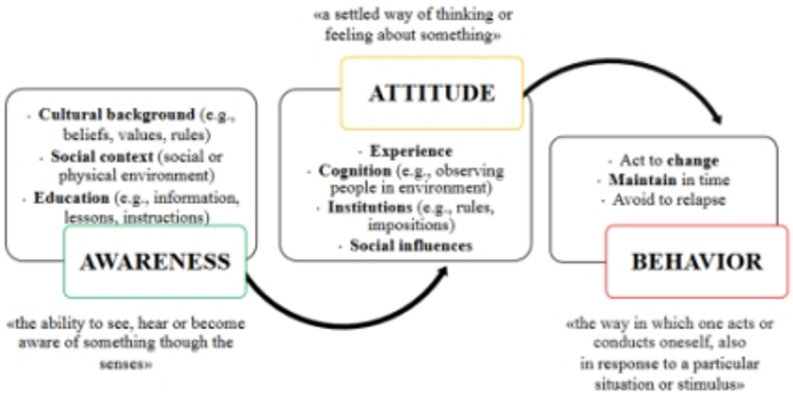

Fig. 1. Stages of change in behavior regarding household waste, environmental cleanliness and clean and healthy living behavior always start with raising awareness or concern by providing information and knowledge about the dangers of waste and household waste management methods[11] [12].

Limited resources in SIM require domestic higher education institutions to be involved in overcoming problems in SIM[10]. A health education application has been developed to develope awareness of household waste based on a web site in the form of an edugame. One of the problems among young high school students is that they easily get bored if they are required to attend online lectures for a long time, so the material about household waste awareness is realized in the form of edugames[13][14]. A game-based health education platform that cares about the environment in the form of a Visual Novel was developed as a character education medium, which will help students improve learning outcomes while helping to realize character education that cares about the environment. In Visual Novel Games, students will be exposed to a story that can be used as a role model, so that they can change their behavior[15]. Students will be interested and learn more about family waste management material and understand the importance of maintaining a clean environment. By applying the positive values contained in the game, characters who care about waste in the family, and care about environmental cleanliness and clean and healthy living will grow in their souls[16][17]. Health education that cares about clean and healthy living behavior, especially regarding household waste management, a combination of direct education in the classroom with education using applications on edugame-based websites is expected to be effective in increasing students' knowledge of the meaning, types, sorting and processing of household waste.

2 Methodology

We used a quasi-experimental design to increase knowledge about sorting and managing household waste among students at SMU Sekolah Indonesia Mecca (SMU SIM)[18]. The intervention is in the form of health education, a combination of classroom education and health education using a web site-based application in the form of an edugame. The health education program for SIM high school students has received permission from the school principal, the Indonesian education attaché in Mecca and the Government of Saudi Arabia. The health education protocol regarding waste has been reviewed by the health and scientific ethics committee of the Faculty of Medicine and Health Sciences, Muhammadiyah University of Yogyakarta.

2.1 Population and Sample

The population in this study were high school students in Indonesian schools in Saudi Arabia. The sample used in this research initially consisted of 50 subjects, but four potential subjects stated that they had withdrawn due to technical reasons. A total of 46 respondents were willing to be interviewed and fill out a questionnaire about attitudes and behavior in household waste management, but 35 volunteers were willing to take part in the training until completion. Inclusion criteria are respondents with an age range of 13 years – 20 years. Willing to become a participant in a health education program.

2.2 Materials and Instruments

Modules, training materials, evaluation sheets and edugame applications regarding website-based household waste sorting and management to increase participants' knowledge and evaluate program effectiveness. Laptops, sound systems, LCDs and screens as media for implementing education in the classroom. Mobile phone or laptop for implementing website-based education. Researchers used an instrument in the form of a knowledge questionnaire about sorting and managing waste in households. The knowledge questionnaire about sorting and managing waste in households consisted of 10 questions with a nominal scale (yes or no). Ten questions are presented in the Table1.

Table 1. Ten questions evaluating the level of knowledge about the meaning, types, sorting and management of waste in households[19].

NO	Question
1	Garbage/waste is all objects left over from human activities that are no longer used
2	Leaves and vegetable waste are examples of organic waste
3	Inorganic waste management using reuse-reduce-recycle
4	Ecoenzyme is the result of fermentation of inorganic waste, sugar/molasses, and water
5	A composter is a tool for making compost from inorganic waste
6	Waste sorting requires different trash bins
7	Ecoenzyme can function as soap and disinfectant
8	The ecoenzyme method can reduce waste in the environment
9	Ecoenzyme requires fruit peel molasses and water
10.	Ecoenzyme can only be made into fertilizer

2.3 Research Location and Time

This research was carried out in Indonesian schools in Saudi Arabia on January 2 2024– April 20 2024.

2.4 Research Procedures

1. Development of educational materials and media to increase the students' knowledge in the form of modules and PPT materials. Three material modules have been developed for implementing education in the classroom, namely (i) Module
2. Development of an edu-game application about sorting and managing household waste. Before developing a health education website application about sorting and processing household waste, the first step is an in-depth user needs analysis. The results of this analysis are then arranged systematically into a series of stages that guide the application creation process. These stages include initial design of the application's appearance,

searching and selecting material relevant to waste education, creating quizzes appropriate to the educational material, developing a website application, testing the application, and finally, the official launch of the application. The first step in the process of creating this application is designing its appearance. The resulting user interface (UI) design is a visual representation and a guide on how this application will be used to facilitate waste education. This interface is designed to be accessible via both smartphone and laptop/computer devices, accommodating various user preferences.

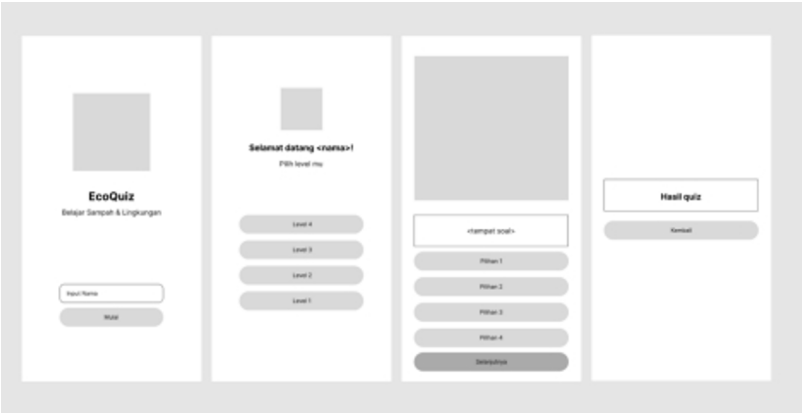

Fig. 2. Application Interface Display

The application interface was designed using Figma design software by taking simple references from the interface of quiz applications that are widely available, such as Duolingo or Kahoot.

After the design stage is complete, the next step is to collect materials related to waste education. These materials cover various topics ranging from waste awareness, types of waste, recycling processes, environmental impacts, to responsible waste management practices, including aspects of Islamic values. Based on the collected material, interactive quizzes are created to test users' understanding of the materials.

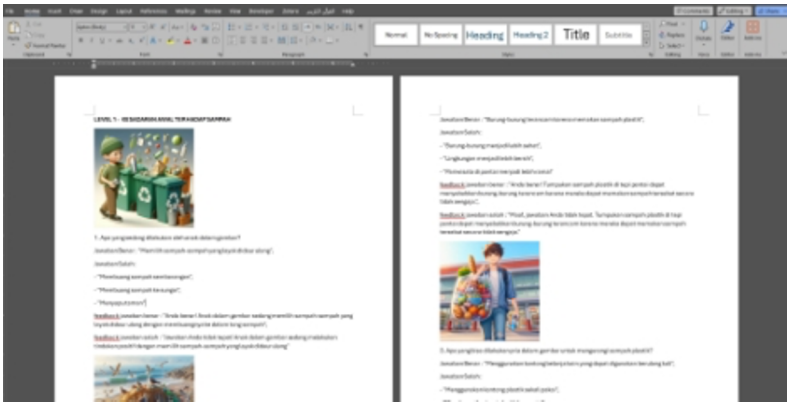

Fig. 3. Collection and arrangement of material

The material prepared consists of 3 themes, each containing ten questions. The first theme is about waste awareness, the second is about sorting and managing waste, and the third is about making and using eco-enzyme. Each question has a picture illustration to help users understand the question and increase their experience working on it. The questions were

prepared using the help of ChatGPT software for writing, Microsoft Image Creator for creating images, and Microsoft Word for taking notes.

The next step is to build a website application. The prepared application display design is implemented in the form of a website using the latest web programming technology. Quiz features are then integrated into the website to increase user motivation in learning. Once development is complete, application testing is conducted to ensure optimal performance across a variety of user devices, including smartphones and computers. If bugs or other problems are found, fixes will be made before proceeding to the launch phase.

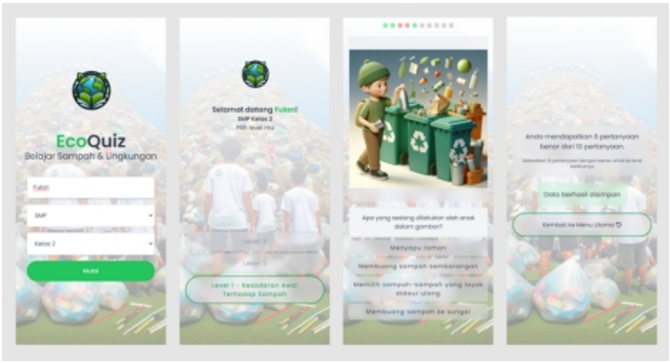

Fig. 4. Appearance of the "Greet Each Other" Application Interface (Aware of the environment and family waste)

The website application was created using HTML, the Tailwind CSS framework, and the Vue JS Framework. The website was prepared and programmed with Visual Studio Code software. It is certain that the appearance and use of the website can be used on various media, such as laptops, tablets and smartphones.

The final stage in the process is the official launch of the application. The website application will be launched publicly, ready to be used by the general public. The hope is that this application can significantly contribute to increasing awareness and individuals' role in preserving the environment through responsible waste management practices. The website application that has been developed has been tested for content validity, feasibility, and ease of use with valid results, and it is easy to use.

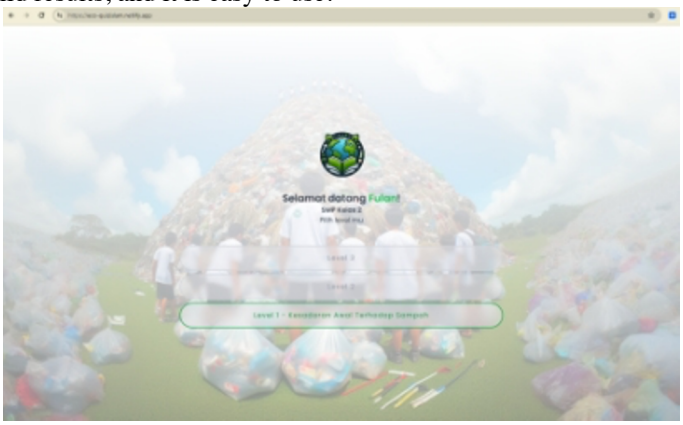

Fig. 5. Aplication Website “Saling sapa”

The website was launched with the help of a free website hosting service provider called Netlify, so that the public can use it.

2.5 Interventions for sorting and managing household waste among SIM high school students in Saudi Arabia

Before the intervention is given, participants have explained the educational objectives and direct benefits for students. If the student agrees, they continue to sign an agreement as a program participant. Students who agreed to participate were then asked to take a pre-test on the definition, types, selection, and management of family waste. The intervention was carried out in two sessions, namely a class session and a website session with the platform

(a). Educational stage in the classroom. Professional trainers (primary care doctors and public health) carry out health education about waste management in class using a short lecture, dialogue, demonstration and practice approach. The training material in class includes (i) types of waste (organic, organic) and how to sort waste, (ii) the dangers of burning waste to health, and (iii) three types of waste management in the family, namely R (reduce, reused and recycle) and the ecoenzyme method . Training material is provided in 3 sessions.

(b). The educational stage uses internet media. After the training class session, a post test was carried out. The second stage is education through a website application in the form of an educational game about knowledge about waste, types, sorting and waste management that has been developed called "Salin Sapa". Participants were explained about educational game applications to increase knowledge about waste, types, sorting and waste management. Health education about waste based on the website-based edugame "Saling Sapa K" consists of three levels. At the end of each level, a score for assessing the suitability of the material at each level is given.

2.6 Data analysis

Data on subject characteristics and description of knowledge in managing family waste before treatment are presented descriptively. Knowledge data regarding the meaning, types, sorting and management of family waste before and after treatment was carried out with a mean difference test with a confidence level of 95%[20].

3 Results and Discussion

3.1 Subject Characteristics

A total of 35 high school students from Indonesian migrant youth in Saudi Arabia are willing to become volunteers and receive training on clean and healthy living behavior and waste processing. Of the 50 Indonesian high school students in Saudi Arabia who were willing to be involved in research activities, 41 were willing to be interviewed, and nine refused. Of the 41 students willing to be interviewed, 35 were willing to participate in the waste management and environmental health care training program. The characteristics of the training participants are presented in Table 2.

Based on Table 2, it is known that there are more male participants than female participants. Table 2 shows that there were 22 (62.85%) more male participants compared to 13 (37.15%) female participants. An overview of the age range of intervention participants is presented in Figure 6. Based on the picture, it is known that the majority of participants have an age range of 16-17 years (61%) followed by the age group 14-15 years (16.7%), 18-20 years (14%), and the lowest is the group <14 years (8.3%). An overview of the distribution of participants based on body mass index (BMI) is presented in Figure 7. Based on Figure 7,

it is known that the majority of participants had an ideal BMI (74%), followed by obesity (17%), overweight (6%) and thin (3%).

Table 2. Characteristics of Indonesian migrant high school students in Saudi Arabia. Participants in the training program on clean and healthy living behavior, waste management and environmental health.

Variabel	Freq	Persentage
Sex		
Male	22	62,85
Female	13	37,15
Total	35	100
Age (year)		
12-13	3	8,5
14-15	6	17
16-17	22	62,85
18-20	5	11,65
total	35	100

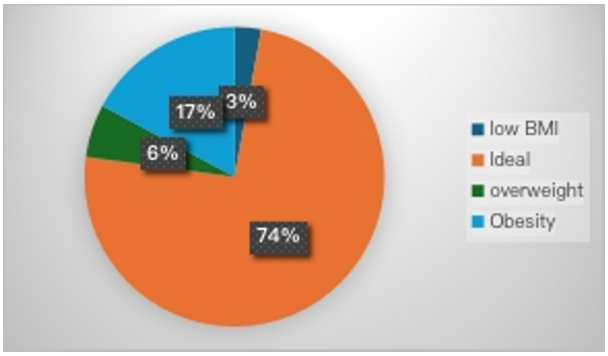

Fig. 6. Distribution of participants based on body mass index (BMI).

3.2 An overview of the subject's knowledge about waste and waste management before being given training

Description of participants' level of knowledge about types of waste, waste processing, and waste management before being given health education. Table 3 shows that the participants' knowledge about waste management is quite good, with an average score of 67.21 ± 27.79%. The three questions with the highest correct answers before the training were about types of organic waste, waste sorting and equipment, and the ecoenzyme method as a way to reduce waste in the environment. Before the training, most participants did not know how to process ecoenzymes (80%) and composters (82.15%).

Table 3. Level of knowledge about the meaning, types, sorting, and management of household waste among high school students at Indonesian Mecca schools before receiving education.

NO	Question	Score (%)
1	Garbage/waste is all objects left over from human activities that are no longer used	62.85
2	Leaves and vegetable waste are examples of organic waste	91.43
3	Inorganic waste management using reuse-reduce-recycle	82.85
4	Ecoenzyme is the result of fermentation of inorganic	20

	waste, sugar/molasses, and water	
5	A composter is a tool for making compost from inorganic waste	17.85
6	Waste sorting requires different trash bins	91.43
7	Ecoenzyme can function as soap and disinfectant	62.85
8	The ecoenzyme method can reduce waste in the environment	91.43
9	Ecoenzyme requires fruit peel molasses and water	68.57
10.	Ecoenzyme can only be made into fertilizer	82.85

3.3 The effect of health education on increasing knowledge about sorting and managing household waste

Changes in the level of knowledge after attending the training are shown in the Table 4. Based on Table 4, it is known that there has been an increase in knowledge about waste, waste management and ecoenzymes.

Table 4. Level of knowledge about the meaning, types, sorting, and management of household waste among high school students at Indonesian Mecca schools after receiving education

NO	Question	**Score (%)**
1	Garbage/waste is all objects left over from human activities that are no longer used	82.8
2	Leaves and vegetable waste are examples of organic waste	96.6
3	Inorganic waste management using reuse-reduce-recycle	93.1
4	Ecoenzyme is the result of fermentation of inorganic waste, sugar/molasses, and water	44.8
5	A composter is a tool for making compost from inorganic waste	51.7
6	Waste sorting requires different trash bins	100
7	Ecoenzyme can function as soap and disinfectant	96.6
8	The ecoenzyme method can reduce waste in the environment	93.1
9	Ecoenzyme requires fruit peel molasses and water	100
10.	Ecoenzyme can only be made into fertilizer	89.7

The participant's level of knowledge about the meaning, types, and how to sort and manage it at home is higher than before the training. The average knowledge score of participants was 84.84 ± 20.00%. After the training, 100% of the participants knew about waste sorting and equipment as well as equipment for making ecoenzymes. There has been an increase in knowledge about composters and fermentation on ecoenzymes. An illustration of changes in knowledge is shown in the figure.

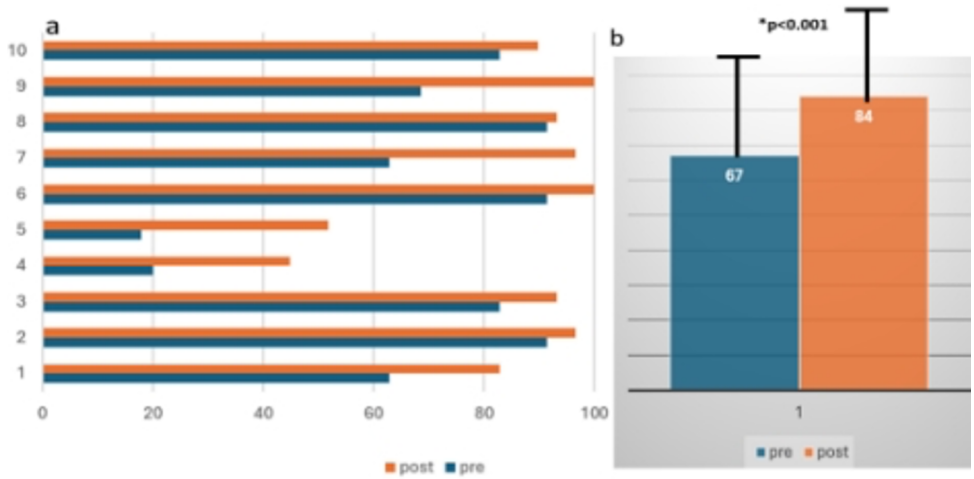

Fig. 7. (a) Bar graph of participants' level of knowledge before and after training. There was an increase in participants' knowledge after training on 10 assessment parameters. (b) The test results of the difference in average knowledge levels before and after training showed that the difference in knowledge scores after training was higher and statistically significant ($p<0.001$).

3.4 Evaluation results of the use of the edu-game application.

The results of assessing mastery of waste management knowledge after using the web-based health education application are presented in Table 5. Based on Table 5, it is known that most of the participants already have a good level of mastery of level I waste management knowledge in the edu-game application.

Table 5. Results of assessing mastery of knowledge about the definition, types, sorting and management of level 1 family waste in the edu-game application by Indonesian Mecca High School Students.

Knowledge level	Frequency	Percent
Bad	14	41,7
Good	21	58,3
total	35	100

Food waste is a social challenge that is increasingly attracting the attention of academics and policymakers at various levels, from global to local [5]. In developed countries, most of the food waste along the supply chain is generated by consumers. Therefore, addressing the systemic factors that drive waste generation by companies, families, and schools along the supply chain is essential [21]. Saudi Arabia is the largest household waste-producing country in the Middle East region[22]. One of Saudi Arabia's visions until 2030 is to preserve the environment and natural resources by increasing waste management efficiency, establishing comprehensive recycling projects, reducing all types of pollution, and fighting desertification. Waste management must be done properly because waste is hazardous for human health and the surrounding environment. Waste recycling must be done correctly so that environmental pollution does not occur, which can harm human health[6]. Not all waste is said to be useless, it turns out that some waste that has been thrown away can still be used by being reprocessed. Health education about sorting and processing family waste from an early age for high school students is a strategic step to realizing the vision of Saudi Arabia [19].

Waste is also produced during teaching and learning activities at school. Sekolah Indonesia Mecca has many students, so educating high school students about household waste management is very important. Of the 50 high school students, 41 were willing to be interviewed, and 35 were willing to take part in the education program. Most of the participants were male students aged 16-17 years with an ideal body mass index. As many as 23% of participants had an overweight-obese BMI. The overweight figure for SIM high school students follows the prevalence of obesity in previous studies. Overweight adolescents generally have more frequent eating habits and produce more household waste [23].

Health education about household waste management by combining classroom education with education using effective website applications to increase high school students' knowledge[24]. Based on the results of evaluating participants' knowledge level, it was proven that health education about waste management succeeded in increasing participants' knowledge level and was statistically significant[25]. The research results are in line with the results of previous research. Following the "Health belief model" theory of behavior change[21] and the "transtheoretical model" theory[26], increasing participants' knowledge becomes a driving force for growing attitudes of concern for environmental cleanliness and health and in the long term for maintaining its sustainability[8][27][28].

4 Conclusions

Based on the results of the study, it can be seen that health education with web-based applications is effective in increasing the knowledge of high school students at Sekolah Indonesia Mecca about the types, methods of sorting, and processing of waste. The increase in knowledge based on the study showed that the knowledge variable increased in the pre-test and post-test tests. statistically also showed that there was a correlation between increased knowledge.

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