DOCUMENT RESUME

ED 370 775 SE 054 345

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TITLE	Middle School Students' Decision-Making on Solid Waste Management in Taiwan.
PUB DATE	Mar 94
NOTE	19p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (Anaheim, CA, March 1994).
PUB TYPE	Reports - Research/Technical (143) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Academic Achievement; Cognitive Prccesses; *Computer Assisted Instruction; *Computer Simulation; *Decision Making; Environmental Education; Foreign Countries; Information Seeking; Junior High Schools; Middle Schools; Recycling; *Solid Wastes; Student Attitudes; Student Behavior; *Waste Disposal
IDENTIFIERS	HyperCard; *Middle School Students; *Taiwan

ABSTRACT

The purpose of the study was to determine the effectiveness of a HyperCard simulation upon student's concepts, opinions, and option-rankings on solid waste management, and to investigate what cognitive activities of the students were involved in the decision-making processes. One hundred eighth-grade students in Taiwan participated in this investigation. The subjects were randomly assigned into the computer-assisted-learning, the simulation-printed-materials, and control groups. The subjects received pre- and post-tests of achievement, opinion, and option-ranking on solid waste management. Students' decision-making behaviors were traced by the computer program for understanding the students; decision-making processes. Interviews verified the consistency of students' decision-making behavior. There were no significant differences on the achievement test score, the opinion assessment score, and the option-ranking score among the three groups. However, the subjects in the computer-assisted-learning group changed significantly on their option-ranking behaviors after the treatment. It was found that the students' information-searching behaviors were very different from each other, though the strategy used most frequently by the students for searching information is the conjunctive strategy. Interviews suggested that students made decisions by using their personal intuitive conceptions and feelings about solid waste management. Contains 16 references. (MDH)

MIDDLE SCHOOL STUDENTS' DECISION-MAKING ON SOLID WASTE MANAGEMENT IN TAIWAN

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Paper presented at the annual meeting of
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Anaheim, CA, 1994

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Abstract

Improving students' decision-making abilities is a major objective for science education. However, there is a difficulty in deciding what to teach and how to teach decision-makings to students. Micromputer can be used as a powerful instructional tool in science teaching. The purpose of the study was to detemine the effectiveness of a HyperCard® simulation upon students' concepts, opinions, and option-rankings on solid waste management, and to investigate what cognitive activities of the students involved in the decision-making processes. One hundred eighth-grade students in Taiwan, including fifty male and fifty female students participated in this investigation. The subjects were randomly assigned into three groups- the computer-assisted-learning group, the simulation-printed-materials group, and the control group. The subjects received pre- and post- tests of achievement, opinion, and option-ranking on solid waste management. In addition, the students' decision-making behaviors, including information searching pathway and the amount of time spent on the information, are traced by the computer program for understanding the students' decision-making processes. After the treatment, the subjects were interviewed for verifying the consistency of the students' decision-making behavior .

The result shows that there are no significant differences on the achievement test score, the opinion assessment score, and the option- ranking score among the three groups. However, the subjects in the computer-assissted-learning group changed significantly on their option-ranking behaviors after the treatment. The percentage of the successful students has increased by 7 to 41 in option-rankings, and the students' average ranking order of the options was close to the preferred ranking after playing the simulation. It is also found that the students' information-searching behaviors are very

different from each other, though the strategy used most frequently by the students for searching information is the conjunctive strategy, the subjects were more concerned with the information relating to the recycling, the environmental aspects of the options, and the disadvantages of the options. Finally, the result of the interview suggests that the students made decisions by using their personal intuitive conceptions and feelings about the solid waste management.

INTRODUCTION

In the present science-technology society, decision-making is one of the most commonly used cognitive processes of daily life. Every day we have to make choices based on our scientific knowledge, if the decisions relate to STS issues and problems . As a result, many science educators suggest that teaching decision-making on science-technology-society (STS) issues must be a major objective in science education (Aikenhead, 1985; Bybee,1987; National Science Teacher Association, NSTA, 1982; Yager,1986). Finding appropriate tasks and methods which allow students to learn STS issues has become crucial. One major difficulty in teaching STS tasks is that we often lack good instructional materials and methods (Rosenthal, 1989). Solid waste management is qualified as an issue of STS. Management of solid waste is becoming a major problem in many cities. Many face the problem of increasing amount of solid waste, rising costs of waste disposal, and landfills are filling up. As solid waste management becomes complicated, decision-makers need a more understanding in alternatives of disposing solid waste and the interrelationship of these alternatives of solid waste management (U.S. Environmental Protection Agency, EPA, 1989).

Several studies suggest that the microcomputer can be used as a powerful instructional tool in teaching children to generate alternatives and evaluate consequences before making decisions (Braun & Slobodzian, 1982; Weller, 1983). Bybee (1987) also suggested that simulation is especially useful for students studying science and technology-related social problems. The HyperCard® system designed for personal computers is a software package which has been a popular information management package used in education. In 1988, Imhof praised the HyperCard® system is an ideal tool for managing and creating information. The advantages of the HyperCard® system raise our interests in considering it as a new environment for developing courseware. However, the problems of using HyperCard®, as Conklin (1987) noted, include disorientation and cognitive overload, must be researched before bringing the HyperCard® environment to the classroom.

Teaching decision-making in science class is necessary but requires more information about students' cognitive, affective, and social aspects. The major goal of this study is ,therefore, to understand what benefits students take from a computer-assisstedle-learning, and what the nature of the learner in a decision-making process in a HyperCard® environment.

An attempted of this study was made to answer the following question:

I. Can the HyperCard® simulation effectively help the student comprehend concepts, be aware of the issues and practice decision-making of solid waste management?

II. What are cognitive activities, involved in decision-making processes on solid waste management, as shown by the students by using HyperCard® simulation as an instructional tool?

RESEARCH DESIGN

Subjects

One hundred junior high school students in Taiwan, including fifty male and fifty female students from two individual male and female classes, participated in this investigation. Thirty subjects (fifteen male and fifteen female students) were randomly assigned into computer-assisted-learning group, another thirty subjects (fifteen male and fifteen female students) were randomly selected to the group using the simulation-printed materials on solid waste management. The rest of the students participated into the control group .

Instructional Materials

The simulation -- Solid Waste Management: Decisions and Outcomes --allows the user to make proposals about solving the crisis of the solid waste disposal. The student takes the role of Director of the project and assists the mayor in dealing with the crisis. As Director, the player must focus on three dependent variables; the concerns of economics, environmental health, and popularity, and then rank the options to help solve the community's problem of solid waste disposal. The options include composting, landfilling, recycling, source reduction, and waste-to-energy (incineration with energy recovery). An objective quality measure for solutions to the problem is obtained by summing the absolute values of the deviations of ranks assigned by a problem-solver from the preferred ranks assigned by the Waste Management Board (i.e. the numbers 1, 2, 3, 4, 5 are assigned to Source Reduction, Recycling, Composting, Waste-to-energy, and Landfilling, respectively). A successful solid waste management depends upon whether or not the subjects produce the solution close to the preferred ranking. The lower the sum of the deviations from the preferred ranks, the higher the quality of the solution. To get re-appointed, the player must get a sum of the deviations that is less than 4. While completing the ranking, the student is asked to supply a written protocol for the ranking. The simulation allows the player to play a maximum of four times. The first three option rankings gives the player instant feedback after rankings. The final ranking decides whether the player gets reappointed or fired. The time for playing the simulation is 40 minutes, which allows most of subjects to complete the simulation.

Instrumentation

Three forms of researcher-developed instrumentations, an objective test, an opinion assessment, and an option-ranking task on solid waste management, were used to collect data for examining students' cognitive activities, involved in decision-making processes on solid waste management, while playing the simulation. The KR20 of the objective test is 0.89 and its test -retest reliability is 0.91.

Procedure

Two weeks before the treatment, the subjects received the objective pretest, the opinion pre-assessment, and the option-ranking task on solid waste management. On the day of the treatment, the computer-assissted-learning group was asked to play the simulation, the printed-material group was told to read the simulation-printed materials, and the control group received no treatment. A process-tracing technique was used in this study to assess the students' cognitive processes in decision-makings. After the treatment, the subjects were interviewed for verifying the consistency of the students' decision-making behavior . The data were collected by testing the subjects in a general science laboratory with computers of the school.

FINDINGS OF THE STUDY

1. Changes of concepts, opinions, and option-rankings on Solid Waste Management

No significant differences were found on (1) the objective posttest score; (2) the opinion assessment score; and (3) the final option-ranking score between the simulation group and the printed-material group (refer Table I). The HyperCard® simulation was just as effective, no more, no less, as the printed-material on the students' concepts, opinions, and option-ranking changes.

Insert Table I approximately here

However, the students did improve their option-rankings after the trials in the simulation group. As shown in the Fig I, the percentage of the successful students has increased by 7 to 41 in option rankings after playing the simulation. On the other hand, the printed-material group revealed no improvement on the option-ranking task. The percentage of the successful students in the printed-material group has decreased by 44 to 22 in option rankings after the trials. The control group showed no change on their two trials.

Insert Fig.I approximately here

Furthermore, it also shows that the simulation group did improve their option-rankings after the trials(refer Fig II). The students' average ranking order of the five options of solid waste management on the final option-ranking was close to the preferred ranking.

Insert Fig.II approximately here

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2. Cognitive activities, involved in decision-making processes on solid waste management, as shown by the students by using HyperCard® simulation as an instructional tool.

(1).The Number of Card Read

Examining the number of cards through which the student navigated and the amount of time that the student spent on the cards is assumed to indicate the degree of attention that the student paid to the information.

Figure III shows that the changes of the students' information search for the four option-rankings. In general, the students searched information from 3 to 36 cards, totally. The average number of the cards read by each student was 16.70 cards. The students searched mostly on the initial option-ranking, the average student read 40% of the total information (11.04 out of 30 cards) provided in decision table of the simulation. However, it was suddenly decreased after the second ranking. The average number of the cards read by each student were 3.78 cards, 1.07 cards, and 0.81cards for the second, third, and final option-ranking respectively.

Insert Fig.III approximately here

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(2). <u>The amount of time Spent</u>

The amount of time spent on the cards by the students are various very much(refer Figure IV). The students use from 29 seconds to 440 seconds to read information for the four option-ranking. The average time spent on cards by each student is 181.44 seconds. However, the students spent much more time on the initial ranking, but decreased quickly after the second ranking.

Insert Fig.IV approximately here

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(3). <u>The kind of information searched</u>

The students used preferred information for their option-rankings(refer Table II). The cards selected most frequently by the students are those cards relating to recycling, followed by the cards about Waste-to-Energy, Composting, Landfilling, and Source Reduction (F=5.21, p=0.023). In addition , the students read most frequently on the environmental aspects of the options. Finally, although there is no significant difference between the number of card selected by the students on the advantages and disadvantages of the options(t=2.04,p=0.14), the students seems to be more concerned with the disadvantages of the options.

Insert Table II approximately here

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(4). <u>Information Search Pattern</u>

The scheme used to classify the subject's information-viewing strategy was adapted from the Payne (1976) model. Table III shows the summary frequency distribution of the information-viewing strategies used by all students in the HyperCard® simulation group. It indicates that the students used some strategies to search information for the initial ranking, however, most of the students did not search for the rest of rankings.

On the initial ranking, 8 out of 27(30%) students used the conjunctive strategy, 4 students used the additive strategy, 4 students used additive difference, 5 used elimination-by-aspects strategy, the remaining six students viewed so few cards that no rule can appiy to them. Furthermore, Table III also shows that no specific information-viewing strategy was sured to be used by successful students.

Insert Table III approximately here

(5). Students' Views of Solid Waste Management and Decision-making

In the investigation about how students view solid waste management and decision-making, we interviewed with the subjects of the simulation group after they play the simulation. Table IV shows the students' general conceptions on the solid waste management and decision-making. There are 56% of the subjects defined the solid waste management as the way to reduce the garbage, such as recycling and source reduction. 48% students told that the problems of dealing with the solid waste are people's protests and the increasing amounts of the garbage. The students think that the most important objective of solid waste management is to protect the environment. Most of the students in this study thought recycling is the best to deal with solid waste before playing the simulation because the school was implementing recycling program . However, they changed into source reduction as the best to deal with solid waste after playing the simulation. The decision-making on science-technology-and society issues, such as solid waste management, must take account of public reaction, environmental health, and land costs.

Insert Table IV approximately here

CONCLUSIONS AND IMPLICATIONS

Ranking the options, which is a major step in decision-making, requires that the student represent the task environment, use existing knowledge, and synthesize and evaluate the information to obtain a solution. This study examine the effectiveness of the HyperCard® simulation upon students' option-ranking outcomes. Although the result shows the HyperCard® simulation was just as effective, no more, no less, as the printed-material on the students' concepts, opinions, and option-ranking changes. The students did improve and refine their option-ranking (see Fig I and II). The percentage of the successful students has increased by 7 % to 41%. In addition, the average ranking order for the options on the final ranking are closed to the preferred ranking. The HyperCard® simulation did provide the subjects with an opportunity to practice and to refine their option-ranking skills.

Examining the number of cards through which the student navigated and the amount of time that the student spent on the cards lead to understand that the student's cognitive activities, involved in decision-making processes on solid waste management, by using HyperCard® simulation as an instructional tool. The result indicates that students in the HyperCard® simulation group did not view much information on the simulation(see Fig III and IV). According to the HyperCard® tracking script data, the average number of the most important information cards read by each student was 11.04 out of 30 cards (40% of the total information). And the amount of time spent by the students for viewing information was getting less and less after initial ranking. It seems that students pick their own perceived necessary or preferred information for ranking the options without considering other valid information(see Table II and III). As Heller(1990) suggested that "the beginner may be unwilling, or unable, to formulate a search objective and thereby be unable to take advantage of the richness of the system offered through the browser".

The result also showed that the students commonly experienced difficulties at three different epistemological levels: 1. Solid waste management knowledge. 2.

Decision-making ability- many students could not predict or explain the reasons why they ranked options of solid waste management. 3. Explanatory ideals- many students demonstrated a preference for explanations based on superficial analogies with their everday experience. Findings appear to support Fleming (1986) research which found that knowledge of the physical and social word influences student's reasoning in social-scientific issues. Recent cognitive study suggest that increase of knowledge of a domain can greatly increase capability of performance (Chi,1987). As the management of waste becomes increasingly complex, the students need a more through understanding of the options available to them and the interrelationship of these options.

The results of the present investigation indicate that the HyperCard® simulation exhibited its effectiveness which provides students opportunites to learn to make decisions and allows the the researcher or the teacher to better understand student cognition through navigation in the simulation. Understanding student cognitive characteristics in decision-making process can help educators and teachers design and develop curriculum for improving students' abilities for a responsible decisions on their future lives. This kind of instructional design is supported by many science educators for the twenty-first century society.

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Appendix

Table I. Summary of Anaysis of Covariance for The Objective Test, The Opinion Assessment, and The Final Option-ranking Scores among The Three Groups

Item	simulation group		Printed-material group		Controal group		F value	P value
	M	SD	M	SD	M	SD		
Objective Test	22.51	0.89	23.83	0.79	22.01	0.66	1.59	0.21
opinion Assessment	113.85	9.62	115.34	25.04	114.48	13.40	0.11	0.8974
Final option-ranking	4.32	3.15	4.98	2.97	3.94	2.40	0.86	0.4256

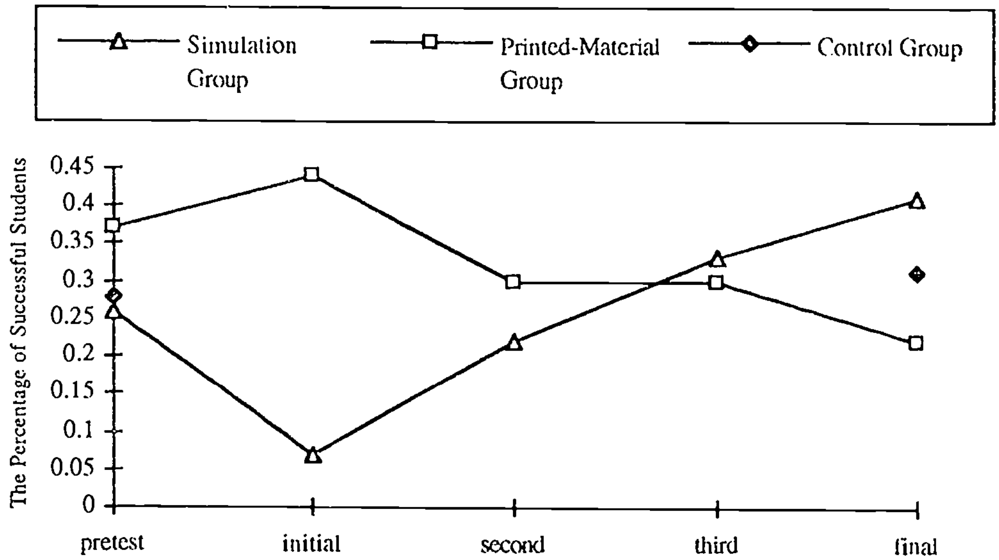
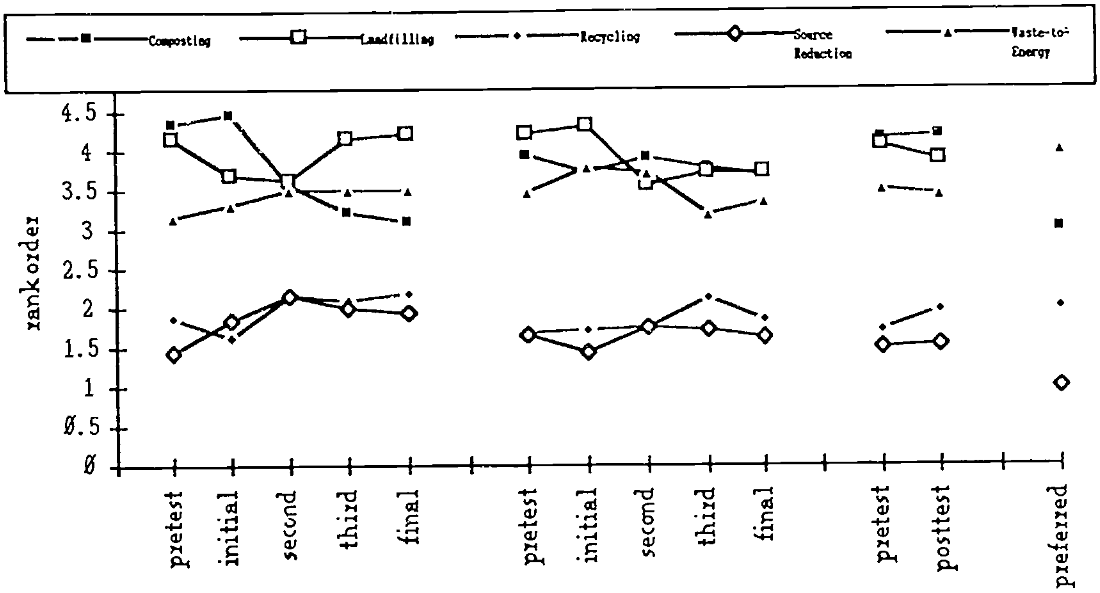


Fig I. The Percentage of The Successful Students on The Option-rankings among The Three Groups



FigII. The Changes of Average Ranking Order of the Five Alternatives on Solid Waste Management Given by the Three Groups after the Trials

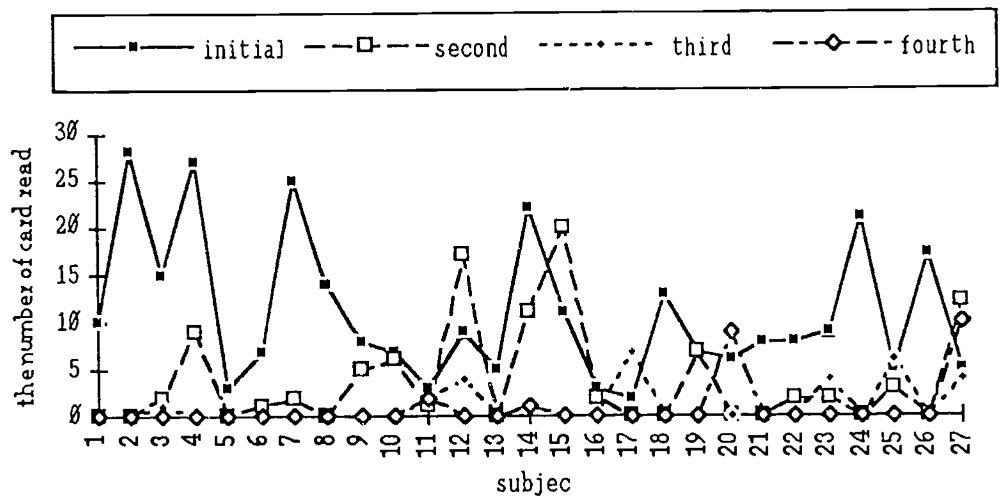


Fig III. The number of cards read by the students for four option-ranking in the simulation

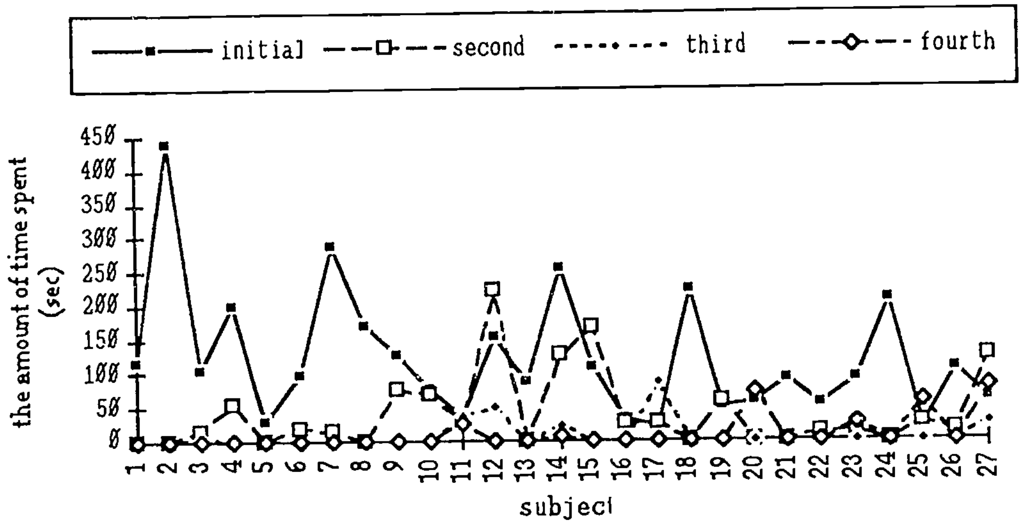


Fig IV. The Amount of Time Spent on the Cards Read by the Students for Four Option-ranking in the Simulation

Table II. Analysis of Variance for the Number of Card Read by the Subjects on the Kind of Information on Solid Waste Management

Item	Mean	SD	Significance Test
Composting	29.67	3.51	
Landfilling	28.33	1.53	
Recycling	35*	5.29	F=5.21,P=0.0230
Source Reduction	25.67	3.51	
Waste-to-Energy	30.67	5.77	
Economic	26.4	4.16	
Environmental	33.4*	4.72	F=9.05,P=0.0088
Poster	29.8	3.03	
Advantage	14	3.12	t=2.04,P=0.14
Disadvantage	15.87	3.60	

Table III. Summary of Frequency Distribution of Information-viewing Strategy Used by The Students in The Simulation Group

Option-rankings	Additive	Conjuctive	Additive Difference	Elimation-by-Aspect	No Rule	No Searching	Total
Initial	4	8(1)	4(1)	5	6	0	27(2)
Second	0	4(1)	2	2	12(4)	7(1)	27(6)
Third	0	2(1)	1(1)	0	5(1)	19(6)	27(9)
Fourth	0	2(1)	1(1)	0	2	21(9)	27(11)
Total	4	16(4)	8(3)	7	25(5)	47(16)	108(28)

The number in parentheses represent instances of successful students

Table IV. Students' Views of Solid Waste Management and Decision-making

Answer Categories	Answer (N=27)	frequency (%)
The solid waste management is the way to reduce the garbage, such as recycling and reduction.	15	56
The problems of dealing with the solid waste are people's protests and the increasing amounts of the garbage.	13	48
The most important objective of dealing with the solid waste is to protect the environment.	16	59
Recycling is the best to deal with solid waste before playing the simulation.	16	59
Source reduction is the best to deal with solid waste after playing the simulation.	13	48
The decision-making on science-technology-and society issues, such as solid waste management, must take account of public response, environmental health, and land costs.	14	52