DEVELOPMENT OF COMPUTATIONAL SOFTWARE FOR IMPROVEMENT OF PERSONAL ABILITY OF DISASTER PREPAREDNESS IN SCHOOL

（学校における個人の防災力向上のためのソフトウェアの開発に関する研究）

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DEVELOPMENT OF COMPUTATIONAL SOFTWARE FOR IMPROVEMENT OF PERSONAL ABILIY OF DISASTER PREPAREDNESS IN SCHOOL

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ABSTRACT

Today, there are no appropriate teaching materials with which teachers acquire and teach school children knowledge about disaster preparedness in schools even if they feel it necessary. Therefore, the author developed four kinds of computational software for disaster preparedness education in schools because knowledge about disaster preparedness and evacuation after disasters are indispensable as vital information from past disasters and descriptions written by people who had experienced earthquake disasters.

First, the author developed an interactive personal computer software to be used for earthquake preparedness education, which is designed for teachers' use in elementary and junior high schools. Prior to developing the software, the author distributed 200 questionnaires to elementary and junior high schools in Shizuoka and Yamaguchi prefectures to ascertain the appropriate information to be included in the software.

After the completion of the software package, the author distributed it to a total of 10 elementary and junior high schools in Yamaguchi prefecture and then evaluated its effectiveness by examining teachers' understanding before and after its presentation. As a result it was found that teacher understanding of earthquake disaster prevention had improved and that the software level was appropriate.

Secondly, the author developed a software for earthquake preparedness education of school children because schoolchildren should learn earthquake preparedness, such as, characteristics of earthquake or preparation for earthquake. Furthermore, a method for evaluation the learning effect by introducing the field of educational technology such as S-P(Student-Problem) curves, Caution Index and IRS(Items Relational Structure Analysis[1)]) was also proposed.

As a result, it was found that students improved understanding of earthquake preparedness. After the evaluation, the learning order in the curriculum was changed according to the result of IRS, and the improved software was reevaluated. As a result, S-P curves shifted toward a higher percentage of correct answers compared to the first evaluation. From these results, it can be useful for students to use the software and for us to

evaluate its effectiveness easily.

Thirdly, the author developed a 3D evacuation simulation software by using a low-end personal computer without special devices and software. Because it is very important for school children to grasp their behavioral tendency in a following disaster after an earthquake even if they have knowledge about what to do for earthquake disasters referring to previous disasters. 3D evacuation simulation software consists of two parts. One is "Data editor" and the other is "Simulator". Data editor is a kind of sub–software that supports users in making 3D CG objects, such as, a virtual structure. Users such as school children can easily make 3D CG objects by using Data editor. In the simulator, 3D CG images are displayed on screen on the basis of the data that is edited by Data Editor. Users can move or turn a viewpoint on screen as if they were actually walking in 3D CG by pushing buttons on a control pad.

In order to evaluate the simulator, evacuation experiments in simulator were performed by using two kinds of maze that imitated underground shopping center. One is the maze with many exits and the other is constructed based on the model of an actual maze with one exit that was used in Watabe's experiment.

As a result of the former maze experiment, it is found that three typical characteristics of wayfinding behavior that was the same results as Matsushita's wayfinding experiments[2] were derived.

As the result of latter maze experiment, it is found that tendencies of the simulator is the same as that of Watabe's experiment[3] from the point of view of the relation between crossings and average time to find out each crossing.

From these results, Students and teachers can grasp characteristics of their wayfindings by using this simulator themselves instead of a fire drill.

Fourthly, the author developed computational simulation software of evacuation that teachers can use in order that teachers investigate the characteristics of students' behavior and the way of conduct for students beforehand with ease. Furthermore, the author introduced a simulation model by using chained codes used in the field of information processing in order that people who are unfamiliar with a computer language such as teachers can change parameters of evacuee models.

The author applied this simulation model to an actual underground shopping center in Tokyo. As a result, it was found that the more guides assist, the more evacuees could evacuate quickly and its instructions provided by a mobile guides are more effective than those by a stationary guide.

The author independently developed and evaluated four kinds of software. However, people often simultaneously need knowledge about earthquakes and way of evacuation during an earthquake disaster. It is necessary to combine four kinds of software and generally evaluate children's diminishing fear of earthquakes especially considering the field of educational psychology.

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CHAPTER 5

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CHAPTER 1

General Introduction

1.1 Introduction

For years, earthquakes have frequently occurred in Japan and numerous people were either killed or injured in disasters. Many children were also among the casualties caused by collapsing structures, such as, fallen houses in strong tremors. And others died because they had no information about earthquake disaster preventive measures.

On the former, for example, more than 6000 people were killed by the great Hashin-Awaji earthquake that occurred in 1995, which was an inland earthquake with Magnitude of 7.8 on Richiter scale[1)]. Many casualties resulted in deaths and injuries from collapsed houses. As a countermeasure, many buildings and houses have been built recently with improved earthquake proof technology that can withstand the strong tremers.

On the latter, for example, the Japan Sea coast in the Tohoku region of northern honshu island was struck by a strong earthquake (the Nihonkai-chubu earthquake) in 1983. Of the one hundred and four people who died, one hundred were killed by the tsunami subsequent to the earthquake[2]. Thirteen school children on a picnic by the Japan Sea were among the victims. Unfortunately, not only the children but the accompanying teachers and the bus driver knew nothing about the potential danger of a tsunami following an earthquake that takes place under the ocean. They had no knowledge about tsunamis because they lived in a village of a mountainous region.

On the other hand, there were no casualties at the New Ireland earthquake tsunami in Papua New Guinea on November 2000. Especially the residents at coastal areas near Rabaul immediately evacuated to higher grounds right after the earthquake because pamphlets about tsunami awareness were produced and distributed by ADRC(Asian Disaster Research Center) and Papua New Guinea Government on October 2000 from the lesson of damages of 1998 Aitape Tsunami[3]. It is a typical case in saving lives due to disasters preparedness education.

From these lessons, people who have knowledge about earthquakes and are well prepared for earthquake disasters can avoid damage when they do encounter an unexpected earthquake. So earthquake preparedness is one of the most important and the indispensable factor for disaster prevention measure. Furthermore, it is ideal that people learn earthquake preparedness in their childhood. Therefore, schools should play an important role in providing earthquake preparedness education.

1.2 Present Condition of Earthquake Preparedness Awareness and Education in Schools

School teachers must have awareness of earthquake preparedness in order to teach school children knowledge about earthquake preparedness. Therefore, present condition of earthquake preparedness awareness in schools in Japan is first described in references to Naruse's questionnaire research (1987)[4] and questionnaires by Takimoto et al. (1990)[5].

The former is a questionnaire, which Naruse et al. distributed to 1117 elementary and junior high schools in seven prefectures: Hokkaido, Tokyo, Kanagawa, Shizuoka, Aichi, Yamaguchi and Kumamoto in 1987. The latter is a questionnaire, which the author et al. distributed to 200 elementary and junior high schools in Yamaguchi and Shizuoka Prefectures in 1990.

1.2.1 Teachers' Earthquake Prevention Awareness

Figure 1.1 shows that the percentage of teachers who thought that their schools would be safe in an earthquake.

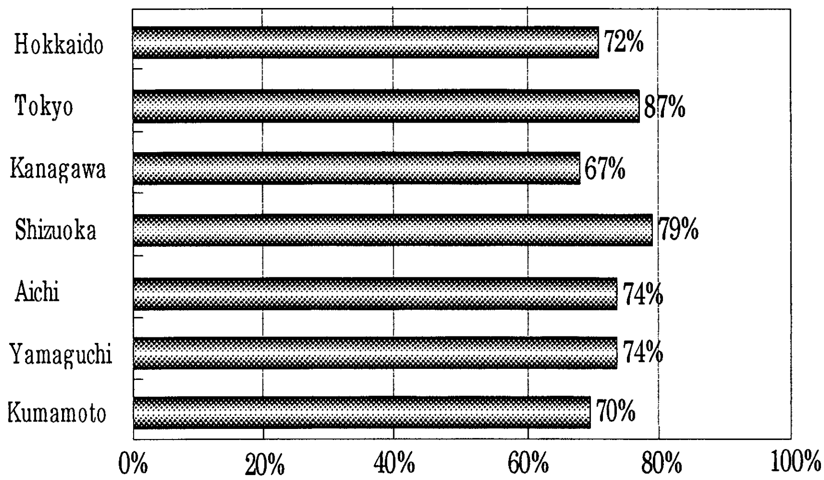

Figure 1.1 Is your school secure in an earthquake? Teachers' responses[4].

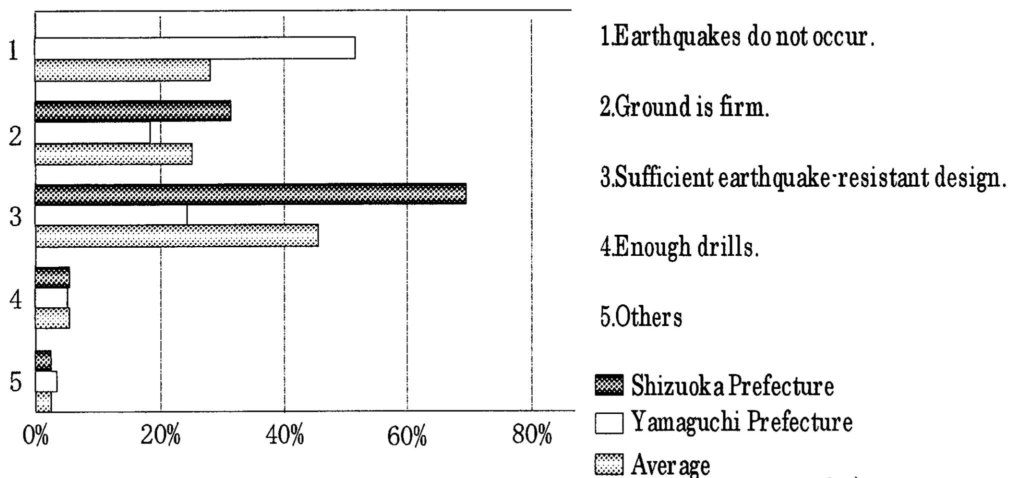

Figure 1.2 Reasons that teachers thought their school safe[4].

This figure shows that about 70 % teachers of each school thought their school safe. From this result, most school teachers were optimistic in handling an impending crisis if an earthquake should occur. Especially, attention should be paid to Shizuoka where Tokai earthquake frequently occurs and Yamaguchi because they are at almost equal ratios.

Furthermore, Figure 1.2 shows why teachers thought their school safe in Shizuoka and Yamaguchi Prefectures. Teachers in both prefectures answered that their school buildings were of sufficient earthquake-resistant design. From these results, it is found that teachers depended too much on material aspect of protection, such as, an earthquake-proof structure. However, there have been repeated casualties due to lack of knowledge about earthquakes, as mentioned in the case of the Nihonkai-chubu earthquake, even if school buildings were strong enough in an earthquake.

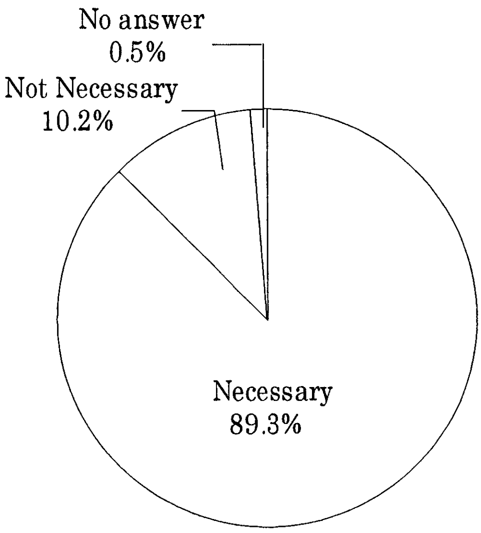

Figure 1.3 Is earthquake disaster preparedness education necessary? Teachers' responses[4].

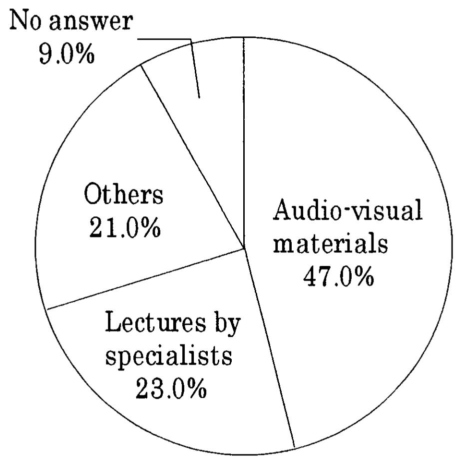

Figure 1.4 Teachers' preferences for earthquake disaster preparedness education materials or methods[4].

On the other hand, it was found that teachers thought earthquake preparedness education important. Figure 1.3 shows school teachers' responses to the question of whether earthquake preparedness education is necessary in seven prefectures. About 90% teachers felt strongly that such education is necessary. From this figure, it is found that most teachers strongly thought earthquake preparedness education necessary. Figure 1.4

gives a summary to opinions regarding the most desirable teaching materials or methods. Almost 50% teachers considered audio-visual materials the most effective.

From these results, it was found that teaching materials by using an audio-visual device should be developed for schools.

1.2.2 Present Condition of Fire Drills

It is very important not to only learn knowledge about earthquakes but also to practice evacuation in a fire drill in order to perform earthquake preparedness education in schools. Teachers' responses to the question of the number of times of a fire drill was performed in their school for a year are as follows:

(1) 90% schools in Tokyo perform a fire drill more than six times a year.
(2) 70% schools in Kanagawa also perform a fire drill more than six times a year.
(3) 90%-100% schools in other prefectures perform a fire drill less than six times a year.

Table 1.1 shows percentage of schools that performs a fire drill assuming a real earthquake. Most schools in this table assume a real earthquake except the ones in Yamaguchi and Kumamoto Prefectures. Yamaguchi Prefecture has the lowest percentage among the seven prefectures.

Table 1.1 Percentage of schools that perform a fire drill assuming a real earthquake

	Hokkaido	Tokyo	Kanagawa	Shizuoka	Aichi	Yamaguchi	Kumamoto
%	72	85	76	74	64	6	31

From these results, a fire drill as a part of earthquake disaster prevention education should be carried out repeatedly. However, there is no spare time to perform a fire drill in present school events. Therefore, it is necessary to develop a simulator so that school children can practice a virtual evacuation instead of a fire drill. Moreover, equipment to help teachers grasp school children's evacuation behavior should be developed.

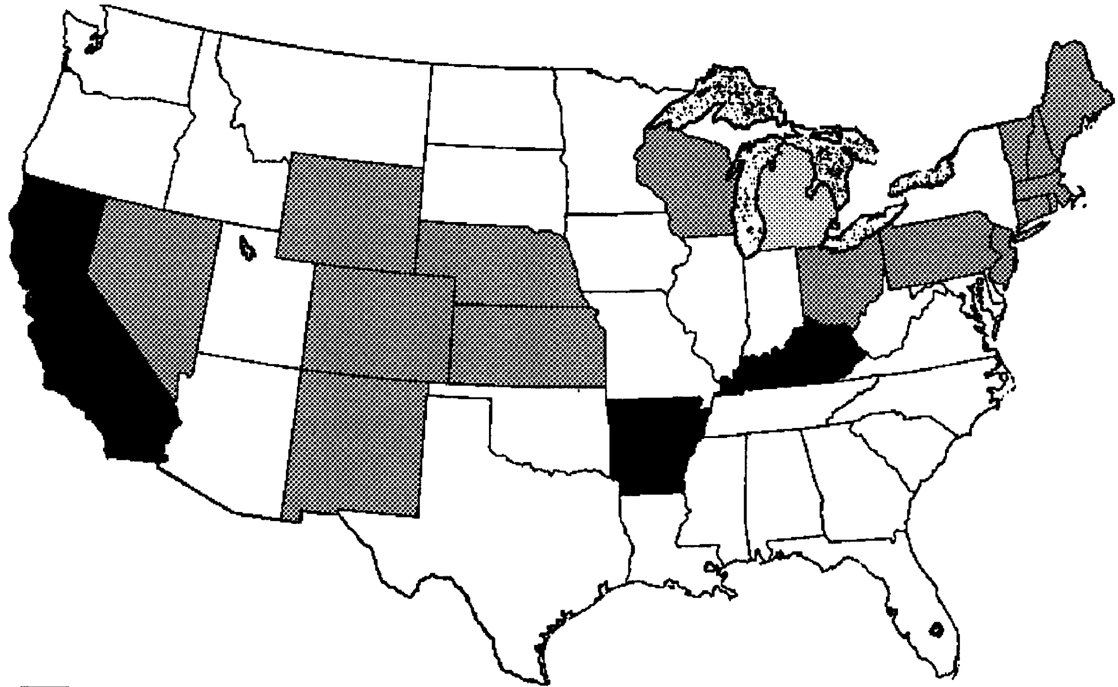

Figure 1.5 Present earthquake education in the United States[6)]

1.2.3 Earthquake Preparedness Education in the United States

For reference, present earthquake preparedness education in the United States is described below. In the United States, on the other hand, Federal Emergency Management Agency (FEMA) made manuals for earthquake prevention in school and publicized earthquake preparedness[9)]. Bay Area Regional Earthquake Preparedness Project (BAPEPP) that was established by California government distributed pamphlets of earthquake preparedness.

National Center for Earthquake Engineering Research (NCEER) started to research and study in many states as the project of earthquake preparedness education (1988). At first, NCEER grasped an earthquake preparedness education and they also researched useful teaching materials for every state[6]. The situation of dealing with an earthquake preparedness education at school in each state is shown in Figure 1.5. This figure shows that an earthquake preparedness education at school is introduced as education policy of a state government in California, Arkansas and Kentucky. Especially, both states of Arkansas and Kentucky lay emphasis on an earthquake preparedness education because New Madrid was struck repeatedly by 1880's New Madrid earthquake. On the other hand, other state governments thought earthquake preparedness important.

So NCEER let FEMA, BAREPP, every state government and National Science Teachers Association held a workshop for an earthquake preparedness education at school regularly afterwards[7, 8]. NCEER also provides a list of teaching materials which people can use[9].

BAREPP has continued enlightenment activity while cooperating with UCLA, NCEER and The Red Cross in California. Furthermore, it set a California Earthquake Preparedness Month with large campaigns aiming at an administration in the first week, the industrial circles in the second week, school in the third week and home and communications in the fourth week in April in 1989 before the Roma prieta earthquake occurred[10]. It was reported that the campaigns was effective during the Roma prieta earthquake.

However, it was reported that school teachers had no interest in and knowledge about an earthquake preparedness[11].

1.3 Review of Previous Studies

First, studies by other researchers related to earthquake preparedness education are described below.

Ohmachi et al. (1986), for example, tried to teach earthquake preparedness education by using videos with the explanations of earthquake disasters in elementary schools[12]. He investigated the change of children's earthquake preparedness awareness before and after they watched the video. Therefore, he found that their awareness about earthquake preparedness became heightened after they watched the video.

Taniguchi et al. (1992) devised a way to estimate damage based on natural and artificial environment at school[13]. They also analyzed the damage occurrence system, characteristics of damage occurrence based on viewpoints of previous earthquake damages and correspondence and countermeasures in school.

The software curriculum that the author develops is constructed taking into account these results.

Second, some researchers who have studied simulation models and simulators during a disaster are described below.

Meguro et al. developed a simulation model considered as a potential model[14]. It was devised with a human model evacuating in accordance with potential values. Differences in evacuees' wayfindings could be expressed. The method of potential values is introduced in the simulation model that the author develops.

Hayashi et al., for example, analyzed behavior of a leader in a fire by using a simulator in which users could let people take refuge as they look at a blueprint of a virtual building that was displayed on a screen[15].

Meguro et al. have also developed a simulator software by using technique of virtual reality and have compared its results with the result of wayfinding behavior by an actual experiment[16]. The author develops a simulator that can be performed on low-end personal computers considering a spec of personal computer in school.

1.4 Purpose of this Study

From written descriptions by people who had been involved in an earthquake, the author considered knowledge about earthquake preparedness and evacuation after an earthquake are indispensable as vital information as shown in Figure 1.6. However, there are no appropriate teaching materials with which teachers acquire and teach school children knowledge about earthquake preparedness in school even if they feel that it is necessary referring to the results of questionnaire survey as mentioned above. Moreover, there is no any equipments to practice evacuation, only participation in a fire drill.

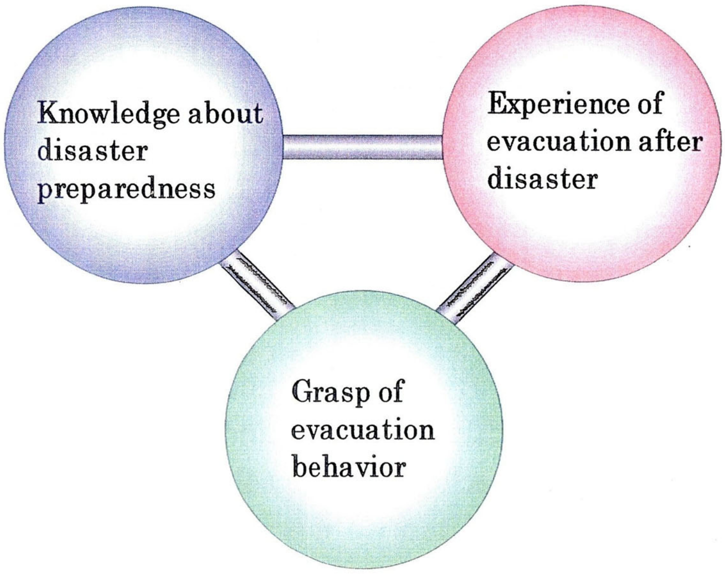

Figure 1.6 Three factors necessary for disaster preparedness education

Therefore, from these conditions and Masuda's proposal about disaster preparedness education (1988) [17], the author develops four kinds of software by using a personal computer to solve these problems in school. These software are as follows

First, the author developed the software for schoolteachers to acquire generic knowledge about earthquake preparedness and knowledge on earthquake prevention in schools[5]. Secondly, the software was developed for school children to learn experience about earthquake disasters and the method of coping with an earthquake experience[18],[19]. Thirdly, the simulator was developed for school children and school teachers to experience a virtual evacuation[20]. Lastly, the author developed the simulation software for schoolteachers to grasp school children's evacuation behavior[21], [22], [23].

1.5 Contents of this Paper

This dissertation is composed of six chapters. Chapter 1 is the preliminary of this paper where necessity and importance of earthquake preparedness education in school is discussed by examining past disasters, present earthquake preparedness education in school and previous studies on earthquake preparedness education. Furthermore, the objective of this study is explained.

In Chapter 2, the author first explains the questionnaire in 1990 in order to construct a curriculum for schoolteachers. Secondly, the summary of the software development for earthquake preparedness education for schoolteachers is explained. Furthermore, the learning effectiveness of the software is discussed.

In Chapter 3, the summary of software development for earthquake preparedness for school children is explained. Before developing the software, a new curriculum for school children that is constructed by using the Brain writing technique and the KJ method is described. The author evaluates its learning effects by distributing the software to an elementary and a junior high school in Ube City, and discussed the result of the evaluation.

In Chapter 4, the details in developing the evacuation simulator software on a 3 dimensional image is explained. To evaluate this software, the author explores wayfinding behavior by experiment using two kinds of mazes. The result of the evaluation is discussed by comparing the result of the simulator with that of actual maze experiments.

In Chapter 5, the outline of developing of the computational simulation model including the modeling of evacuees, guides and a fire is explained. To evaluate this simulation model, the author simulates evacuation by modeling an actual underground shopping center in Tokyo assuming that school children were involved in a fire during an earthquake on a school excursion. The result of the simulation is discussed.

Finally, conclusion and summary are described in Chapter 6. Moreover, direction for future research is discussed based on problems left in this study.

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CHAPTER 2

Development of Software for Earthquake Preparedness Education for School Teachers

2.1 Introduction

It is necessary for teachers to have knowledge about earthquake preparedness because they may play an important role in school during earthquake disasters occurrences. As mentioned in the previous chapter, Naruse's questionnaire survey (1987) found that many teachers understood the necessity of earthquake preparedness education, but felt that the available audio-visual materials were unsatisfactorily interactive.

In response, the author developed an interactive personal computer software to be used for earthquake preparedness education, which is designed for teachers' use in elementary and junior high schools. Prior to developing the software, the author distributed 200 questionnaires to elementary and junior high schools in Shizuoka and Yamaguchi prefectures to ascertain the appropriate information be included in the software. To maintain teachers' interest, the software was developed with animation, sound effects and narration used wherever possible.

After the completion of the software package, the author distributed it to a total of 10 elementary and junior high schools in Yamaguchi prefecture and then evaluated its effectiveness by examining teachers' understanding before and after its presentation.

In this chapter, the author first outlines the result of the 1990 questionnaire survey excluding the result that was described in Chapter1, then it describes the hardware and software application which were used to develop the software for teachers' use and outlines its contents. Finally, the effectiveness of the software is discussed.

2.2 Questionnaire Survey on Contents of the Software

As described in Chapter 1, 200 questionnaires were distributed to elementary and junior high schools in Shizuoka and Yamaguchi Prefectures. The main objectives of the questionnaires in 1990 were not only to examine the level of awareness of earthquake disaster prevention but also to ascertain the measures taken by teachers in schools. Samples of the results are shown in Figures 2.1 and 2.2. Figure 2.1 lists what teachers want to know most about earthquake preparedness. A very high percentage of teachers wanted to know how past disasters had affected schools and the mental state of children during an earthquake in both prefectures. From this finding, the teachers interested in protecting school children from earthquake disasters is found as follows: 60% wanted to know the plans for earthquake drills in Yamaguchi Prefecture and 50% wanted to know earthquake predictions in Shizuoka Prefecture. They also emphasize the lack of attractive and effective teaching materials on this subject. These results reflect the problem peculiar to both prefectures.

The author collected written accounts by people who experienced earthquake disasters from libraries in Akita, Miyagi, Chiba, Shizuoka, Nagano, Niigata, Fukui and Kochi Prefectures in Japan, because the

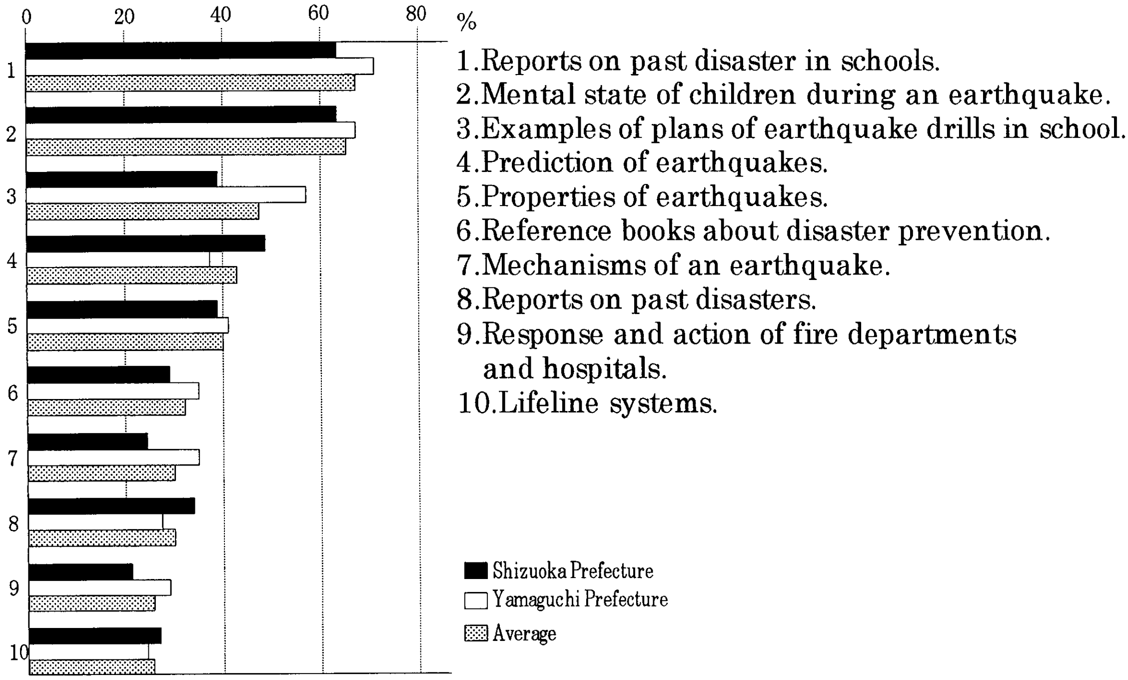


Figure 2.1 Items revelant to disaster preparedness education that teachers want to know about

authors thought it was very important to learn from past disasters in order to develop a suitable curriculum. The result of the analysis is shown in Figure 2.2. Figure 2.2 (a) shows us a pie graph of written description format. It is found that about 50% are essays based on impression in this figure. Figure 2.2 (b) shows the time the document was written about. From this figure, around 50% wrote the content about their experience during an earthquake. It is found that their experience left them a strong impression of earthquakes. Figure 2.2 (c) shows the places of their earthquake experiences with where they experiences with 25% felt at school or home. What they feared is shown in Figure 2.2 (d). Most of them feared the collapse of a building or ground motion in an earthquake. From this figure, it is found that explanations of earthquake-proof structures and the characteristics of earthquake are necessary in devising a software curriculum.

From those findings, the author learned that knowledge about earthquakes and what might happen during an earthquake play a critical

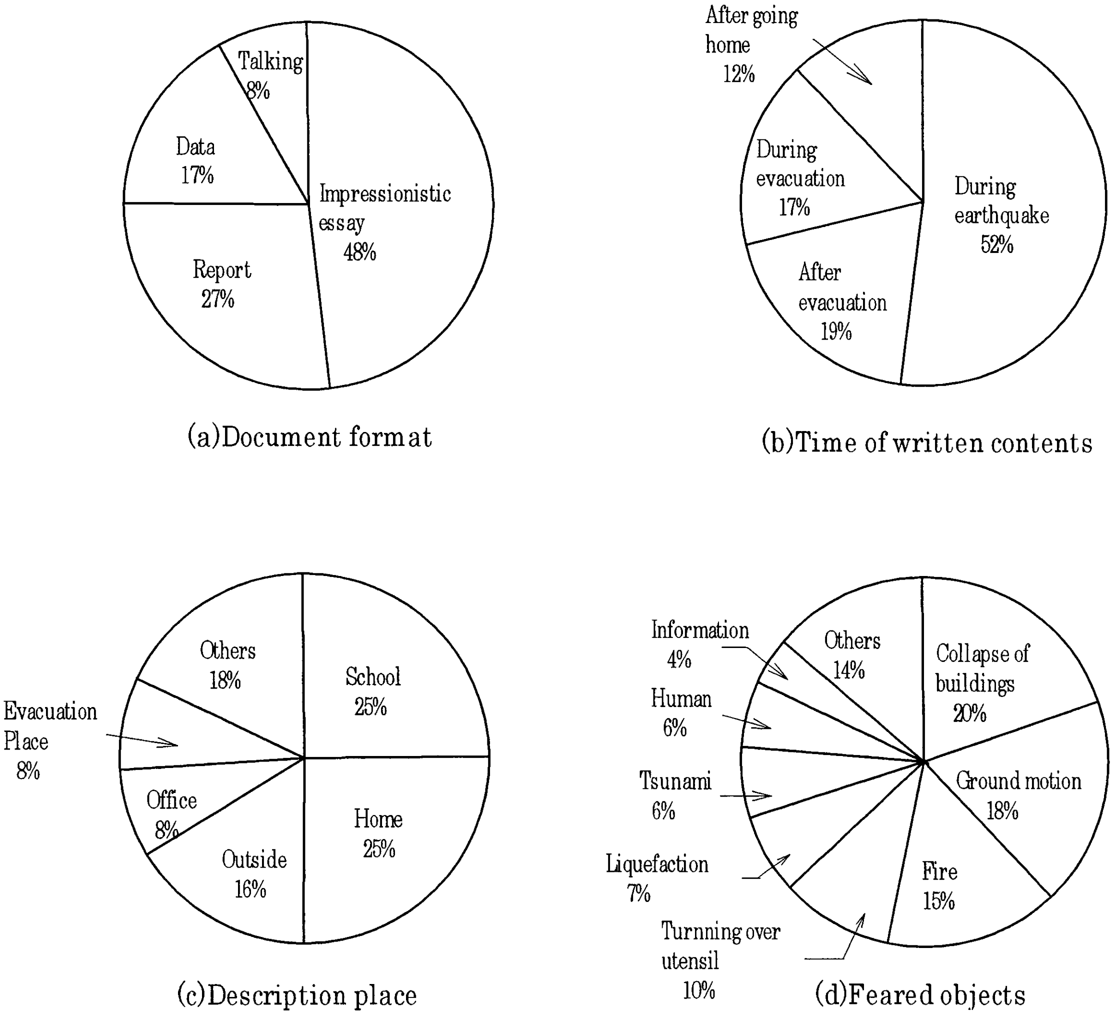


Figure 2.2 Analysis of descriptions written by people who experienced earthquake disasters

role in survival . This highlighted the importance of earthquake preparedness education, especially for schoolchildren.

Therefore, the author constructed a curriculum based on the results of the questionnaire and the analysis of descriptions written by people who experienced earthquake disasters.

2.3 Procedure of Development of Software

2.3.1 System Configuration

The author developed the software on a Macintosh IIci micro computer (Apple Computer, Inc.) with the software application package Hyper Card. Because Hyper Card uses only black and white, the package Canvas 3.0 which enabled us to use a 256-colors screen was utilized. To apply pictures taken after earthquakes to the Quake Busters program, we used the package Color Magician III to scan relevant pictures. The hardware and software utilized are shown in Table 2.1 and Figure 2.3. These hardware and software was selected because of the following reasons.

(1) It is very simple to use with a mouse.
(2) Hyper Card is easily controlled by the associated programming language, Hyper Talk.
(3) Sound could be recorded and played with the aid of the package Mac Recorder.
(4) Further modifications and improvements can be made with ease.

Table2.1 Application software used

Software	Function
HyperCard 2.0J	Controlling software
Canvas 3.0	Drawing pictures
Color magician III	Scanning pictures
Mac Recorder	Recording sounds
Quick Time 1.0	Playing movies on HyperCard
Director 3.0J	Creating animation

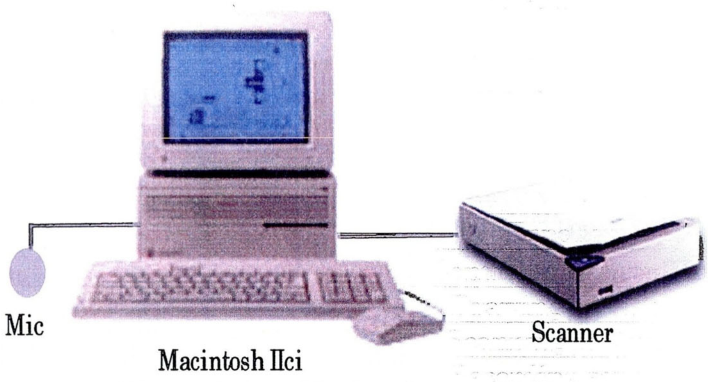


Figure 2.3 The hardware system

2.3.2 Construction of Software

As Hyper Card uses only black and white (1bit, 2colors), a sophisticated technique was needed to introduce color on screen[1]. The process is outlined in Figure 2.4. First, a window was set up on a HyperCard screen. Then we drew a color picture using Canvas 3.0 or scanned a picture using Color Magician III, which then was saved in a movie library folder as a special type of file PICT. Afterwards, the PICT file was transmitted to the open window on the HyperCard screen by a control program written in Hyper Talk. Animations drawn with Director (Macromedia, Inc.) also were converted into files and saved in the movie folder. These files could be transmitted to the open window on the Hyper Card screen by using the HyperTalk, a kind of programming language, and QuickTime (Apple Computer, Inc.). By interlinking color pictures with color animations and adding sound effects, the author have developed a multi-media presentation on the HyperCard screen.

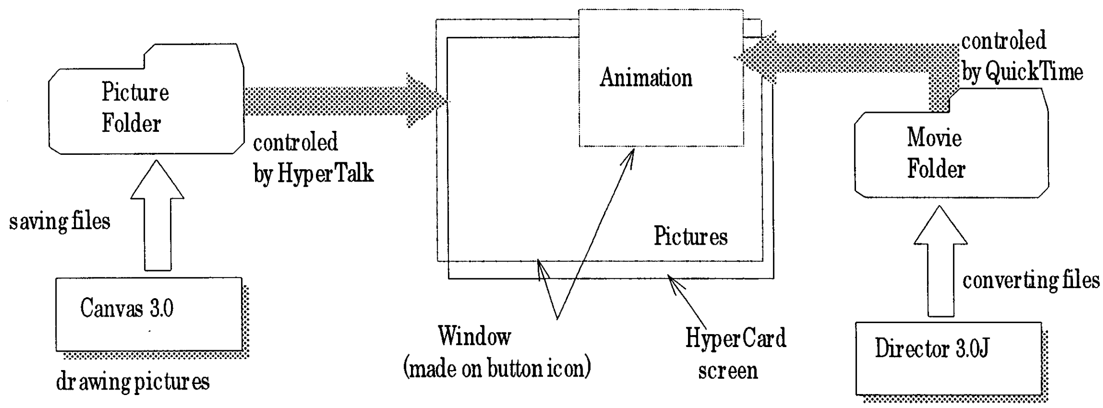


Figure 2.4 Procedures for showing color pictures and animations on HyperCard

2.4 Learning Contents

2.4.1 Construction of the Curriculum

In learning about earthquake preparedness, understanding of the earth sciences, earthquake engineering, the psychology of human responses to emergencies, past earthquake disasters, etc., are all necessary. Furthermore, such information needs to be integrated and well presented in order to provide learners clear guidance on how to cope with and survive an earthquake. Therefore, the author gathered information collected from reference books about earthquake prevention, pamphlets published by local governments and other reference books on earthquake disaster prevention. The author tried to develop a software based on the results of the 1990 questionnaires and the collected information.

With this in mind, the information was divided into three modules under the headings: "Understanding earthquake", "Past earthquake disasters and survival", and "Preparation for earthquake hazards" based on Taniguchi's research[2] and linked them through the "Menu Card" shown in Figure 2.5. Each module is explained later.

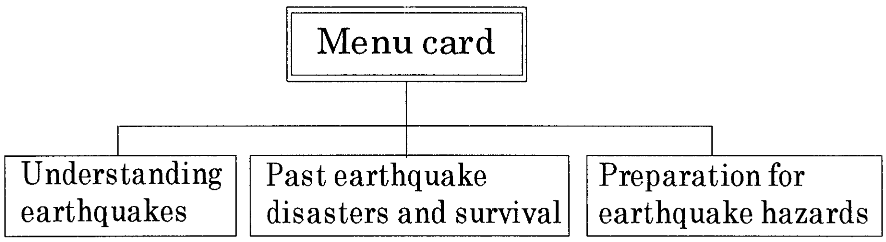


Figure 2.5　Contents of the software

2.4.2 Introduction to Software

After the opening animation theme music, the Menu Card appears on the screen (Photo 2.1). This is a control card and has five "buttons." By clicking one of the buttons, users can have access to any one of the three modules and the users' guide.

Selecting a module brings up a screen with five buttons in the bottom right corner and an indigo blue box in the left corner (Photo 2.2). This box called Navigation Palette gives directions for using the software program. The functions of the five buttons are

(1) "?" accesses the help menu (users' guide),
(2) "Another curriculum" moves to another module,
(3) "REW" moves back to the previous card, and
(4) "FF" moves forward to the next card.

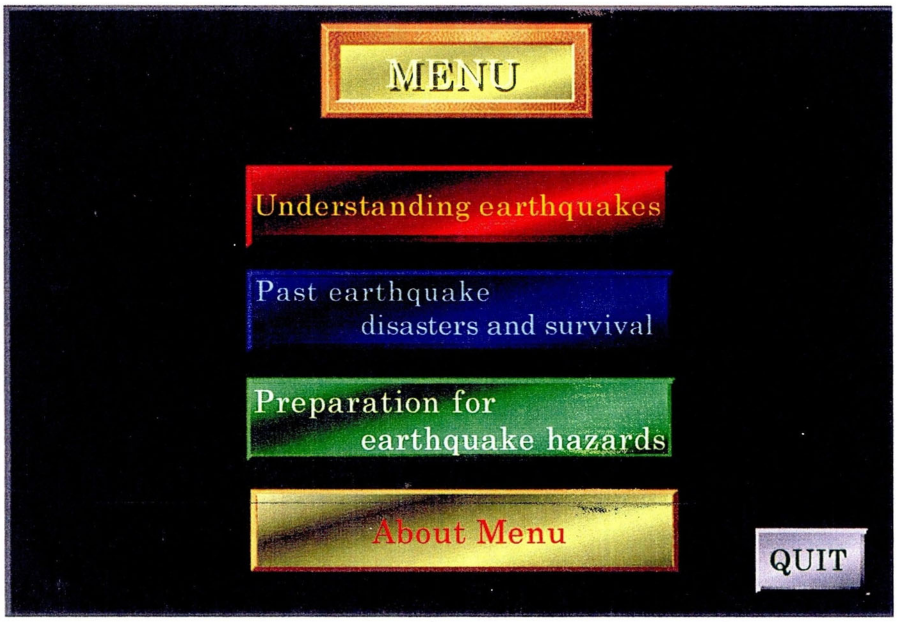


Photo 2.1 Menu Card

Photo 2.2 Navigation Palette

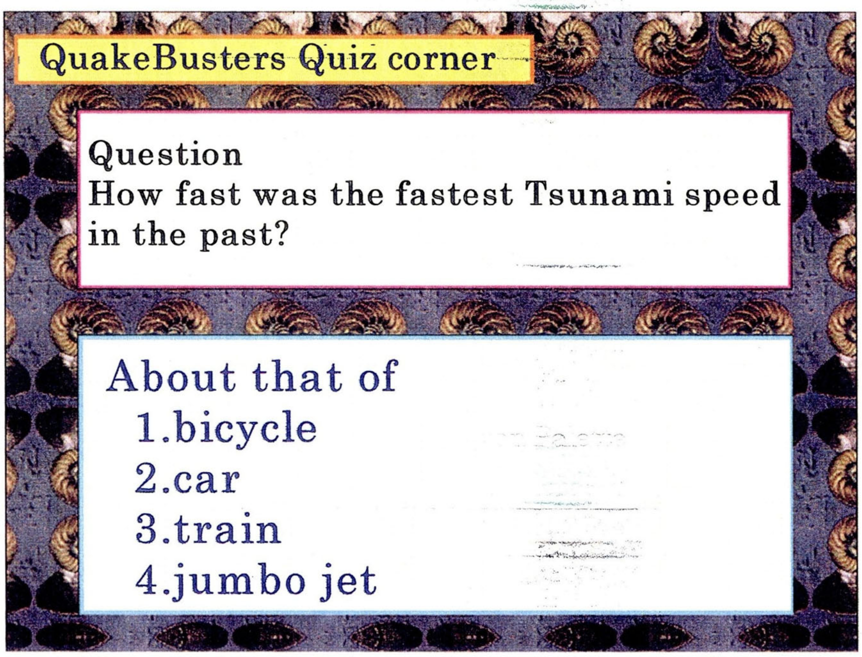


Photo 2.3 Sample of a quiz

With the use of a mouse for these five buttons, anyone who is not accustomed to personal computers can move through the cards in a module and learn about earthquake disaster prevention. We also inserted quizzes in each module. A sample card for a quiz is shown in Photo 2.3.

2.4.3 Understanding Earthquake

This module, divided into six areas, explains earthquake mechanisms, characteristics and terminology. If users learn about and understand the processes which have shaped the earth as it now exists, they will be less fearful of earthquakes. The six areas in this module are

(1) Structure of the earth,
(2) Continental drift,
(3) Plate tectonics,
(4) Mechanisms of an earthquake,
(5) Characteristics of earthquake motions, and
(6) Explanation of technical terms.

Three sample cards for this module are shown in Photos 2.4, 2.5, 2.6 and 2.7. Photo 2.4 is the front screen of the this module. Photo 2.5 explains

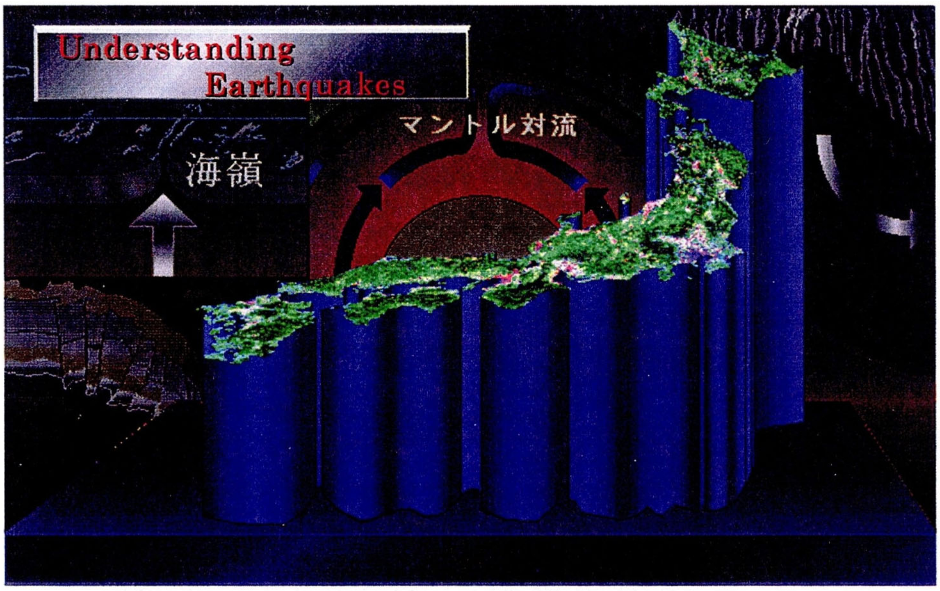


Photo 2.4 Front screen of Understanding earthquakes

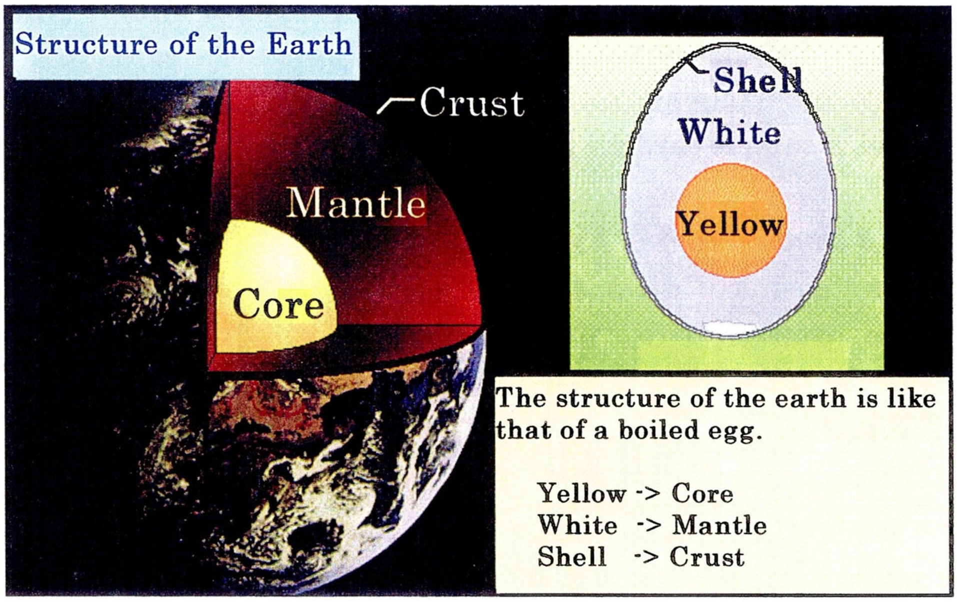


Photo 2.5 Structure of the earth

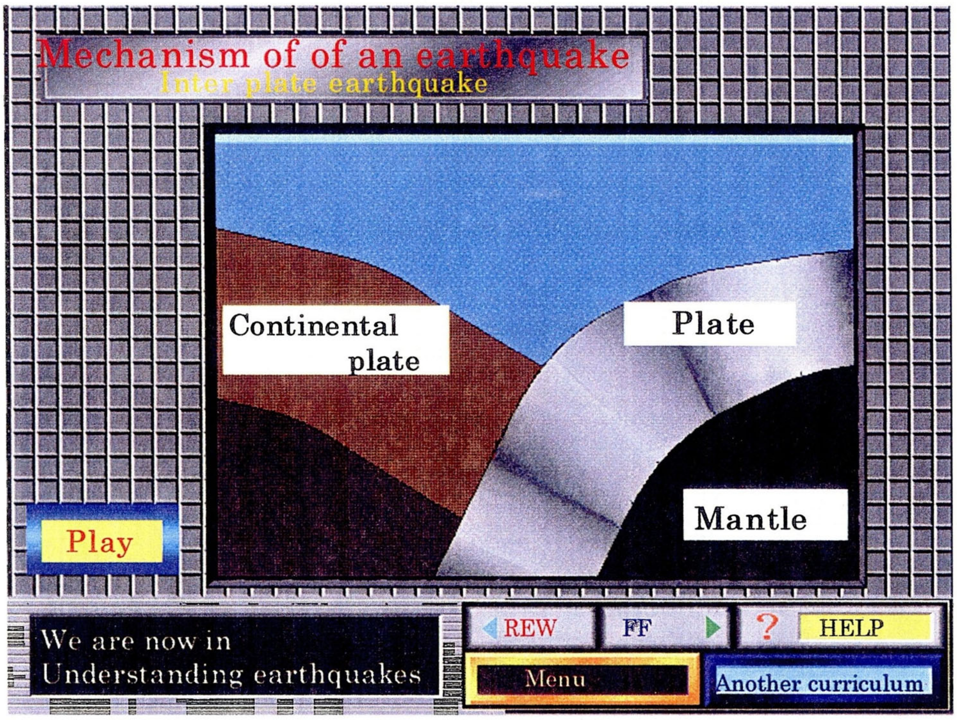


Photo 2.6 Mechanism of earthquake

the interior of the earth. The earth is compared to a boiled egg to help explain the layered structure of the earth. Photo 2.6 is an animation frame that explains the mechanism of inter-plate earthquakes. Photo 2.7 explains

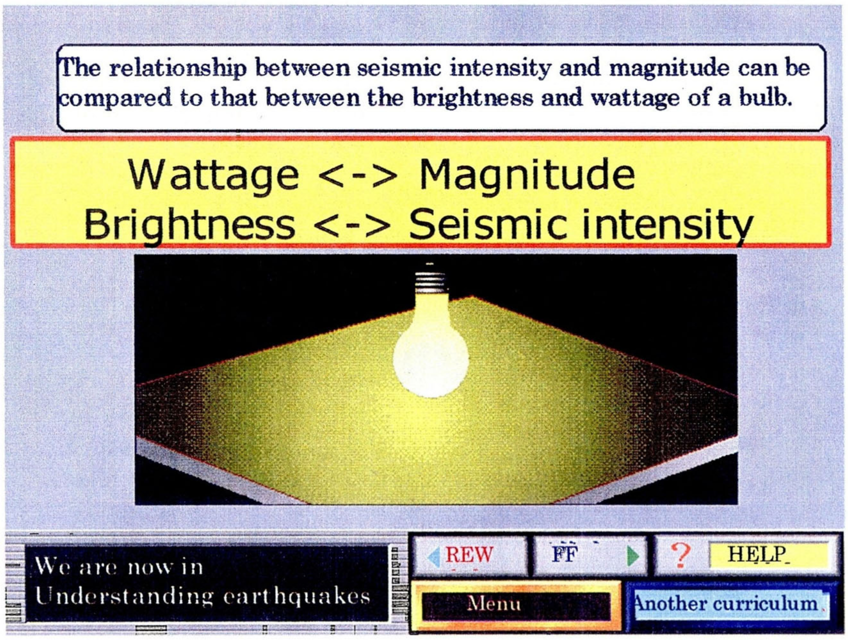


Photo 2.7 Relationship between the brightness and the wattage of a bulb

the relationship between seismic intensity and magnitude, which can be compared to the relationship between the brightness and the wattage of a bulb.

2.4.4 Earthquake Disasters and Survival

This module stack offers practical knowledge about an earthquake, for example, a manual for teacher's action during and after an earthquake. Factors which trigger secondary disasters around schools also are explained. The main areas in this module are

(1) Fear of fire,
(2) Mechanism and danger of liquefaction,
(3) Characteristics of soft ground,
(4) Mental state during an earthquake,
(5) Planning for safe evacuation, and
(6) Earthquake-proof structures.

Sample cards are shown in Photos 2.8, 2.9, 2.10 and 2.11. This module starts at the screen as shown in Photo 2.8. Photo 2.9 explains the

Photo 2.8 Top of the module "Earthquake Disaster and Survival"

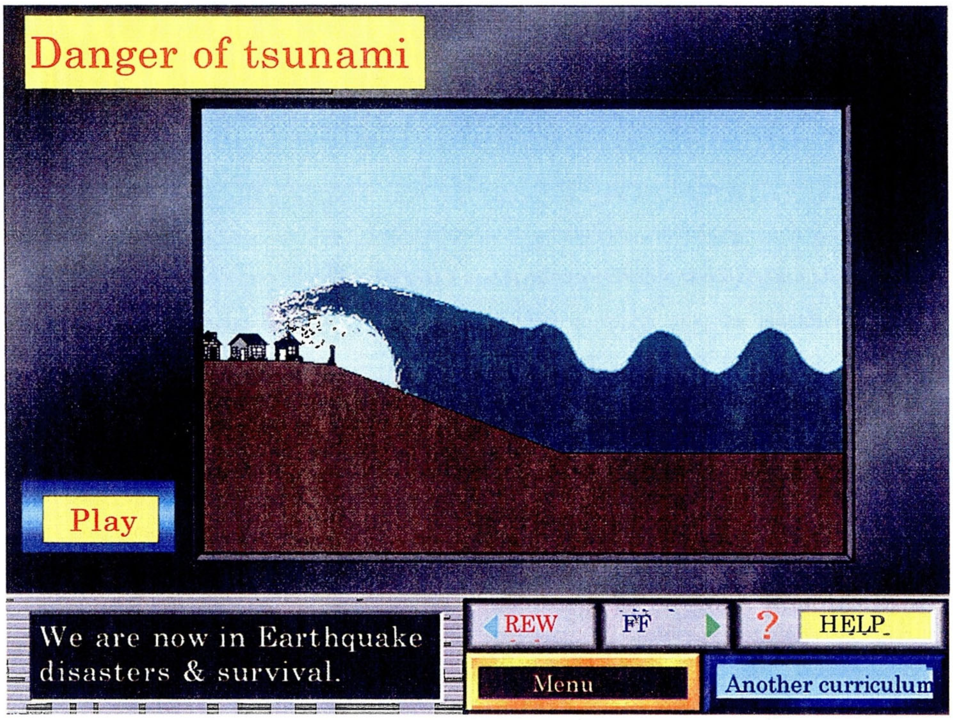


Photo 2.9 Danger of tsunami

characteristics and danger of a tsunami. The height of a tsunami steadily increases as it runs into an inlet or narrow bay. Animation is used to emphasis the height, velocity and danger of tsunamis as they are usually

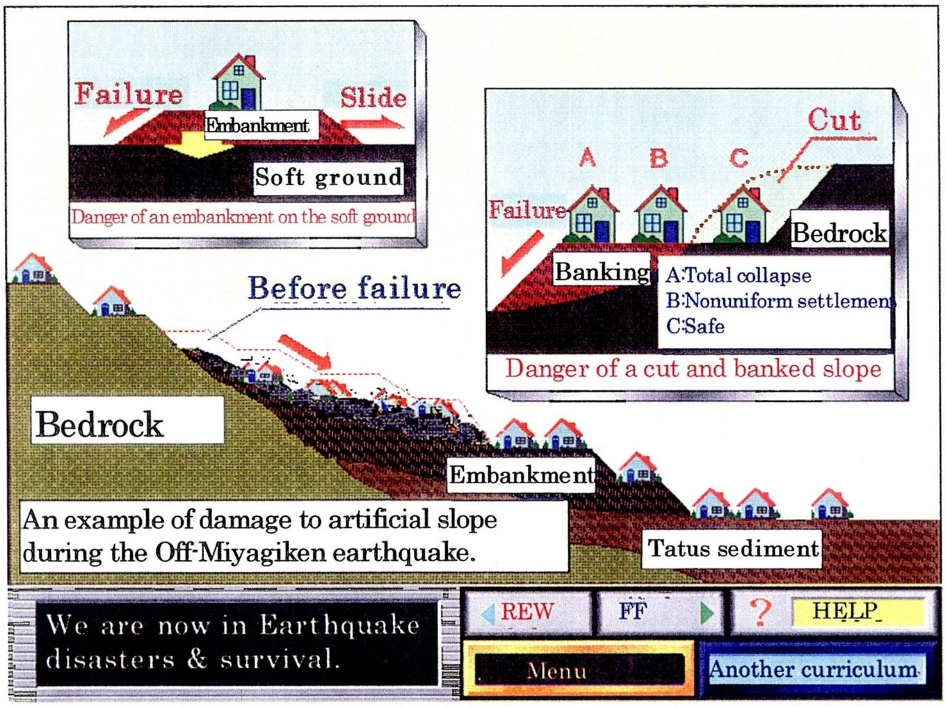


Photo 2.10 Danger of embankments

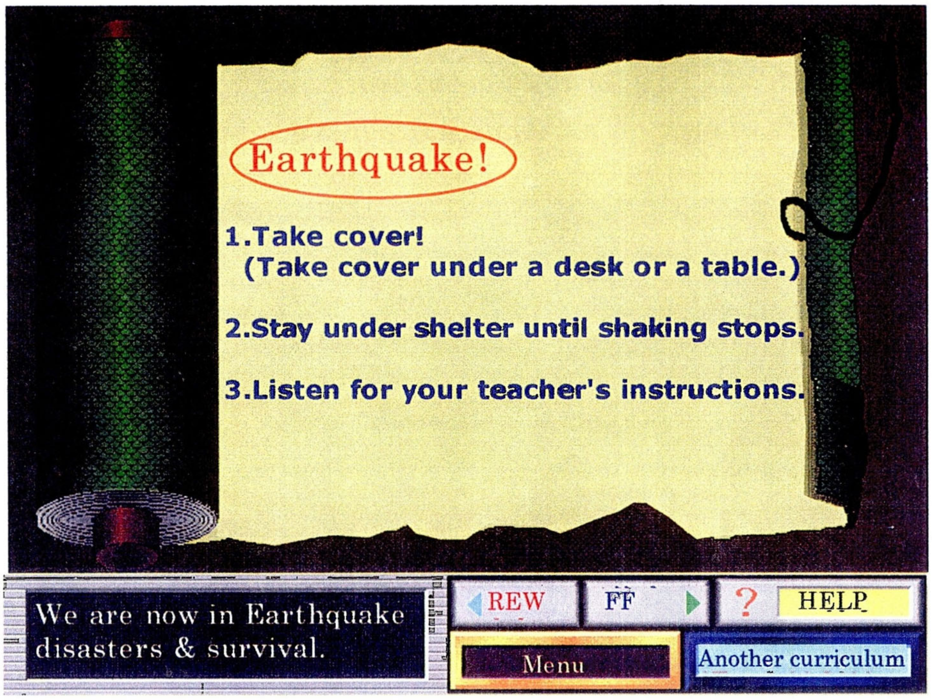


Photo 2.11 How to react to an earthquake

underestimated by commoners. Photo 2.10 explains the danger of embankments set on soft ground or artificial slopes. Photo 2.11 shows a

Makimono, i.e., a text book of *ninja.* This *ninja-text* teaches users how to react if the classroom floor starts to shake.

2.4.5 Preparation for Earthquake Hazards

This stacks focuses on ways to counter potential hazards, such as, fires, broken windows and overturned free-standing furniture (e.g., bookcases or cabinet) in school buildings during an earthquake. The importance of communication and lifeline systems such as the electricity, gas, water supply and telephone lines are emphasized. The four areas in this module are

(1) Potential hazards and preventive countermeasures in school,
(2) Fire prevention,
(3) Situation of lifeline systems after an earthquake, and
(4) Communication and information during and after disasters.

Sample cards are shown in Photos 2.12, 2.13, 2.14 and 2.15. Screen as shown in Photo 2.12 is indicated at the beginning of this module. Photo 2.13 explains how to prevent a chemical fire in a science classroom. Photo

Photo 2.12 Front screen of the module "Preparation for Earthquake hazards"

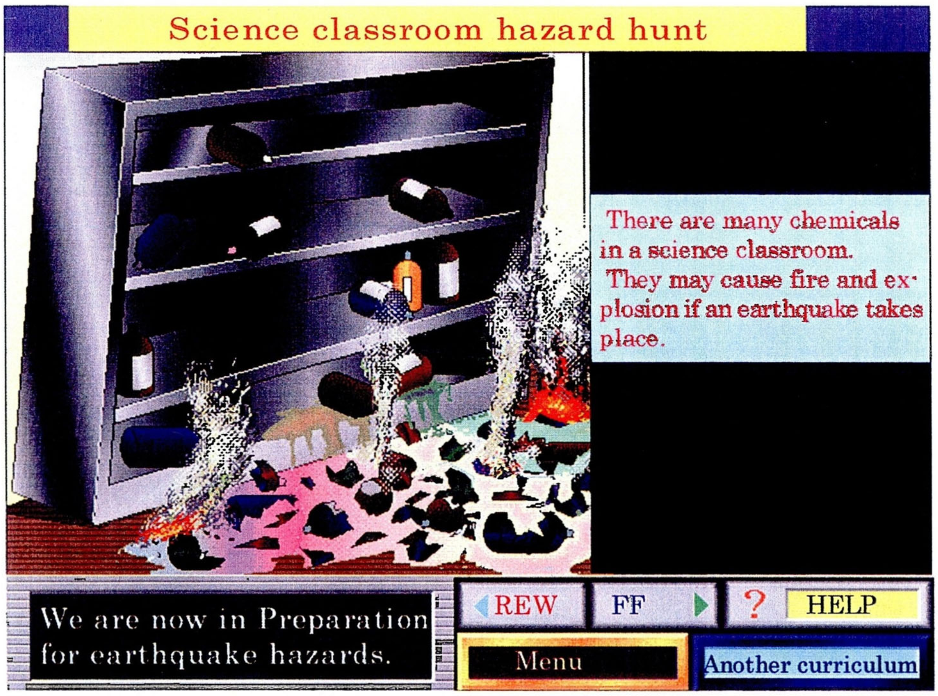


Photo 2.13 Danger of science classroom

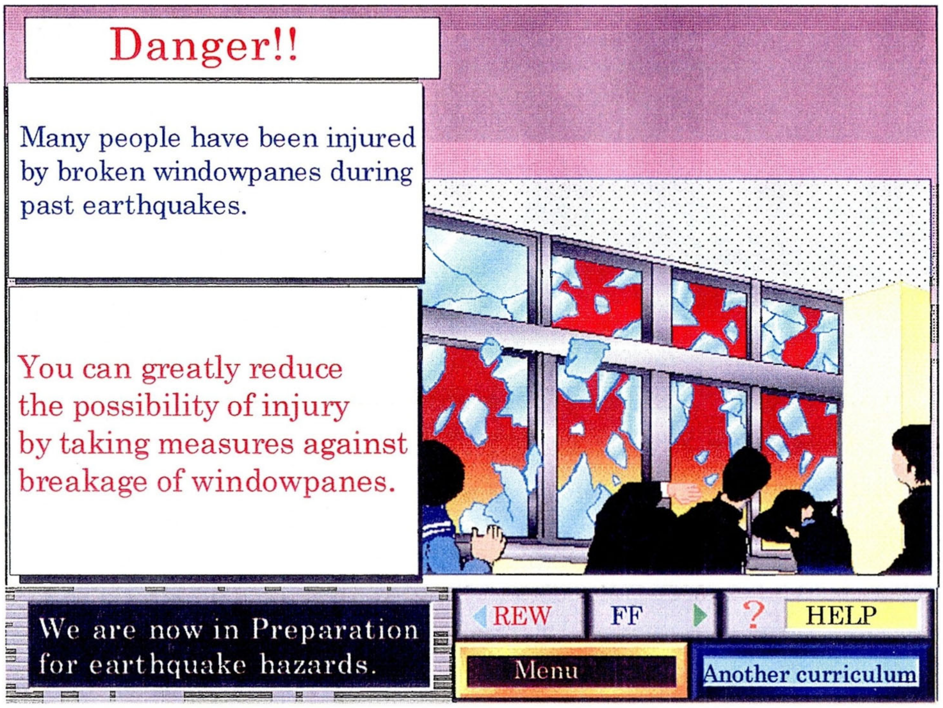


Photo 2.14 Danger of windowpanes

2.14 explains the danger of broken windowpanes. Photo 2.15 shows the route of communication from school to home.

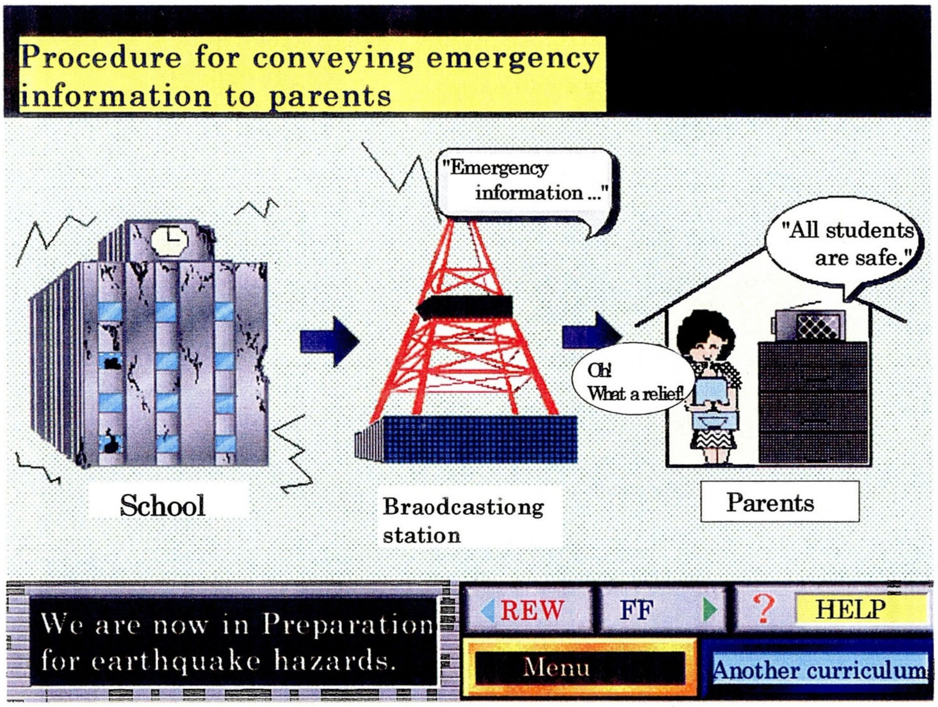


Photo 2.15 Route of information from school to home

2.5 Evaluation of Software

2.5.1 Method of Evaluation

To evaluate the effectiveness of the developed software, the author distributed it to 10 schools, three elementary and seven junior high schools, in Yamaguchi Prefecture. Teachers in these schools were given the same test on earthquake preparedness before and a week later using Quake Busters.

2.5.2 Results of Evaluation

Replies were received from 26 teachers. A comparison of the percentage of correct answers in the three areas before and after the introduction of Quake Busters is shown in Figure 2.6. Before its introduction, only 20% of teachers gave correct answers for the "Past earthquake disasters and survival" and about 40% for the "Preparation for earthquake hazards". These results indicate the lack of knowledge about earthquake preparedness among teachers in Yamaguchi Prefecture, which is attributed to the infrequent and small size of earthquakes experienced in that prefecture. After Quake Busters was introduced, the answers showed an improvement for all modules, particularly in the “Preparation for earthquake hazards”, for which correct answers almost reached 80%. In the “Past earthquake disaster and survival”, however, the correct answers did not reach 50% even after the introduction of Quake Busters.

Figure 2.7 shows the level of difficulty of the curriculum felt by the respondents. From this figure, most of them felt that the level of difficulty is appropriate for every module. The result of operability of the software is shown in Figure 2.7. This figure shows us that 60% respondents felt the operation was easy. The reason is due to the effectiveness of using a mouse. Lastly, the result of understanding screen displays is shown in Figure 2.8. From this figure, about 90% respondents felt that the screen was clear and understandable. The reason is due to the effectiveness of introducing color pictures and animation.

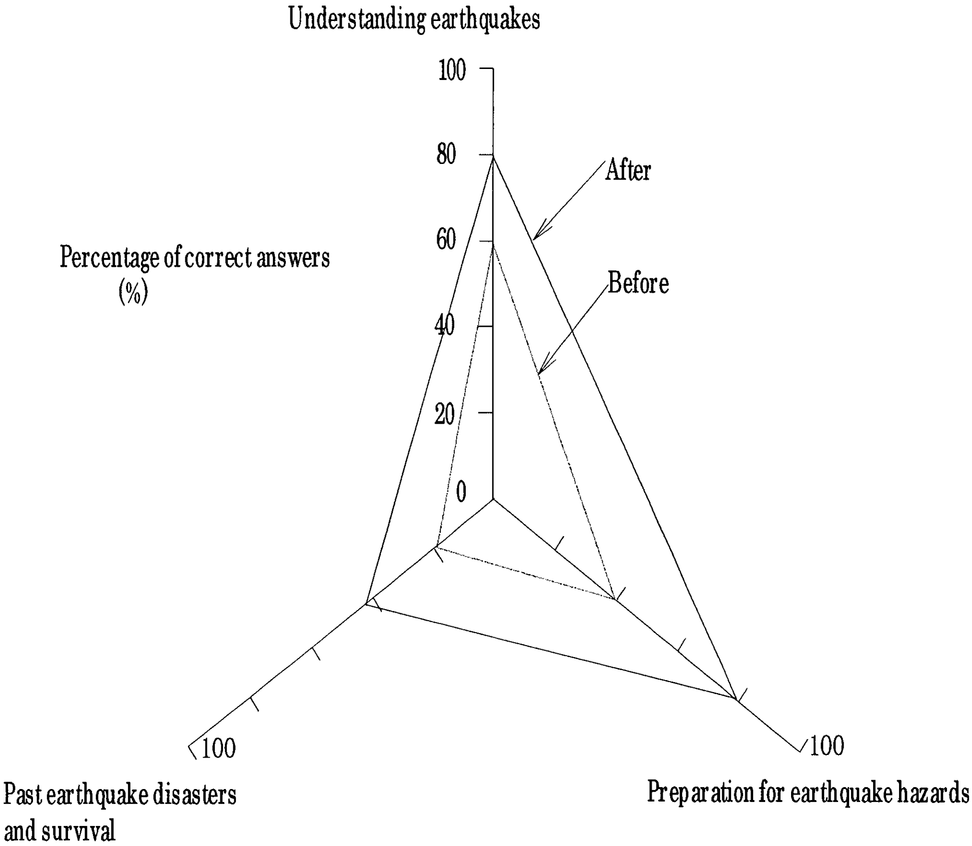


Figure 2.6 Comparison of the results of tests give before and after the introduction of the developed software.

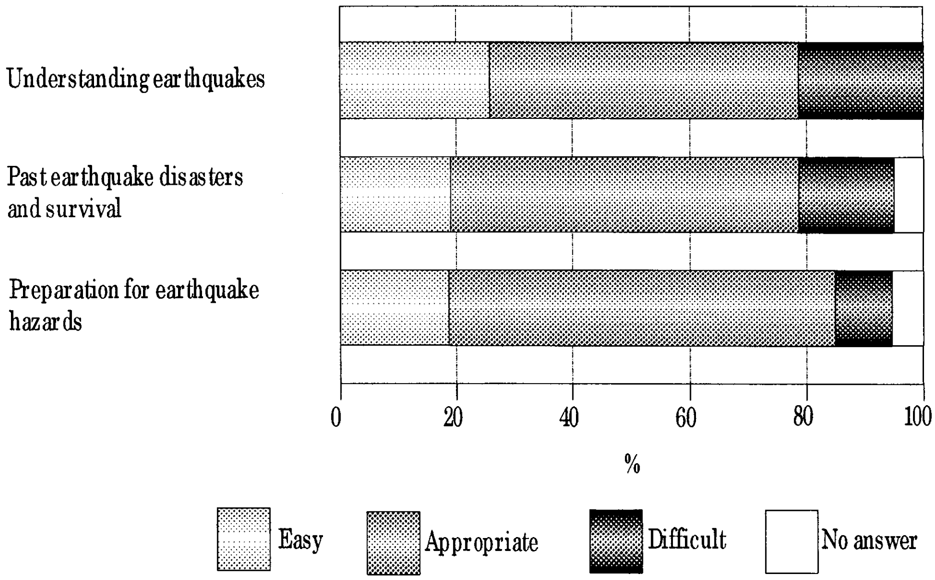


Figure 2.7 Levels of difficulty of the curriculum

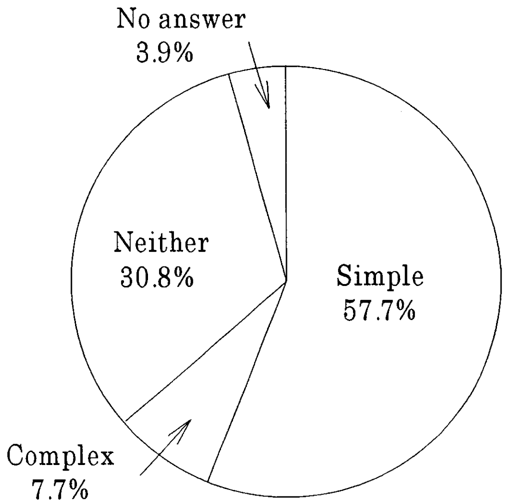


Figure 2.8 Operability of the software

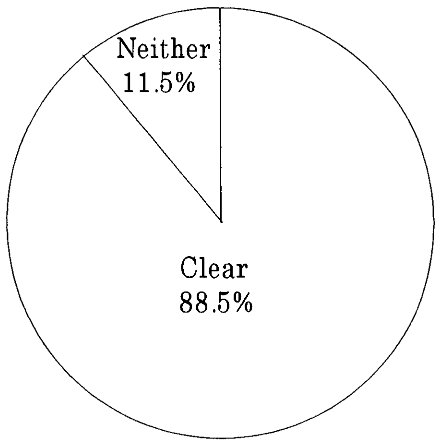


Figure 2.9 Understanding screen display

2.6 Summary

In this chapter, the author has developed a software for earthquake education for school teachers. The educational software for teachers consists of three modules: “Understandings earthquakes”, “Past earthquake disasters and survival”, and “Preparation for earthquake hazards”. The areas included in the first module are "Structure of the earth", "Continental drift", "Plate tectonics", "Mechanism of an earthquake", Characteristics of earthquake motions" and "Explanation of technical terms". The items in the second module are "Secondary disasters", "Planning for an emergency evacuation", "Earthquake-proof structures" and "Mental state during an earthquake". The items include in the last module are "Potential Hazards and preventive countermeasures", "Lifeline systems" and "Communication and information during disasters". All information can be accessed simply by clicking a mouse.

The author distributed Quake Busters to three elementary schools and seven junior high schools in Yamaguchi Prefecture in1993 in order to evaluate its effectiveness and merit. Results showed that teacher understanding of earthquake disaster prevention had improved and that the software level was appropriate.

The cards in the modules are put in order like a book. Users, therefore, must learn the items according to the arranged order. The structure is not very attractive to users because they cannot choose other items freely. If users could move through the various areas at will, there would be greater appeal and probably higher potential of learning. Therefore, we plan to attach a random access function to the structure of the modules.

Lastly, the author evaluated the effectiveness of the software based on 26 replies and found it effective. It is necessary, however, to distribute it to more elementary and junior high schools in other prefectures as well as in Yamaguchi Prefecture and to evaluate the actual effectiveness of it.

References

1) Danny Goodman et al.: Development Technique of HyperCard Stackware –The First Book-, BNN, pp.85-124, 1989.
2) Hitoshi Taniguchi: The Way of Damage Estimation Based on Natural and Artificial Environment at School, Report on Questionnaire Survey about Earthquake Preparedness Education in School, p.42, 1992 (in Japanese).

CHAPTER 3

Development of Software for Earthquake Preparedness Education for School Children

3.1 Introduction

The author already explained that school children might be killed because of the lack of vital information about earthquake and its disasters in an encounter with an unexpected earthquake, in reference to the previous disasters. Accordingly, school children should learn earthquake preparedness, such as, characteristics of earthquake or preparation for earthquake. On the other hand, teachers need to understand the students' grasp of learning earthquake prevention. Therefore, the author developed a software for earthquake preparedness education for school children and proposed a method for evaluating the learning effect.

In this chapter, the procedure for constructing a new curriculum for school children by using the Brain writing technique and the KJ method is first described, and the contents of the software is explained. Furthermore, to evaluate the effectiveness of earthquake preparedness education visually, methods in the field of educational technology are introduced as follows:

(1) S-P(Student-Problem) score and S-P(Student-Problem) curves,
(2) Caution Index, and
(3) Item Relational Structure Analysis (IRS).

These methods will be explained later. Finally, after developing the software, it was distributed to an elementary and a junior high school and analyzed as shown in the results of (1), (2) and (3) mentioned above for evaluating the software.

3.2 Construction of the Curriculum for School Children

The author constructed a new curriculum for school children based on the curriculum for teachers that was already developed in chapter 2.

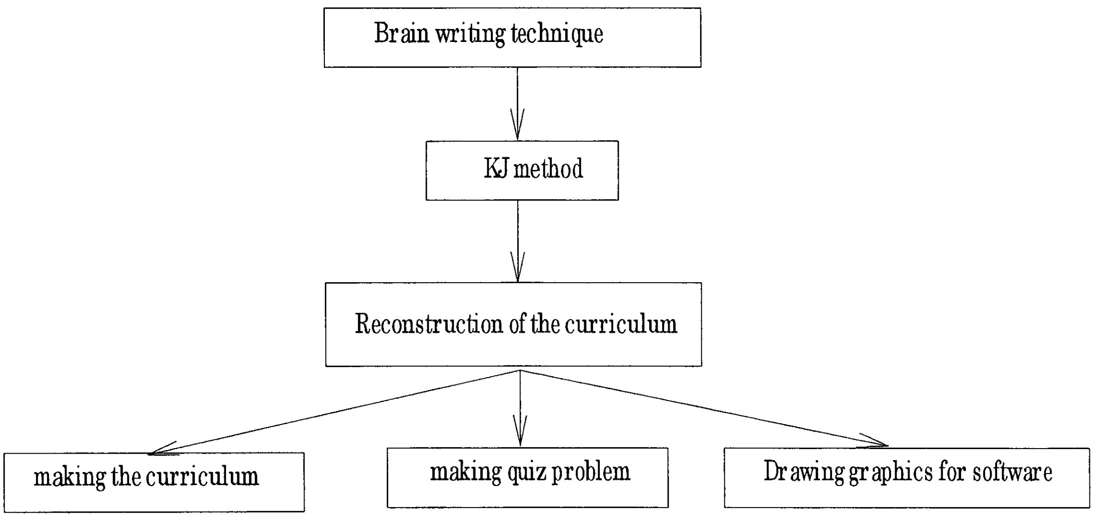


Figure 3.1 Procedure of constructing the curriculum

The procedure of curriculum construction is shown in Figure 3.1. In order to construct the curriculum, the author first employed the brain writing technique to help collect items that should be included in the new curriculum. Collected items are then classified by using the KJ method. Classified items are rearranged based on the report "Education program of fire prevention for the youth" from the Fire Defense Agency of the Ministry of Home Affairs[1)]. Lastly, quiz problems are made for the curriculum.

3.2.1 Arrangement of Curriculum by using the Brain Writing Technique

The brain writing technique is one of the methods used in the field of system engineering. People's written thoughts and opinions were collected in a list[1)].

In this study, two researchers who major in earthquake engineering including the author and 10 university students wrote down key words that are necessary for earthquake preparedness education according to the procedure of the brain writing technique. The total number of responses is 480. Commonalities in these responses are as follows:

(1) there are few opinions on the scientific knowledge, such as, the mechanism of earthquake,
(2) many opinions on volunteer and cooperation were sent in because many volunteers were attracted to the attention of the 1995 Hanshin-Awaji earthquake, and
(3) there were also many opinions on evacuation shelters, telephone communication during disasters and victims' heart conditions.

3.2.2 Grouping of Items by using the KJ Method

The comments obtained by the brains writing were numerous and complicated. Therefore, the comments were sorted into some groups, then by items using the KJ method[2)].

First, comments obtained by the brains writing is divided into 17 groups with titles representing contents. The contents and characteristics are shown in Table 3.1. Special features are also listed in the following:

(1) there are 8 items about fire because fire often breaks out in an earthquakes, especially the ones in the 1995 Hanshin – Awaji

Table 3.1 Learning items grouped by the KJ method

	Learning items		
Earthquake	·History of earthquake ·Fault ·Volcanic earthquake ·Example of earthquake damage	·Magnitude and seismic intensity ·Earthquake prediction ·Period of earthquake ·Plate tectonics	·Experience of an earthquake ·Example of damage in school ·inland earthquake
Natural disasters	·Tsunami ·Liquefaction ·Knowing topographic features	·Topographic features ·Ground	·Landslide ·Rain
Disasters of man-made structures	·Response of skyscraper ·Foundation of architecture ·Architecture period and type	·Lifeline systems ·Bridge ·Danger of downstream of dam	·Road ·Power failure
Information	·Canard and panic ·Communication method	·Getting correct information ·Source of information	·Safety information
City after earthquake	·Traffic ·Car	·Money	…………………
Fire	·Fire extinguishing ·Electric leakage and fire by Electricity ·Gas	·Fire prevention ·Characteristics of smoke ·Escape from a fire	·Characteristics of a fire ·Alarming a neighborhood about a fire
Right after earthquake	·Way of evacuation ·Rescue ·Calm ·Danger of fluorescent light ·Occurrence time of earthquake ·Judgment of danger ·Ability of children	·Danger of window glass pane ·Wait for rescue ·Collapse of structures ·Danger of block wall ·Escape from sea ·Danger of electric light pole ·Behavior at earthquake	·Emergency exit ·Rubbles ·Elevator ·Escalator ·Falling objects ·Shaking of an earthquake
Behavior during earthquake	·In class for the handicapped ·During an extracurricular activities	·While outside ·Athletic field ·During a class	·In attending and leaving school ·In condominium
Countermeasure	·Fixture of furniture ·Don't put things in passages	·Keep room tidy ·Electric security	· Unstaple food
Goods	·Emergency of water supply ·First-aid kit	·Disaster preparedness goods	………
Crisis management plan	·Family meeting ·Crisis management ·Disaster prevention manual	·Grasp of dangerous places ·Importance of earthquake preparedness	·Relief goods ·Contribution
Cooperation	·Volunteer	·Handicapped person at disasters	·Thinking
Disaster prevention awareness	·Disaster prevention awareness ·Day of disaster prevention	·Improvement of disaster prevention awareness	·Injury ·How to make a fire
Survival	· Hygiene ·First aid ·Neighborhood friendship	·Fire extinguisher ·Condition of heart	·Carrying handkerchief ·Importance of life
Preparation for earthquake	·Tell parents destination	·Identification	·Evacuation place
Victim	·Evacuation place at school	·Cigarette lighter ·Hardship of victims	·Life at evacuation shelter
Human	·Crime prevention	·Role of police	……………………

earthquake attached much attention,

(2) most contents are about correspondence after an earthquake, and

(3) learning contents according to real earthquake disasters is necessary.

3.2.3 Construction of the Curriculum

Groups which were divided by KJ method are classified according to grade level of students at an elementary and a junior high school based on the report "Education program of fire prevention for the youth"[3] from the Fire Defense Agency of the Ministry of Home Affairs. The grade level is divided into 4 divisions: preschool children, elementary school lower grades, elementary school upper grades and relevant knowledge in this report. The curriculum constructed is shown in Table 3.2. In this table, the grade level is divided into elementary school lower grades and upper grades and junior high school level.

In an elementary school lower grade, school children can first learn the fear of an earthquake disaster referring to the examples of historical

Table 3.2 Contents of the curriculum for school children

	Lower grades of elementary school	Higher grades of elementary school	Junior high school level
Knowledge about earthquakes	·What is earthquake? ·Earthquake country ·Fear of earthquake disasters ·Collapse of daily life	·Previous severe earthquakes ·Earthquake mechanism ·Magnitude and intensity ·Earthquake disasters ·Hard life	·Previous severe earthquakes ·The reason why Japan is an earthquake country ·Magnitude and intensity ·Earthquake disasters ·Effect on the life
Cope with an earthquake	·Basic behavior during an earthquake ·Advanced behavior during an earthquake ·Evacuation according to adult's guidance ·Action in a fire	·Basic behavior during an earthquake ·Advanced behavior during an earthquake ·Evacuation according to adult's guidance ·Action in a fire	·Basic behavior during an earthquake ·Advanced behavior during an earthquake ·Evacuation according to adult's guidance ·Action in a fire ·Not to cause a fire
Preparation for an earthquake	·Putting rooms in order ·Express condition of oneself and families	·Recognition of danger things and protection ·Emergency goods ·Family meeting	·Recognition of the situation after an earthquake ·Recognition of dangerous things and protection ·Emergency goods ·Family meeting
Social responsibility	·Mutual aid ·Safe life style ·Life in a refuge	·Mutual aid ·An earthquake drill ·Life in a refuge ·Protection of juniors	·Volunteer activity ·An earthquake drill ·First aids ·Protection of juniors ·Life in a refuge

earthquake disasters. Furthermore, they can evacuate adequately according to guidance of teachers or their parents when an earthquake occurs. Even if school children encounter a disaster, such as, a fire, it is emphasized that they should not extinguish it but escape from it considering their inadequate judgment at this level of the curriculum.

In an elementary school upper grade, school children can learn about the danger and cause of disasters by an earthquake. Furthermore, they are taught that they should evacuate using their own judgment and pay attention to lower grade students when an earthquake occurs.

In a junior high school level, students can understand many kinds of earthquake disasters and the mechanism of them. They can learn that they can act according to their own judgment and to a change of circumstances. Furthermore, it is emphasized that they should join many activities as the members of community.

In addition, preschool children were not introduced in the curriculum because preschool children cannot only operate a personal computer but also they cannot make sound judgment at disasters. In this case, their parents or teachers of a kindergarten should protect them against disasters.

3.3 System Configuration

The software for school children was developed on IBM PC/AT compatible computer with MS-Windows (Microsoft Inc.) by using the programming language software Visual Basic 5.0 (Microsoft Inc.) considering the availability of personal computers in an elementary and junior high school. The hardware and software used are shown in Table 3.3 and Figure 3.2.

These hardware and software were used because of the following reasons.

(1) recently, Windows95/NT is the mainstream OS of personal computer. The software can be developed based on the multiusability of the software.

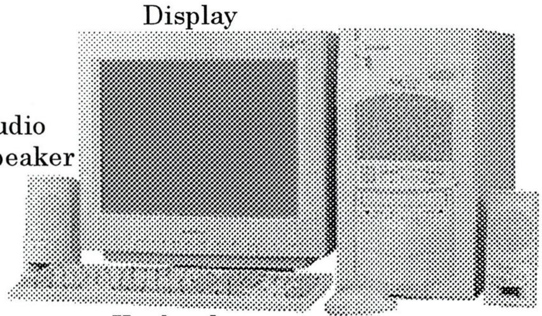


Figure 3.2 Hardware system employed

Table 3.3 Application software used

Software	Function
WindowsNT4.0 Workstation (Microsoft Inc.)	Operating system
Visual Basic 5.0 (Microsoft Inc.)	Programming language
Photoshop 4.0J (Adobe Inc.)	Processing images

(2) Visual Basic is easily executed by simple programs.

(3) contents of the program can be modified and improved easily by the function of object oriented language.

3.4 Contents of the Software

The contents of the software developed is shown in Figure 3.3. The software consists of a larger program including the program for learning and the program for evaluating learners and the curriculum, and some data including graphic data, text data and the learner data.

The program for learning registers learner data and controls sequence of the screen that is used for learning. The program for learning loads the graphic data and text data to be displayed on a screen. The program for evaluation is explained later.

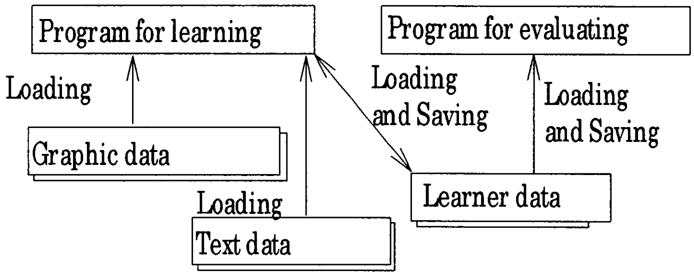


Figure 3.3　Constitution of software

The flowchart of the program is shown in Figure 3.4. When users start the program, it first requires the users to register (Photo 3.1). Then the users register their name, grade and sex. The registered data is used in evaluating of their learning effect, etc.

After this registration, the users are to take tests that are called "Opening quiz" (Photo 3.2). The users learn about earthquake disaster prevention by answering the questions asked by the software. After finishing the learning part of the main body, the software requires them to answer problems in the "Ending quiz".

These quizzes test the most important content of the curriculum. The numbers of quizzes are 10 for lower grades of an elementary school, 15 for higher grades of an elementary school and 20 for a junior high school level.

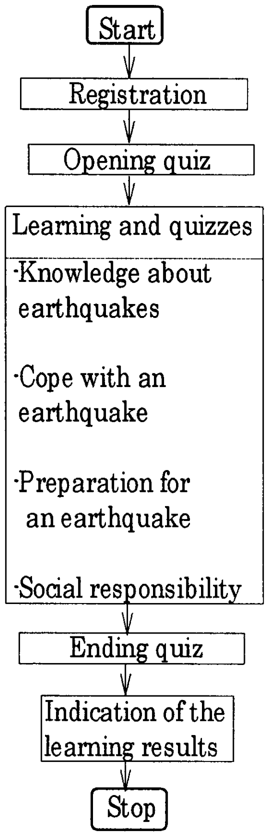


Figure 3.4　Flowchart of a new version for schoolchildren

The constitution of the screen for learning is shown in Photo 3.3 based on Question-Driven CAI[4]. In this method, quizzes are introduced at the learning screen and users cannot continue the program learn if they did not answer these quizzes because some children tend to skip the screen for learning and not understand its contents if the constitution of the screen is the same as the software in chapter 2. The advantage of this method can evaluate whether contents of the curriculum are appropriate or not and whether learners can understand them or not.

A correct answer rate indicating scores of quizzes after learning is shown in Photo 3.4. When a comment is displayed according to the result, the software program is then finished. All scores are stored to be analyzed later evaluating users achievement by the "S-P curves" and "Caution Index" which are used in the field of educational technology.

The program for evaluation is developed in order that school teachers or researchers may evaluate result of learning and contents of the curriculum by using children's learning stored data. When users start the program, two windows appear on the screen. These windows are shown in Figure 3.5. One window shows us the number of learners, percentage of correct answers, the learning effect by the S-P curve and the number of large Caution Index which are explained later. The other shows the reason why both of Caution index become large.

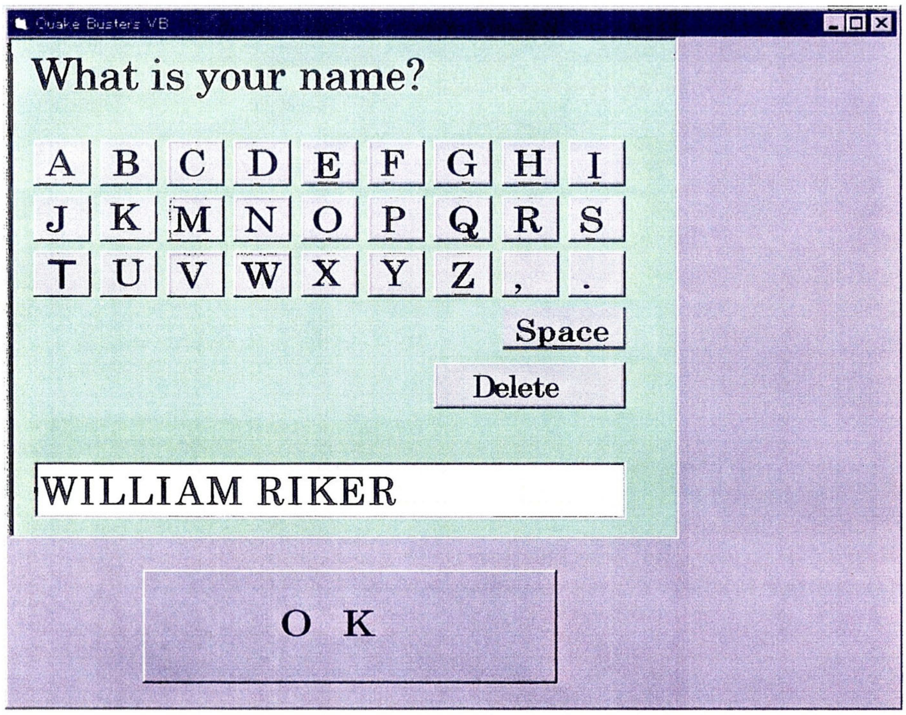


Photo 3.1 Example of registration

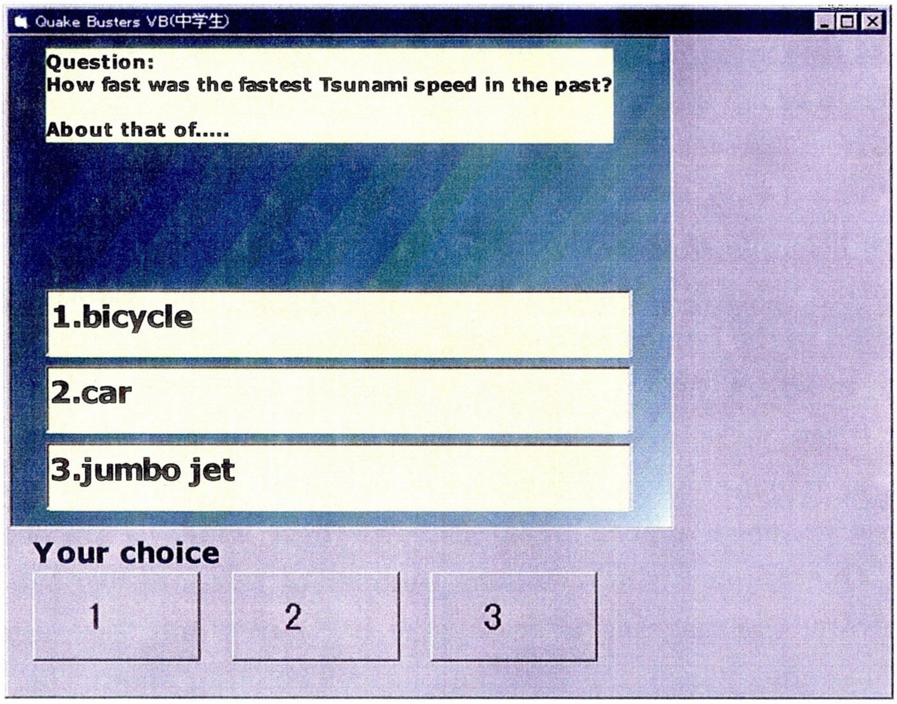


Photo 3.2 Screen of quizzes

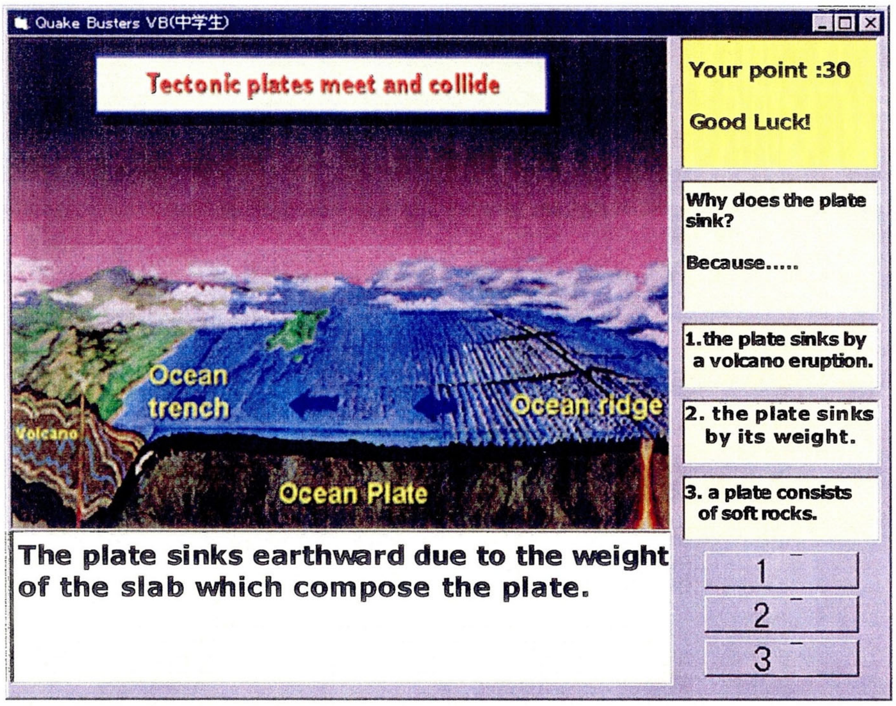


Photo 3.3 Example of screen of learning

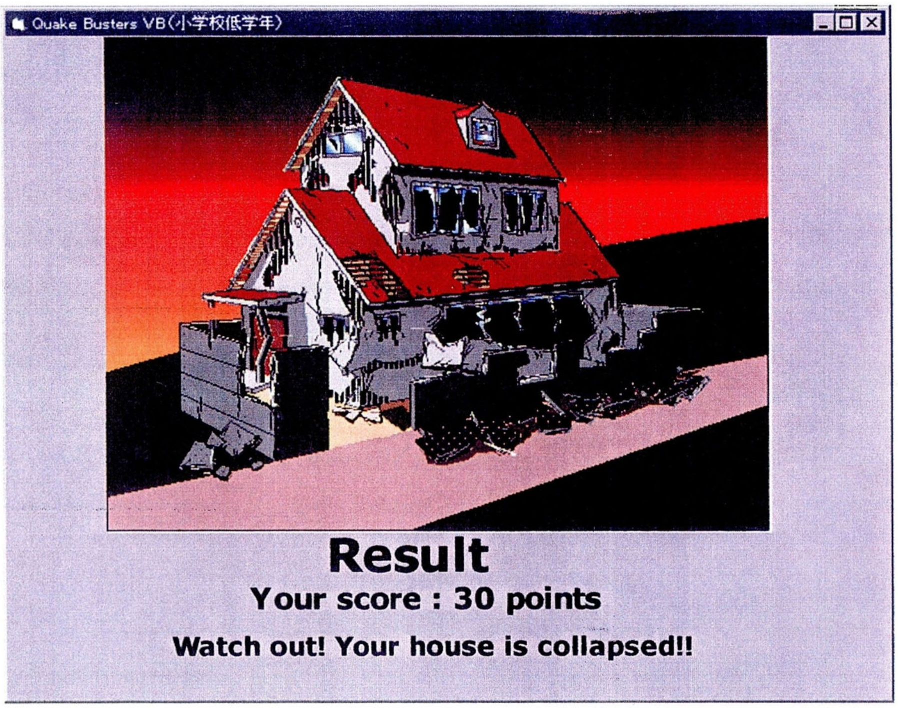


Photo 3.4 Indication of result of quizzes

3.5 Evaluation Method of Achievement of Users and Contents of the Curriculum

To evaluate the effectiveness of earthquake preparedness education visually, S-P curves and Caution Index used in the field of educational technology are introduced. Summary of S-P curves and Caution Index are described in the following sections.

3.5.1 Summary of S-P Curves

S-P curves are applied to the evaluation of learning effects. In general, teachers make use of S-P curves when they decide the policy of school lessons and evaluate the level of the examination, and the contents of curricula[5]. Procedure of S-P curve is described in Figure 3.5.

(1) Learners are listed vertically in the table, and learners' answers resulting in 1:correct, 0:incorrect for each problem are filled horizontally

Learner	Problem							
A	0	1	1	0	1	0	0	1
B	0	0	1	0	0	0	1	0
C	1	1	1	1	1	0	1	1
D	1	1	1	1	1	1	1	1

1 : Correct 0 : Incorrect

(a)Learners and their answers are filled in the table

Learner	Problem							
D	1	1	1	1	1	1	1	1
C	1	1	1	1	1	0	1	1
A	0	1	1	0	1	0	0	1
B	0	0	1	0	0	0	1	0

1 : Correct 0 : Incorrect

(b)Learners are ranked from high to low by scores

Learner	Problem							
D	1	1	1	1	1	1	1	1
C	1	1	1	1	1	1	1	0
A	1	1	1	1	0	0	0	0
B	1	0	0	0	1	0	0	0

1 : Correct 0 : Incorrect

(c)Problems with percentage of correct answers are ranked high to low

Learner	Problem							
D	1	1	1	1	1	1	1	1
C	1	1	1	1	1	1	1	0
A	1	1	1	1	0	0	0	0
B	1	0	0	0	1	0	0	0

1 : Correct 0 : Incorrect

(d)Number of correct answers and leaners counted and partitions made for S-P Curves

Figure 3.5 Procedure to obtain S-P curves

in the table as shown in Figure 3.5(a).

(2) Learners are ranked from high to low scores as shown in Figure 3.5(b).

(3) Problems with percentage of correct answers are ranked from high to low in Figure 3.5(c).

(4) The number of correct answer for each learner is counted from left to right and a virtual partition line is put at the end of the count as shown in dashed line in Figure 3.5(d). The cumulative distribution curve of correct answers is drawn up based on partitions is called S-curve.

(5) The number of learners that got correct answer for each problem is counted from the top to the bottom and a horizontal partition line is put at the end of count as shown in a solid line in Figure 3.5(d). The cumulative distribution curve of learners with correct answers is drawn up based on partitions is called P-curve.

In order to evaluate the rate of correct answer and whether problems are suited to students or not, S-P curve is considered based on

(1) position of S-curve and P-curve,
(2) forms of S-curve and P-curve, and
(3) a gap between S-curve and P-curve.

Figure 3.5 shows a typical example of S-P curves. When both curves are in straight lines whose angles are about 45° as shown in Figure 3.6, the ratio of correct answers is about 50%. If the curves shift toward the upper left, the ratio is less than 50%, inversely; the curves shift toward the lower right, the ratio is more than 50%. Accordingly, results of the score can be ascertained by the positions of the curves.

Moreover, from the shapes of S-curve and P-curve and the difference between them, the characteristics of students and problems can be analyzed. Figure 3.7(a) shows almost ideal S- and P- curves because the level of difficulty of the problems is appropriate to the students. When the inclination of S-curve is very slight as shown in Figure 3.7(b), the students can be clearly divided into two groups, i.e., one is the group of students of high score and the other is that of low score. When the inclination of P-curve is very steep in Figure 3.7(c), the problems are also divided into two groups, i.e., one is the group of very easy problems and the other is that of very hard. When the gap between S-curve and P-curve became large as shown in Figure 3.8(d), the difficulty of the problems does not suit the students. In this case, the problems need to be revised.

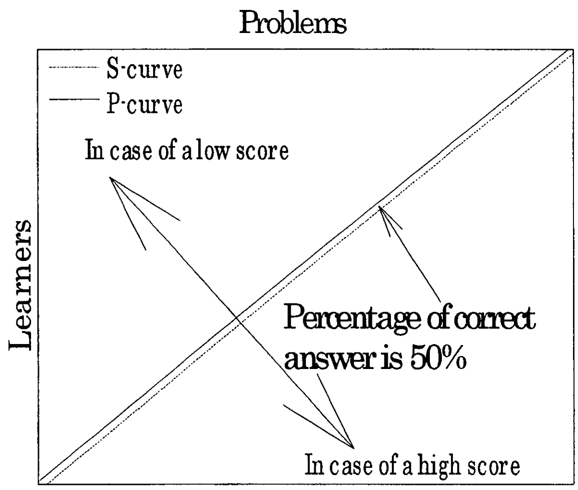


Figure 3.6 Relationship between the position of S-P curves and scores

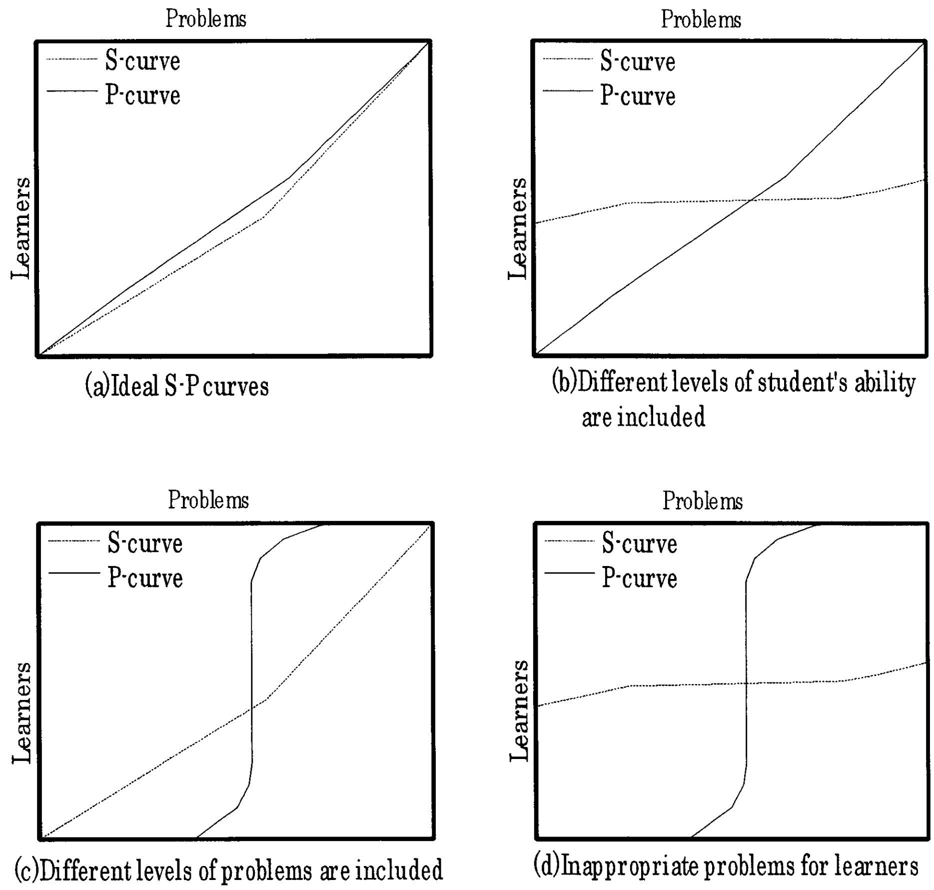
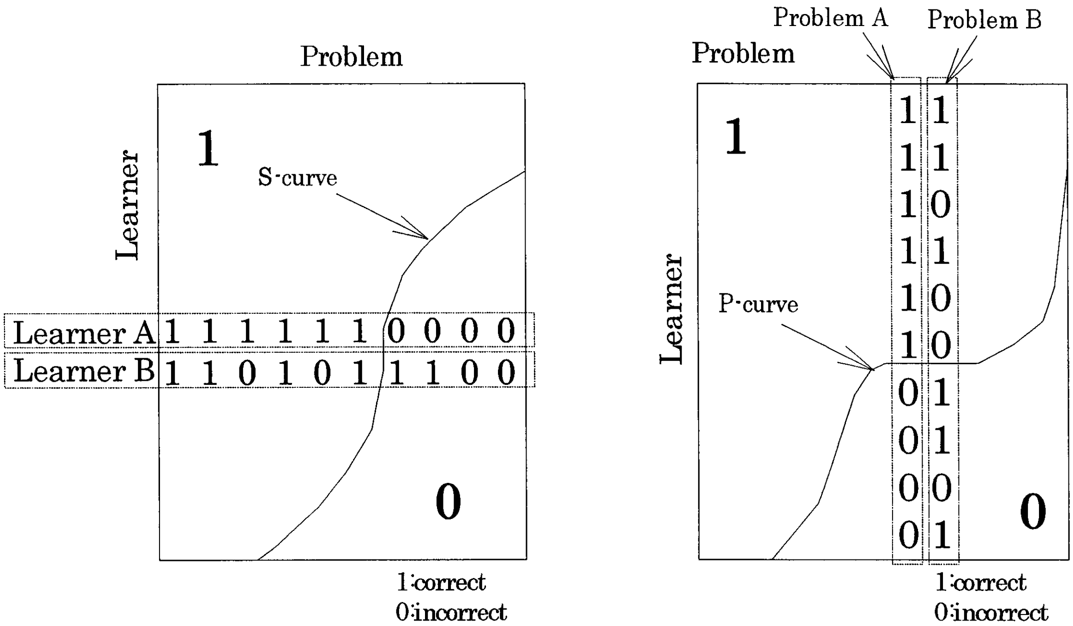


Figure 3.7 Example of typical S-P curves

3.5.2 Introduction of Caution Index

Rate of correct answer for problems and learners can be grasped by the position of S-P curve as mentioned above. However, achievement of learners and learning contents should be analyzed not only for the whole result combining learners and problems but also for their separate results.

For example, the results of two learners and problems that got the number of the same correct answer are show in Figure3.8. In Figure 3.8(a), student A got answers that suited the difficulties of the problem because student A could solve easy problems but not difficult problems. In this case, pattern of learner A's answer in Figure 3.8(a) is called "Complete reaction pattern". On the other hand, student B did not get answers that suited the difficulties of the problem because sometimes he got correct answers for difficult problems. In this case, learner B might get the correct answers by



(a) In case of the same score for learners (b) In case of the same score for problems

Figure 3.8 Differences in the distribution of scores

guessing.

In Figure 3.8(b), problem A was appropriate in difficulty because learners that got a high score could correctly answer problem A and learners that got a low score could not. However, problem B is not a good question because learners who could get correct answers on other problems could not always correctly answer problem B. In this case, problem B may be a good question but cannot be judged from the percentage of correct answers.

Therefore, Caution index is introduced in order to find these students or problems[5)]. Caution index is used to identify unusual aspects of students or problems that is difference from complete reaction pattern. Caution index is defined as

$$\text{Caution index} = \frac{\text{Difference between complete reaction pattern from learner's actual reaction pattern}}{\text{Maximum difference from complete reaction pattern}} \quad \cdots\cdots (3.1)$$

Maximum difference from complete reaction pattern means maximum entropy of learner's or problem's score. The entropy becomes greatest if 1 and 0 are unintentionally distributed. Furthermore, Caution index about students and problems are concretely defined as

$$CS_i = \frac{\begin{pmatrix}\text{Sum of number of learner's correct answer that corresponds} \\ \text{to "0" in the left from S-curve of learner } S_i\end{pmatrix} - \begin{pmatrix}\text{Sum of number of learner's correct answer that corresponds} \\ \text{to "1" in the right from S-curve of learner } S_i\end{pmatrix}}{\begin{pmatrix}\text{Sum of number of learner's correct answer} \\ \text{in the left from S-curve of learner } S_i\end{pmatrix} - \begin{pmatrix}\text{Number of learner's correct} \\ \text{answer in learner } S_i\end{pmatrix} \times \begin{pmatrix}\text{Average of the number of learner's} \\ \text{correct answer}\end{pmatrix}} \quad \cdots\cdots (3.2)$$

$$CP_j = \frac{\begin{pmatrix}\text{Sum of number of learner's correct answer that corresponds} \\ \text{to "0" in the top from P-curve of problem } I_j\end{pmatrix} - \begin{pmatrix}\text{Sum of number of learner's correct answer that corresponds} \\ \text{to "1" in the down from P-curve of problem } I_j\end{pmatrix}}{\begin{pmatrix}\text{Sum of number of learner's correct answer} \\ \text{in the top from P-curve of problem } I_j\end{pmatrix} - \begin{pmatrix}\text{Number of learner's correct} \\ \text{answer in problem } I_j\end{pmatrix} \times \begin{pmatrix}\text{Average of the number of learner's} \\ \text{correct answer}\end{pmatrix}} \quad \cdots\cdots (3.3)$$

Where

CS_i: Caution Index about learners

CP_j: Caution Index about problems

Moreover, high Caution index are defined as

Ratio of correct answer > 85%, $CS_i > 0.75$ $\cdots\cdots$ (3.4)

Ratio of correct answer > 85%, $CP_j > 0.75$ $\cdots\cdots$ (3.5)

For example, when the students are in bad physical condition and cannot answer or does not answer seriously, the index becomes large. When the index is more than 0.75 and ratio of correct answer is more than 85%, it can be said that there is something wrong with the problem or the student. In that case, the problem needs to be checked and the student needs guidance.

S-P curves and Caution index are automatically processed and displayed by the evaluation program.

3.6 Evaluation of the Software

In order to evaluate the software that the author developed for school children, the author distributed it to an elementary and a junior high school in Ube City of Yamaguchi Prefecture. Replies were received from 65 school children, of which 33 from lower grades and 10 from upper grades of the elementary school, and 22 from the junior high school. The software was evaluated from the viewpoint of

(1) learning effects by S-P curve and Caution index, and
(2) adequacy of the curriculum by S-P curve and Caution index.

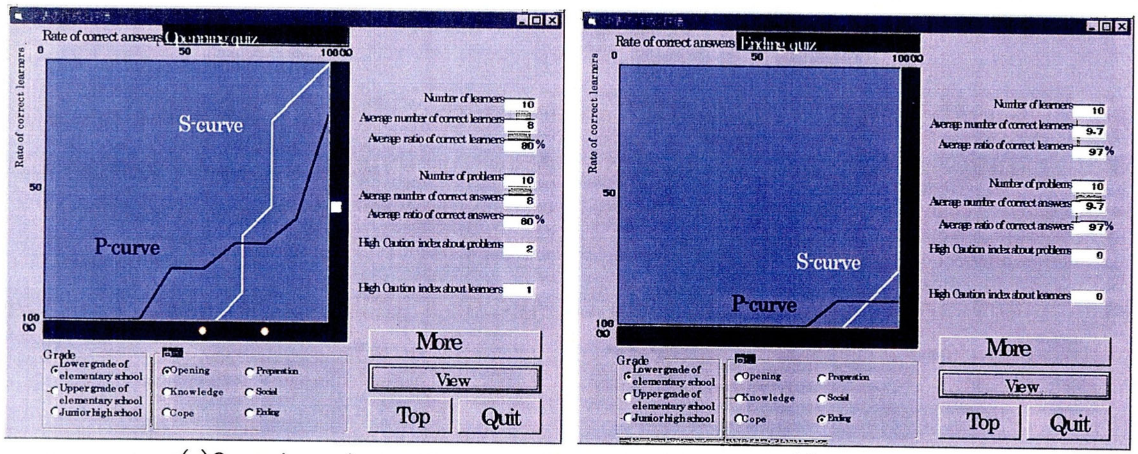
3.6.1 Results of S-P Curves

Figure 3.9, Figure 3.10 and Figure 3.11 show the S-P curves that were obtained from the lower grade and the upper grade of elementary school, and junior high school level. Figure (a) is obtained from the "Opening quiz" and (b) from the "Ending quiz". The symbols of ○ and □ in the figures indicate the high "Caution index" for the problem and the student, respectively. Results of the caution index are described later.

By comparing the positions of S-P curves in Figure 3.9(a) and Figure 3.9(b), the curves shifted toward the lower right in the "Ending quiz". From the viewpoint of curve shift, it is found that the rate of correct answer rose in the "Ending quiz". Actually, the percentage of correct answers has gone up to17 %. From the viewpoint of gap of the curves, the gap decreased in the "Ending quiz". This means that students who made mistakes in the "Opening quiz" understand by getting the correct answers in the "Ending quiz."

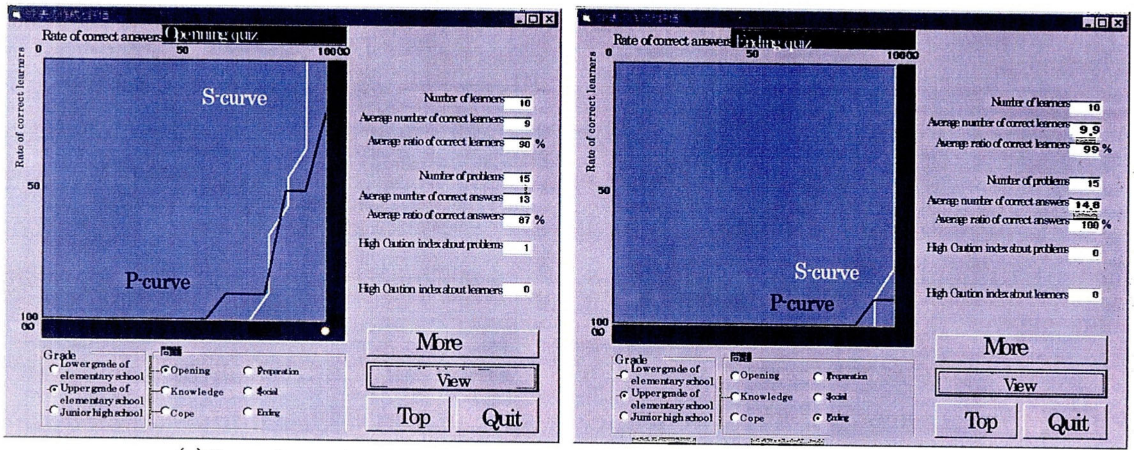
In Figure 3.10, S-P curves shifted just a little toward the lower right in the "Ending quiz". There was a slight curve in the "Opening quiz" because "Opening quiz " was so easy for the upper grade students that they could easily answer it.

In Figure 3.11, the shift of S-P curves could not be seen in the "Ending quiz". Especially, " Ending quiz" was considered to be difficult because the position of P-curve hardly changed. Furthermore, the gap of S-P curves never decreased in the "Ending quiz" by comparing with the



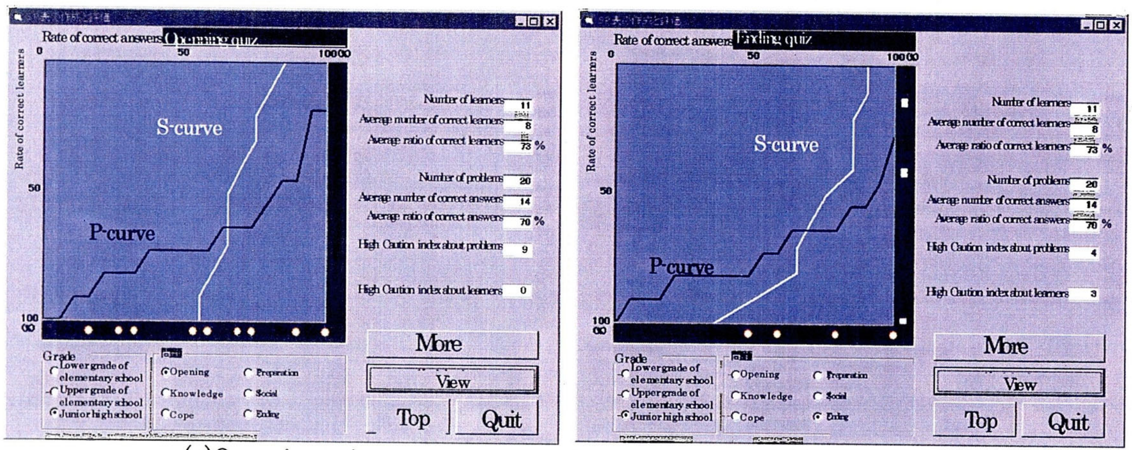
(a)Openning quiz (b)Ending quiz

Figure 3.9 Result of the lower grade of the elementary school children



(a)Openning quiz (b)Ending quiz

Figure 3.10 Result of the upper grade of the elementary school children



(a)Openning quiz (b)Ending quiz

Figure 3.11 Result of the junior high school students

"Opening quiz". Therefore, it is found that there might be a point lacking in the quiz problem and the contents of study, and the learning effect was not obtained in the curriculum for the junior high school students. The points that are lacking will be described later.

3.6.2 Results of Caution Index

As shown in Figure 3.9 and 3.10, the number of the high "Caution index" for students and problems in "Opening quiz" have gone up to 0 in "Ending quiz". From these results, it is not unusual to find these students and problems in lower grade and upper grades of elementary school. In addition, "Caution index" for students became large in "Opening quiz" because they did not understand the meaning of the problem when they answered it.

Next, the number of □ decreased from 9 in "Opening quiz" to 4 in "Ending quiz" as shown in Figure 3.11. It is noted that the number of □ did not decreased much in comparison to Figures 3.9 and 3.10. The reason noticed that there were students who randomly selected chose the same choice, i.e., from the data that was stored. On the other hand, the number of ○ increased from 0 in "Opening quiz" to 3 in "Ending quiz". It lets us know that there are points lacking in the curriculum.

3.6.3 Estimation of Learning Effects

As for the results of lower grade of elementary school, the author supposes the software is effective for the following reasons:

(1) the position of S-P curves shifted toward a higher rate of correct answers.
(2) the gap of S and P curve in "Ending quiz" decreased by comparing to that of S and P curve in "Opening quiz".
(3) the number of high Caution index decreased after learning from the software.

As for the results of upper grade of elementary school, it is noted that the software was slightly effective for the following reasons:

(1) the position of S-P curves slightly shifted toward a higher percentage of correct answers.
(2) changes in the gap of S and P curve did not appear.
(3) the number of high caution index indicated 0 before and after learning the software because problems in "Opening quiz" were too easy

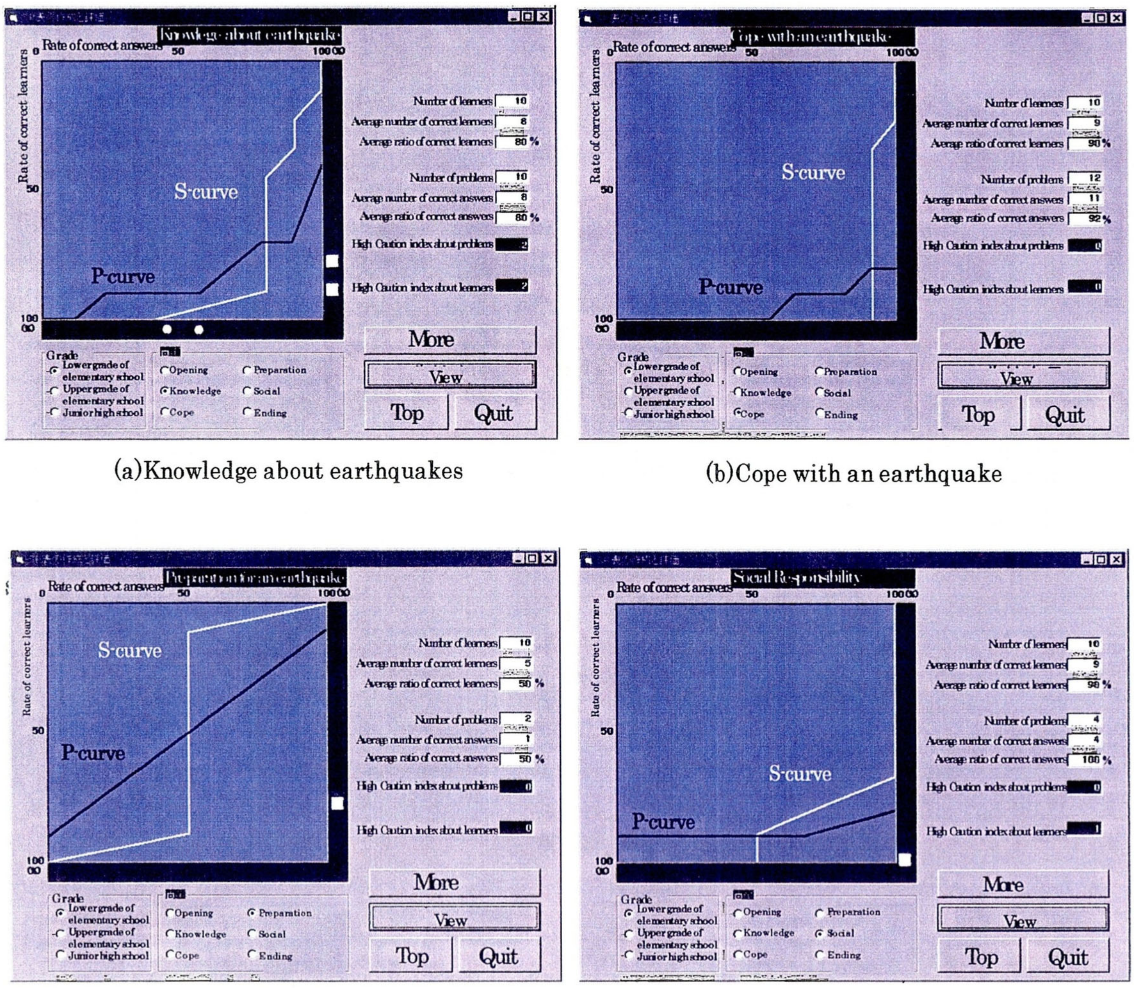
As for the results of junior high school level, it is observed that the software was effective for the following reasons:

(1) the position of S-P curves did not shift in "Ending quiz" compared to "Opening quiz".
(2) the gap of S and P curve never changed before and after learning from the software.
(3) the number of high Caution index increased in "Ending quiz" in comparison to "Opening quiz".

3.6.4 Estimation of Learning Contents by S-P Curves and Caution Index

Figure 3.12, Figure 3.13 and Figure 3.14 show the S-P curves on learning contents obtained from the lower grade and the upper grade of elementary school children, and the junior high school students. Figure (a) is obtained from "Knowledge about earthquakes", (b) from "Cope with an earthquake", (c) from "Preparation for an earthquake" and (d) from "Social responsibility"

The result from lower grade of an elementary school in Figure 3.12 is described. From the view of difficulty in learning contents, "Cope with an earthquake" was comparatively easy because the position of S-P curves shifted toward a high percentage of correct answers in Figure (b). Judging from the position and the degree of learning of P curve in Figure (c), the difficulties of "Preparation for an earthquake" may be appropriate. It is found that many learners had the same percentage of correct answers from the shape of S curve in Figure (c). The shape of P curve in Figure (d) shows us that problems are almost of the same difficulty.



(a)Knowledge about earthquakes

(b)Cope with an earthquake

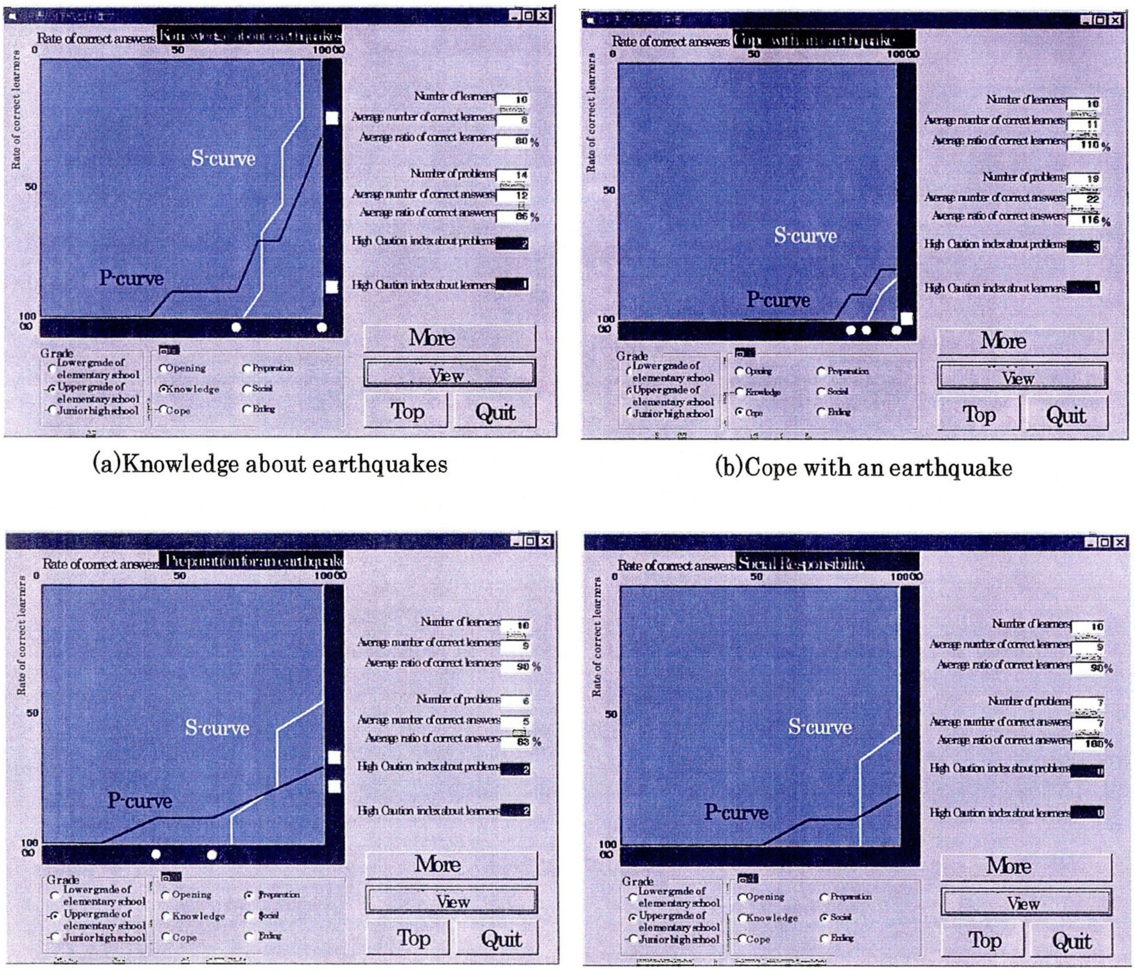
(c)Preparation for an earthquake

(d)Social responsibility

Figure 3.12 Results of S-P curves of learning contents which were obtained from lower grade of an elementary school students

From the view of "Caution index", there are learners and problems that were of high Caution index in Figure (a) and Figure (d). Especially in Figure (a), 3 students and 3 problems are unusual. Therefore, problems that were of high Caution index need to be revised.

The result from upper grade of an elementary school in Figure 3.13 is described. "Cope with an earthquake" and "Social responsibility" were comparatively easy for school children of the upper grade of an elementary school because the position of S-P curves shifted toward a high percentage of correct answers in Figure (b) and Figure (d). However, the percentage of correct answers was not so high in Figure (a) and Figure (c). Some problems



(a)Knowledge about earthquakes

(b)Cope with an earthquake

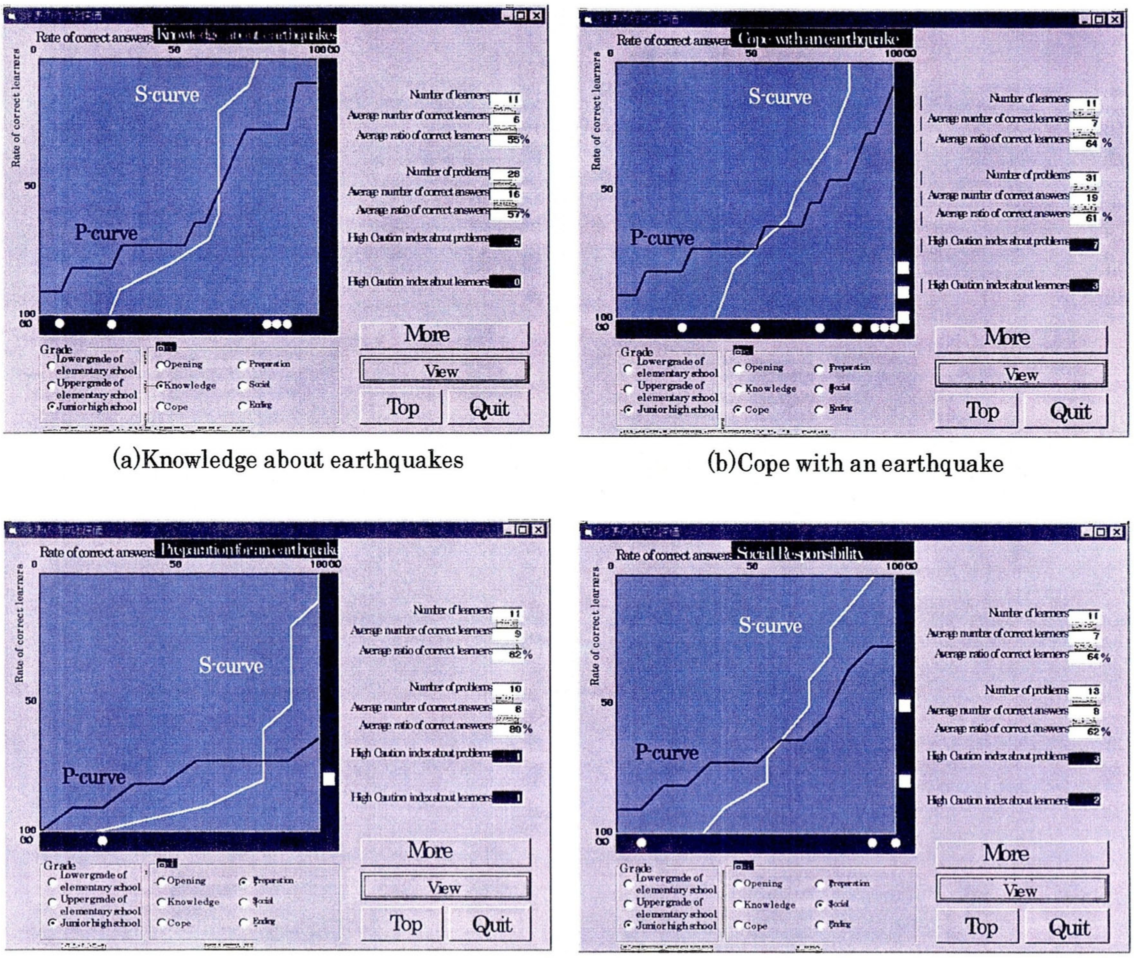
(c)Preparation for an earthquake

(d)Social responsibility

Figure 3.13 Results of S-P curves of learning contents which were obtained from upper grade of an elementary school students

in Figure (a), Figure (b), Figure (c) and Figure (d) that were of high Caution index need to be corrected.

Results from a junior high school are shown in Figure 3.14. S-P curves in all figures shifted toward a low percentage of correct answers. Both of curves indicate problems may be too difficult for junior high school students. In addition, there are many high Caution Index in these figures. Especially, 7 problems in "Cope with an earthquake" may be in inappropriate. Therefore, these figures show us that every learning content in the level of a junior high school needs to be improved.



(a)Knowledge about earthquakes

(b)Cope with an earthquake

(c)Preparation for an earthquake

(d)Social responsibility

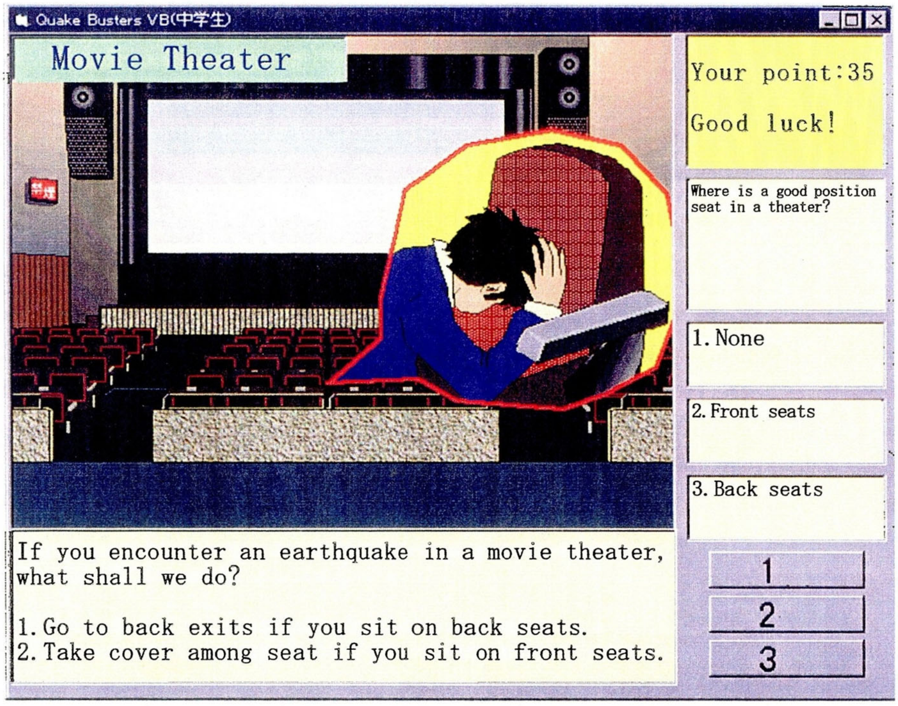
Figure 3.14 Results of S-P curves of learning contents which were obtained from junior high school students

3.6.5 Review of Problems with High Caution Index

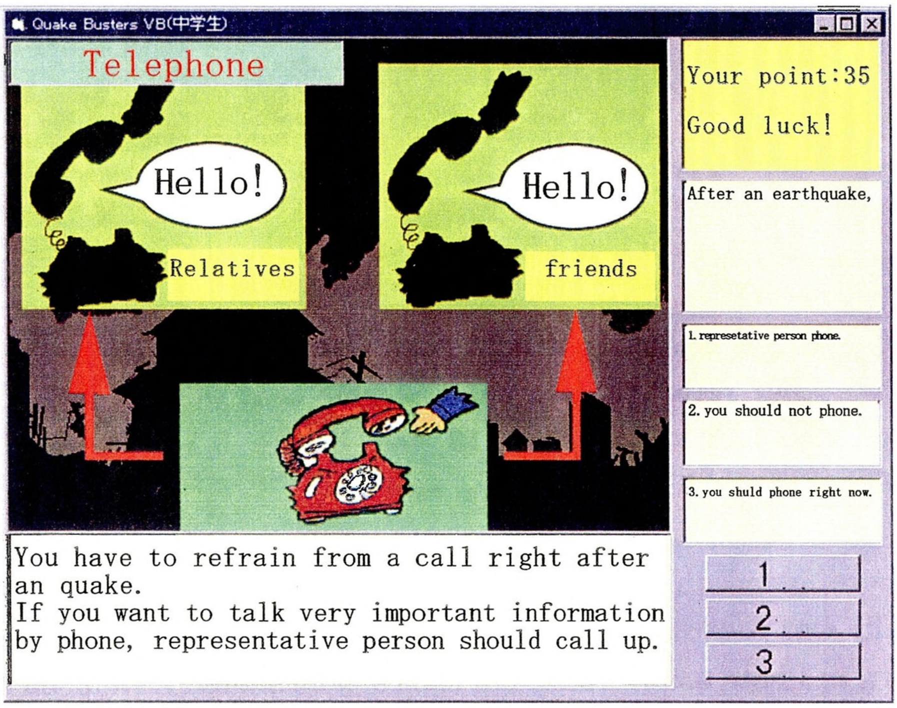
The author reviewed unusual problems that were of high Caution Index from Figure 3.12, Figure 3.13 and Figure 3.14. Three kinds of mistakes found in problems were found as follows:

(1) the choice listed in a problem should have been a correct answer originally was regarded as an incorrect answer. The example of this case is shown in Photo 3.5(a). Although choice No.3 should have been correct, instead choice No.1 was indicated as the correct answer.

(2) the wording of a problem was so confusing that students could not give a correct answer. The example of this case is shown in Photo 3.5(b). If



(a) In case of mistake in choices



(b)In case of confusing explanation

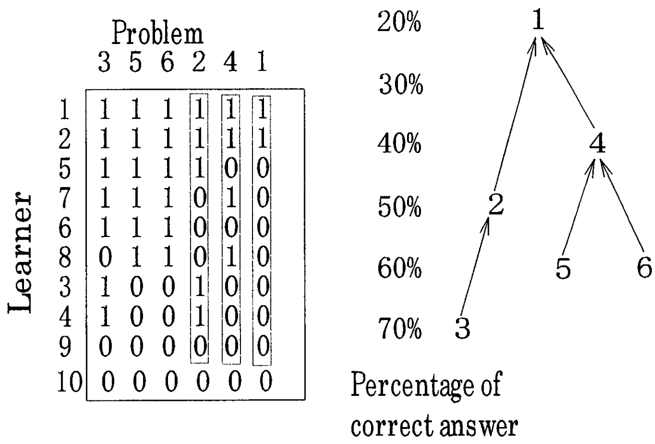
Photo 3.5　Example of learning contents with a high Caution Index students read the explanation, correct answer may be both of choice No.1 and of 2.

(3) There were explanations that students found them too hard to understand.

The author corrected and revised unusual parts of problems in the curriculum.

3.6.6 Summary of IRS Analysis and Application to This Study

IRS (Item Relational Structure Analysis) analyzes structures of learners' understanding from the result of S-P table[6]. S-P table is expressed by a chart, and IRS is expressed by a graph. The making of IRS graph is based on the findings of S-P table. Any leaner that solved problem No.1 could answer problem No.4 correctly as shown in Figure 3.15(a). In this case, "4 → 1" is marked as shown in 3.15(b). Learners that had correctly answered problem No.4 did not always solve problem No.2. In this case, Arrow "→" from 2 to 4 is not marked. By repeating these procedures, IRS graph is drawn as shown in Figure 3.15(b). In the analysis, learners understood the contents of study along two systems: one is for problems No.1, No.2 and No.3; the other is for problems No.4, No.5 and No.6 from Figure 3.17(b). In this method, the appropriate flow of a curriculum can be considered referring to the construction of the IRS graph.



(a)S-P table (b)IRS graph

Figure 3.15 Procedure of making IRS graph

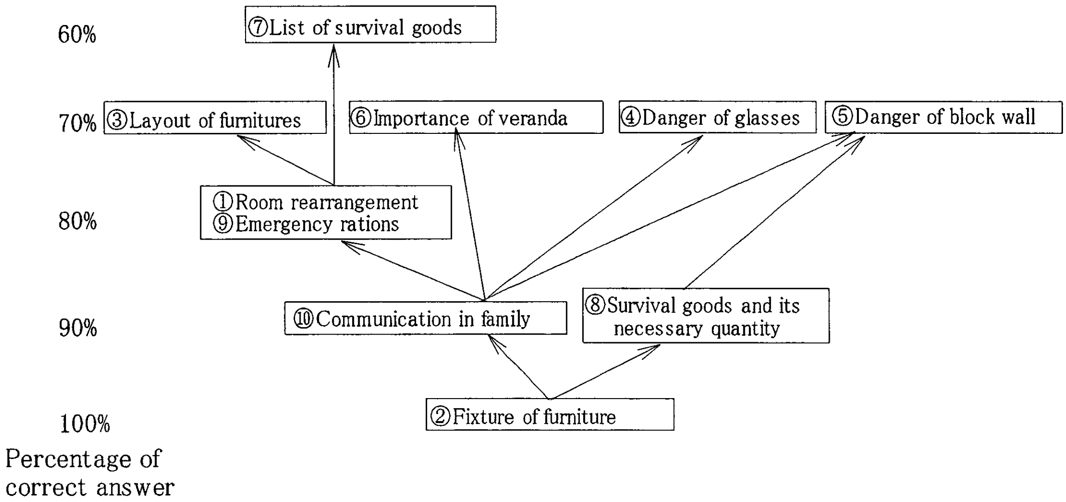


Figure 3.16 Result of IRS graph (Preparation for earthquake)

In this study, the author drew IRS graph about every grade level in the curriculum in Table 3.2. The result of IRS about "preparation for earthquakes" for junior high school students, for example, is shown in Figure 3.16(b). The characteristics of Figure 3.16 are explained below.

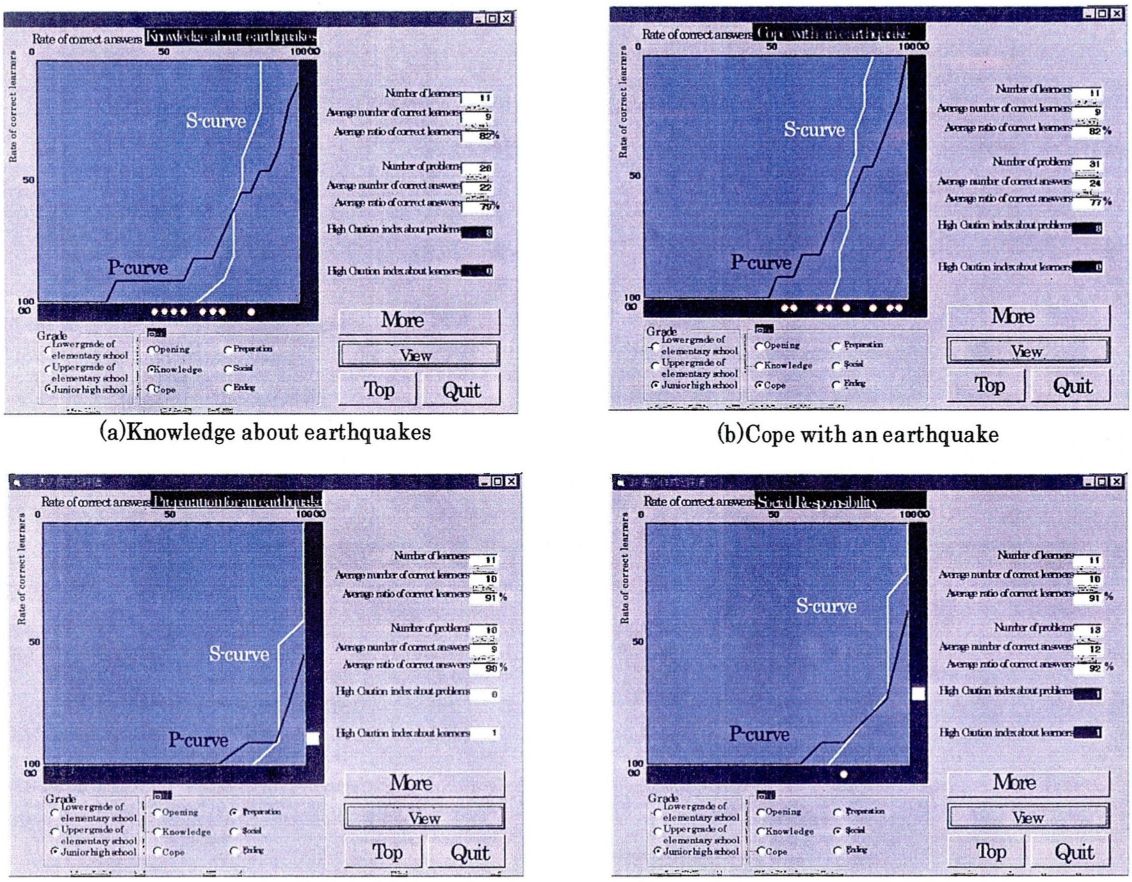
From this figure, it is found that the students first understood the learning contents of "Fixture of furniture ", "Communication in a family" and "Number and quantity of survival goods" because these learning contents attained a high percentage of correct answers. On the other hand, lists of survival goods are difficult for the students. Furthermore, it is effective to explain the necessity of "Communication in a family" before countermeasures against earthquakes because many arrows extend from the item "Communication in a family" to the items about countermeasures against earthquakes, such as, fixture and layout of furniture, danger of window glasses and block walls. Accordingly, from these results, it is more understandable for the students to learn the contents by rearranging the learning order.

Therefore, the author changed the learning order of all contents in the curriculum based on the results of IRS.

3.6.7 Reevaluation of Corrected Curriculum

After reconstructing the curriculum, the author distributed the new software to the same schools again in order to evaluate learning effects. Replies were received from 31 school children, 10 from lower grades and 10 from upper grades of the elementary school, 11 from the junior high school. Results of S-P curves that were obtained from junior high school students are shown in Figure 3.17. The symbols of ○ and □ in the figures indicate the high “Caution index”.

The S-P curves shifted toward the lower right in all figures by comparing the position of S-P curves in Figure 3.14. From this result, the improved curriculum was effective for learning. However, a high Caution index increased in Figure (a) and (b). The reason is that the contents themselves, such as phrase of explanation, were inadequate.



(a)Knowledge about earthquakes

(b)Cope with an earthquake

(c)Preparation for an earthquake

(d)Social responsibility

Figure 3.17 Results of S-P curves of learning contents which were obtained from junior high school students after improving the curriculum

Accordingly, these inadequate parts of learning contents should be improved.

3.7 Evaluation of Change of Earthquake Preparedness Awareness

The author examined a questionnaire in order to grasp the changes of students' awareness about disasters prevention before and after the use of the software. The average results that were obtained from elementary and junior high school students are shown in Figure 3.18, Figure 3.19 and Figure 3.20. Figure (a) shows the result of the question before using the software and Figure (b) shows the result of the question after using the software.

First, students' responses to the question about the horror of earthquakes are shown in Figure 3.18. This figure shows that the percentage of students who felt earthquakes were extremely terrible and terrible decreased after the use of the software. The reason is that most students did not feel uneasy about earthquake after understanding it and found ways to cope with earthquakes. On the other hand, the rate of students who did not feel earthquakes were terrible at all did not change. From this result, these students' awareness should be changed because students who disregard earthquakes as dangerous may be involved in disasters.

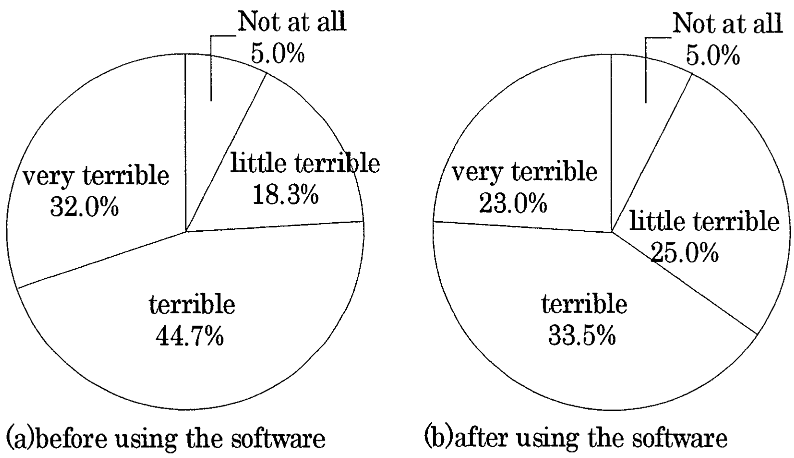
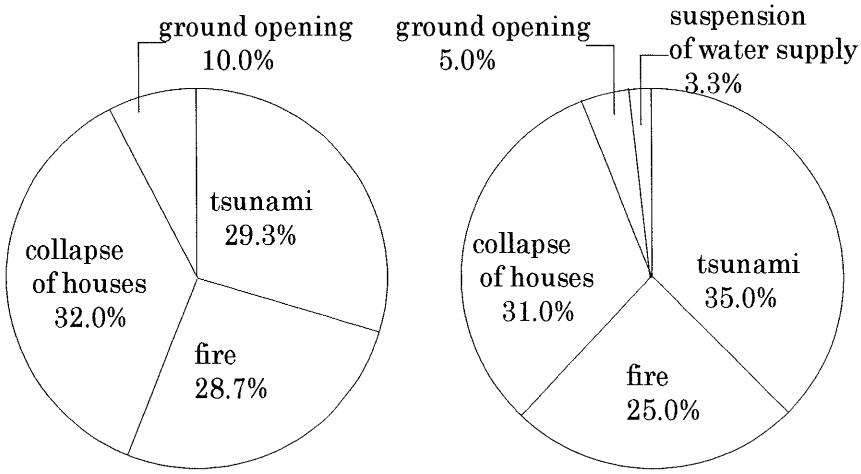
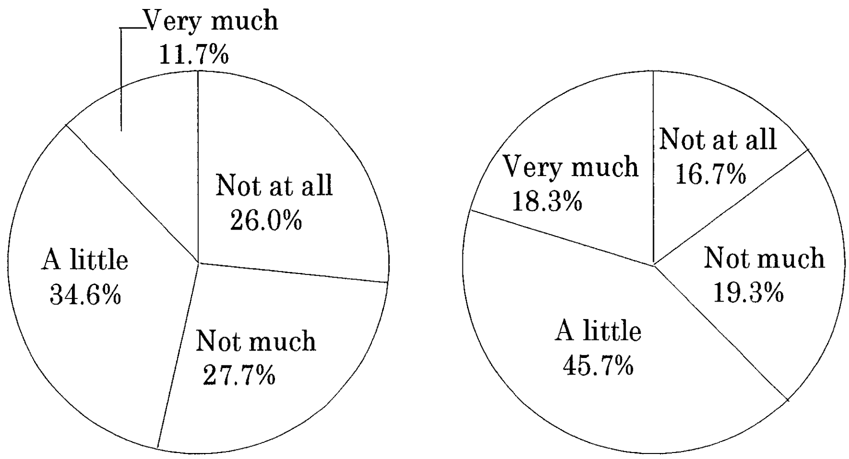


Figure 3.18 Students' responses to the question of whether they felt earthquakes terrible or not



(a)before using the software (b)after using the software

Figure 3.19 Kind of disaster that students are afraid of in an earthquake



(a)before using the software (b)after using the software

Figure 3.20 Are you interested in disaster prevention? Students' responses

The result of the question about feared objects is shown in Figure 3.19. From these results, it is found that the percentage of students who fear ground opening changed from 10% to 5%. Furthermore, there were students who were afraid of suspension of water supply.

The result of changes in students' interest in disaster prevention is shown in Figure 3.20. This figure shows that many students were more interested in disaster preparedness by using the software. However, about 17% students who were not interested in disaster preparedness before using the software significantly changed their minds after using it

3.8 Summary

In this chapter, the author described the development and the evaluation of software for earthquake preparedness education for elementary schools and junior high schools by using a personal computer. Before developing the software, its curriculum was constructed by using the KJ method. Furthermore, S-P curves, Caution Index and Item Relational Structure Analysis (IRS) were introduced in order to evaluate learning effects visually.

After developing the software, the author distributed it to the elementary school and the junior high school in Ube city of Yamaguchi Prefecture and evaluated the software. As a result, it was found that improved understanding of earthquake preparedness from students could be determined by comparing S-P curves and Caution Index before and after the use of the software.

After the evaluation, the learning order in the curriculum was changed according to the result of IRS, and the improved software was reevaluated in the same schools. As the result, S-P curves shifted toward a high percentage of correct answers by comparing it to the first evaluation. However, high Caution index increased in a few learning contents. Therefore, it was found that its inadequate contents should be improved.

References

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CHAPTER 4

Development of Evacuation Simulation Software by Using 3 Dimensional Image

4.1 Introduction

It may not be possible for us to evacuate safely at a disaster even if we know what to do for earthquake disaster prevention. Accordingly, it is very important for us to experience the anticipation of an evacuation when we meet a disaster. Referring to previous disasters, people could not evacuate during and after earthquakes even if they had knowledge about what to do for earthquake disasters. It is very important for school children to grasp their behavior tendency in a following disaster after an earthquake, such as, a fire. However, they hardly understand their own behavior even though they practice fire drills a few times a year. It is dangerous and impossible to do an experiment on human behavior in a fire drill in a real structure during a disaster. Furthermore, simulation models[1)] for forecasting human behavior that used a computer have some problems; it is difficult to determine a parameter for prescribing human behavior and to inspect the validity of results of the model.

Recently, some simulator software have been developed by using a computer to reproduce an experiment on human behavior and an experiment of a virtual fire drill in order to get fundamental data for simulation models. For example, Hayashi et al. analyzed behavior of a leader in a fire by using simulator in which users could let people take refuge as they look at a blueprint of a virtual building that was displayed on a screen[2)]. Meguro et al. developed simulator for evacuation by using virtual reality technique and investigated how evacuation activities in an actual structure change after using the simulator[3)]. However, it is necessary to prepare special devices, such as, a head-mount-display for virtual reality technique if the simulator is used. It is impossible for this kind of the simulator with a special device to be used in school.

Therefore, the author developed a 3D evacuation simulation software by using a low-end personal computer without special devices and software. The reasons why a low-end personal computer was selected are as follows.

1. Generally, old personal computers are used in many schools.
2. The software needs to be compact in order to be distributed to many schools easily.

In the first half of this chapter, the outline on the development of 3D simulation software is explained and in the second half, the method and the evaluation result of the software are described.

4.2 Procedure of Development of Simulator

4.2.1 Employment of Hardware and Software

Components of hardware and software application used in develop-

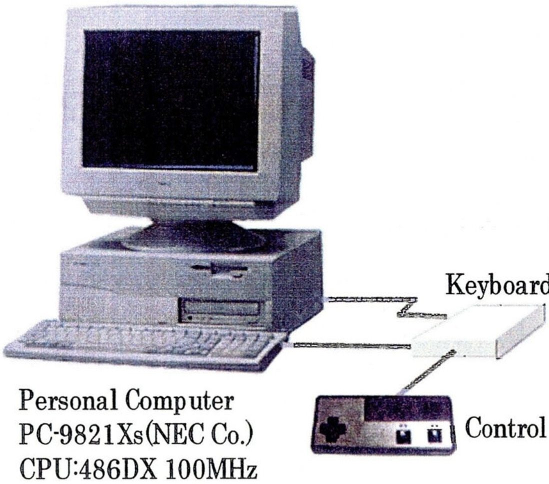


Figure 4.1 Hardware system employed

Table 4.1 List of software employed

Software	Function
MS-DOS Ver.5.0 (Microsoft Inc.)	Operating system
TURBO C++ (BORLAND Inc.)	Compiler of C language
GR.LIB. (Freeware)	Graphics library

ping 3-D simulator are shown in Figure 4.1 and listed in Table 4.1. The reasons why they were selected for developing the simulator are as follows.

1. PC-98 is used in many schools.
2. TURBO C++ that can make a fast executing file can run a simulator faster than any other computer languages.
3. Simulator can perform effectively because C language can connect programs that were written by an assembly language.

4.2.2 Constitution of Evacuation Simulator by Using 3D Image

The characteristics of 3D evacuation simulation software are described as follows:

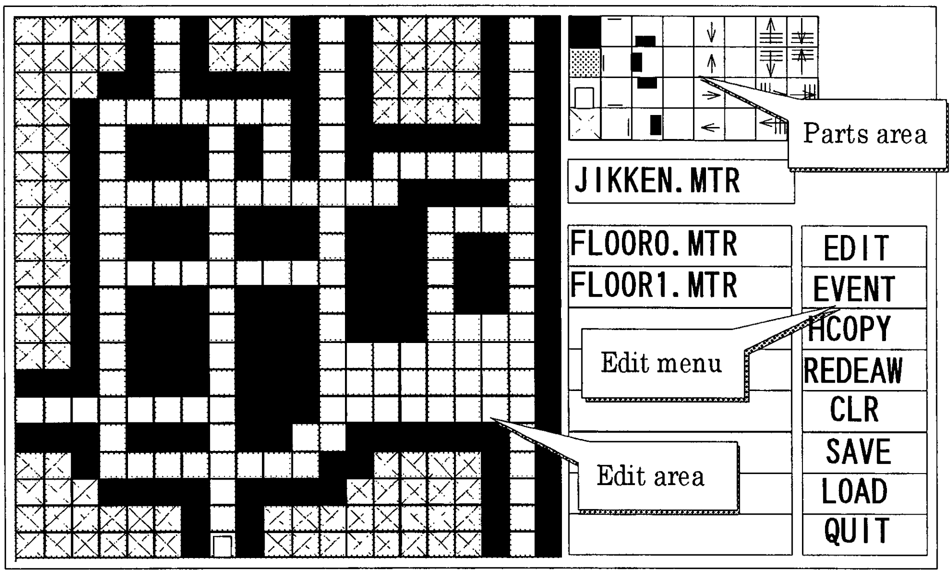


Figure 4.2 Display of data editor

1. Users who are unfamiliar to a personal computer can make 3D images, such as, the interior of an underground shopping center or a department store, etc., and create virtual disasters, such as, a fire by using a simple operation.
2. This simulator can be distributed to many schools because it can perform on a personal computer.

3D evacuation simulation software that the author developed consists of two parts. One is "Data editor" and the other is "Simulator". Each part is explained below.

(1) Data editor

It is necessary for users to make 3D CG object data about the interior of buildings in order to simulate a virtual evacuation by using a computer. In general, however, people who are unfamiliar with the operation of a computer can hardly make such data. Therefore, the author introduces "Data editor." Data editor is a kind of sub–software that supports users in making 3D CG objects, such as, a virtual structure. A sample screen of data editor is shown in Figure 4.2. Data editor consists of "Edit menu", "Parts area" and "Edit area."

There are eight buttons for commands as shown on the right side in the figure: "EDIT" for selecting in "Parts area", "EVENT" for setting events, such as, fire or turnover of utensils, "HCOPY" for printing a screen, "CLR" for resetting a screen, "SAVE" for saving data, "LOAD" for loading a data and "QUIT" for leaving "Data editor". Users can simply execute any command by clicking the button with a mouse.

"Edit area" is just like a bird's-eye view of a drawing. When users click on a part in the "Parts area" with a mouse and click on "Edit area" again, the part is set in place. "Parts area", that is located at the top of right side of the figure, provides parts of virtual structures, such as, columns, walls, stairs, doors and elevators, etc. that are displayed with an icon. Users can plan the inside of a building in a drawing. For example, black parts express walls or columns, white parts express passages and marks of x express area where evacuee can enter in Figure 4.2. This "Edit area" consists of 400 meshes in which the scale is variable. More than $1000m^2$ area can be edited by using the "Data editor".

Virtual disasters can occur before and during evacuation in a simulator. Different kinds of the virtual disasters are described below.

(1) Fire: Pictures of a fire can be displayed at the beginning of or during the simulation.
(2) Turning over of furniture: Virtual furniture turns over at the beginning of the simulation or when users approach it. If furniture turns over in narrow corners or passages, users cannot pass them.
(3) Blackout: Blackout is indicated by darkening the screen except the EXIT light. Blackout occurs at the beginning of the simulation or during the simulation.
(4) Blocking of exits: Exits are blocked when the simulation starts. Blocked doors at exits cannot be opened even if users push a button for opening a door by control pad.
(5) Trouble of elevators: Elevators stop when the simulation starts or users enter into elevators and are trapped. After this event occurs, users cannot use elevators for evacuation.

Furthermore, structures themselves, such as, walls, columns and ceilings are not destroyed in virtual disasters. The reason is that Distinct

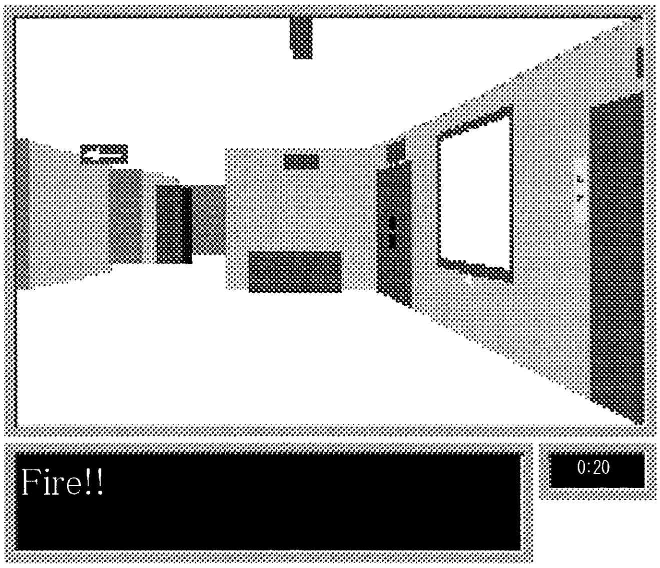


Figure 4.3 Display of the simulator

Element Method is necessary to calculate the process of destruction and it is impossible to display the result of the calculation by using real-time 3D CG during the simulation. In addition, fire is also not introduced as virtual disaster because it is difficult for a personal computer to indicate the spread of fire and smoke on screen with 3D CG. Therefore, only flames of a fire are indicated in red column.

(2) Simulator

In the simulator, 3D CG images are displayed on screen on the basis of the data that is edited by Data Editor. Users can move or turn a viewpoint on screen as if they were actually walking in 3D CG by pushing buttons on a control pad. Screen of simulator is shown in Figure 4.3. "Simulator" consists of three windows: "View-window", "Time-window" and "Message-window". 3D CG images of structures are displayed with 8bit depth colors in "View-window." The time from start of the simulation to complete evacuation is indicated in "Time-window." Messages, such as, notice of fire to users are indicated in "Message-window" during the simulation.

Flowchart of the simulator's process is shown in Figure 4.4. Simulator renders 3D images, such as, walls, columns and doors etc. on the data made by Data Editor and displays starting viewpoint of the simulation

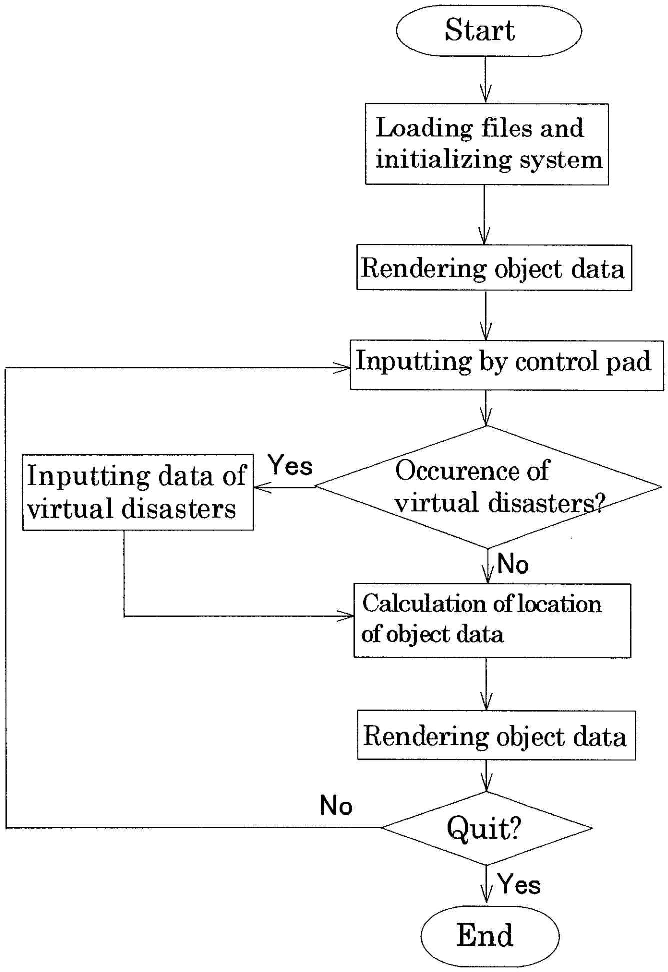


Figure 4.4 Flowchart of the simulator

at initialization. When users push buttons on the control pad as shown in Figure 4.5 in order to move or turn the viewpoint, new locations of columns and walls, etc. are calculated and rendered as new viewpoint. Users can see the motion of viewpoint as if they were walking there by processing input data, calculating and rendering quickly and repeatedly. However, if users collided with a wall, they would stop till they push buttons on the control pad again. Furthermore, the walking speed can be varied according to users' age and sex distinction because there are differences in age and gender in reference by referring to Kurimoto's study[4]. The difference of their skill in operating the pad influences evacuation behavior and time to complete evacuation. Therefore, it is necessary to practice operation by using other structural mazes before doing an evacuation experiment.

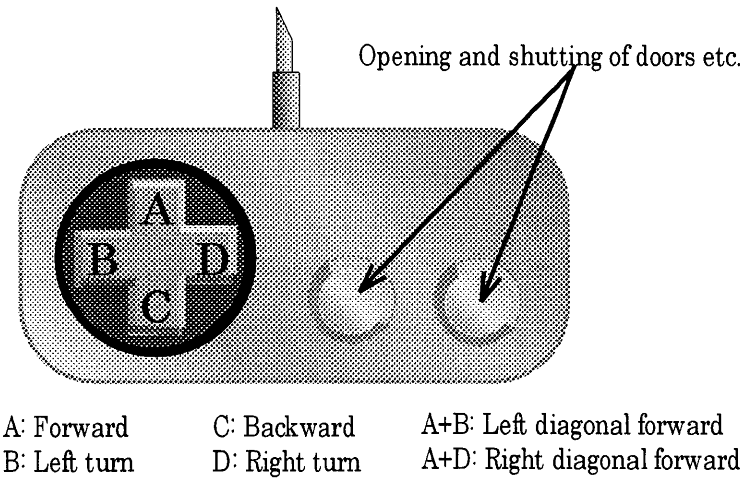


Figure 4.5 Method of movement by control pad

4.2.3 Record and Reproduction of School Children's Data

It is necessary to record school children's way of evacuation and time to complete evacuation during an evacuation experiment. Therefore, data is saved as data files in simulator at the end of the experiment by recording the kinds of buttons pushed and the time to continue pushing buttons of the pad. By using the saved data, users' evacuation is reproduced in "View-window".

4.3 Evaluation of Simulator by Using Maze

The author performed evacuation experiments in the simulator by using two kinds of maze that imitated underground shopping center in order to evaluate the simulator that was developed in this chapter. Testees are 100 students of Yamaguchi University, because students that are used to operating control pads hardly make mistakes.

4.3.1 Evacuation Experiment – In Case of Maze with Many Exits–

<u>(1) Summary of Evacuation Experiments by Simulator</u>

The model of underground shopping center that is used in the experiment is shown in Figure 4.6. Size of length and width is 80m x 90m

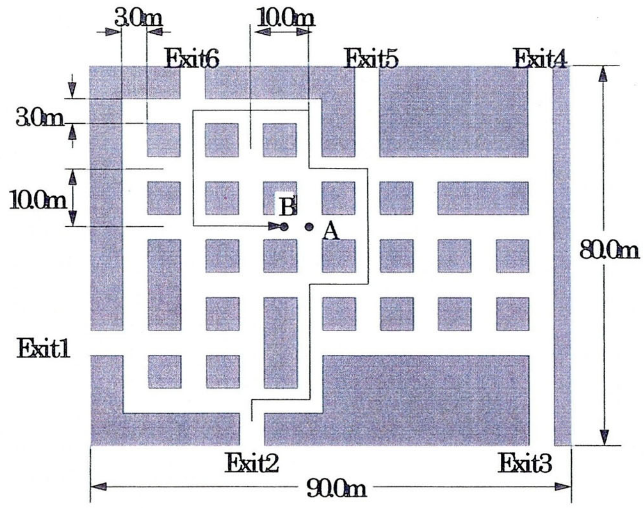


Figure 4.6 Model of maze with 6 exits

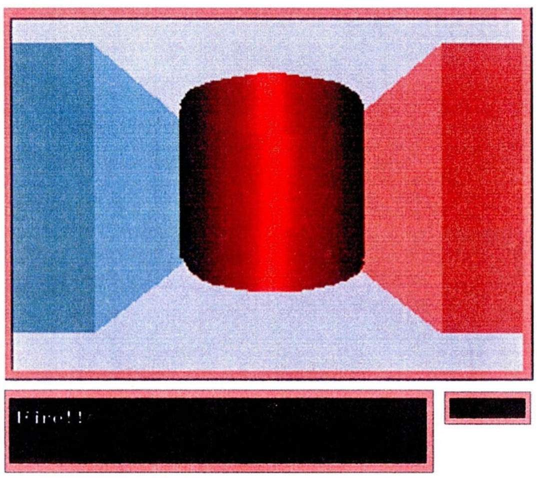


Figure 4.7 Screen of the Simulator during Experiment

with 6 exits. Width of passages is 3m and height from floor to ceiling is 2.5m. Testees practice operating the simulator with a simple maze before doing the experiment. After testees get used to the operation, the experiment starts. The experiment performed with two methods is shown below.

Experiment 1: Testee facing the crossing A stands in point B in Figure4.6. Then, fire occurs at the crossing A as shown in Figure 4.7. As soon as message "Fire!!" appears in the message-window, testee begins to evacuate. When testee completes evacuation, the experiment is over.

Experiment 2: First, tester guides testee's entry to point B along solid line

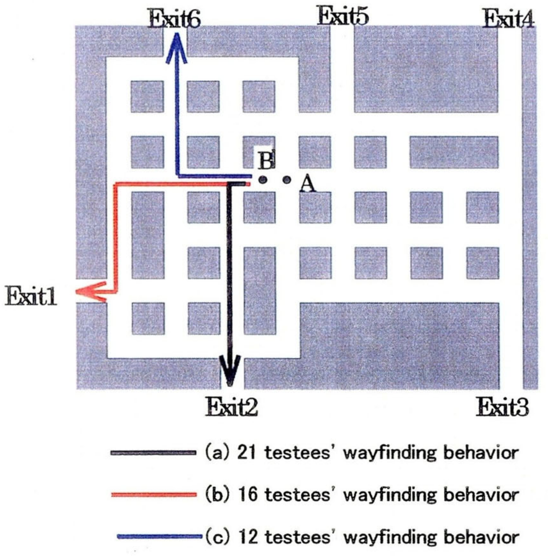


Figure 4.8 Result of wayfinding behavior - In case of experiment 1 -

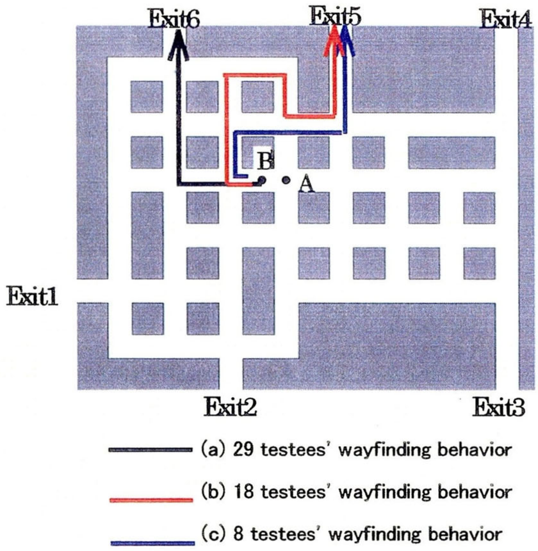


Figure 4.9 Result of wayfinding behavior - In case of experiment 2 -

Table 4.2 Choice of routes and characteristics of walking

Figure	Reason of choice of routes	Characteristics of walking
Figure 4.8	"Walk straight" "Walk straight as long as possible" "Choice of the nearest corner"	Tendency of going straight or Tendency of turning corners
Figure 4.9	"Choice of the routes where they used previously as long as possible"	Memory of routes

as shown in Figure 4.6. As soon as testee arrives at point B, a fire breaks out and a message "Fire!!" appears in the message-window. When testee reaches the exit, the experiment is over.

Testees are not given information about the locations of the exits. Furthermore, another experiment described later was first performed so that testees could not memorize the routes of experiments 1 and 2.

By performing the evacuation experiment in two ways, the author tried to investigate whether past memory influences the choice of evacuation routes. After each experiment, testees were interviewed about the policy and the strategy in an evacuation. The walking speed in simulator was set at 3.0 m/s as walking speed for 20 years old[4)] and view-window was darkened to assume the spread of a smoke.

(2) Investigation of Testees' Evacuation Routes

Frequent patterns of evacuation behavior acquired from experiment 1 are indicated in Figure 4.8. Behavior pattern (a) that 21 testees followed are most frequent. After a fire broke out and testees turned round, they walked straight or turned left in the first crossing and succeeded in reaching Exit 2. Next 16 testees that followed pattern (b) turned round at point B, turned right at second crossing and walked straight to Exit 6. Pattern (c) followed by 12 testees that turned at third crossing and went straight till the crossing that was closed to Exit 1.

Frequent patterns of testees' behavior in experiment 2 are shown in Figure 4.9. Pattern (a) that 26 testees followed is recorded as the most frequent behavior in experiment 2. The testees turned right at the second crossing and go to Exit 6. In pattern (b), as soon as testees turned right at the first crossing, turned right at the next crossing and succeeded in finding Exit 5. Patterns (b) and (c) are almost the same routes of evacuation.

(3) Classification of Wayfindings

The author categorized results of Figure 4.8 and Figure 4.9 into the classification of Matsushita's wayfinding experiments[5)]. The result is shown in Table 4.2. The reasons of choice of wayfindig indicated in Figure 4.8 are "Choice of the nearest corner", "Going as straight as possible" and " Going straight at once." In general, people take these wayfindigs if they don't know courses to a destination. Furthermore, people tend to go straight or turn repeatedly at a corner when there are many corners in their headed direction.

On the other hand, testees tried to go back along the routes where they were guided by tester before the fire broke out and found Exits 5 and 6 as shown in Figure 4.9. So, they evacuated according to their memory. In Figure 4.9(a), it is found that testees remembered the way to the exit where they used in the first experiment. So, most people took refuge to Exit 6 in the experiment 2 as shown in Figure 4.9. Therefore, Figure shows the tendency of wayfindings: " Evacuation by using the routes that have been used before".

As the results of these experiments, the author found characteristics of wayfindings behavior that were well known in Matsushita's experiments were observed by using the simulator.

4.3.2 Evacuation Experiment – In Case of Maze with One Exit

(1) Summary of Experiment

To evaluate the simulator, author also performed an experiment in a maze with one exit which was actually used in Watabe's experiment[6] as shown in Figure 4.10. Entrance and exit are also displayed with S and G, and crossings are numbered to easily explain results of the experiment with Figure.

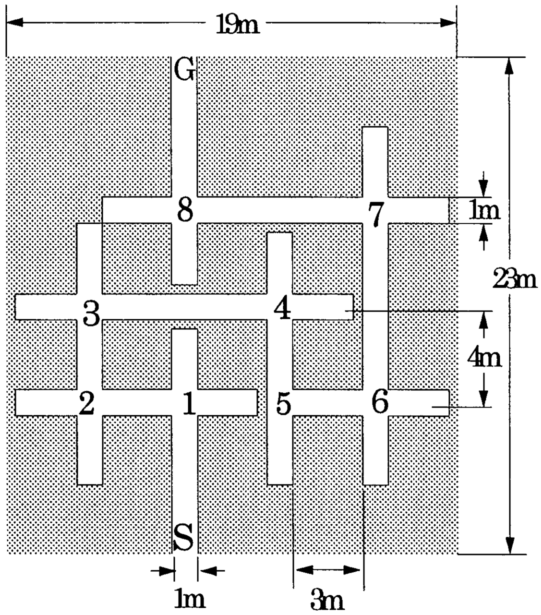


Figure 4.10 Model of maze with one exit referring to Watabe's experiment

Each testee was told that he entered Entrance S of the maze and to search for the exit. Before the experiment, the view-window was adjusted as shown in Figure 4.11 because Watabe set a limit to testees' visual field by covering them with a hood in order to see only their footsteps. Sizes of visible area through view-window are 1.7 m in front and 2 m in flank. Walking speed 0.7 m/s[7] was set on the assumption that testees walked in a thin cloud. Furthermore, some different marks were attached on floors in crossings and blind alleys referring to Watabe's experiment as show in Figure 4.11. In addition, testees were only taught that there were some marks in each crossing and not taught the shape of the maze, the number of crossings and the location of the exit.

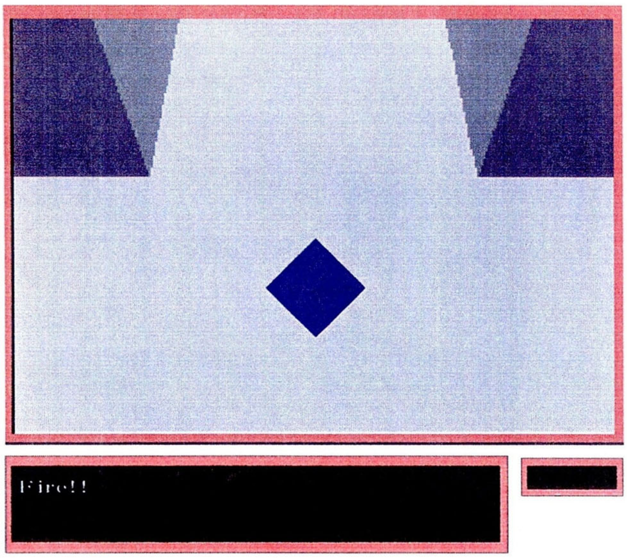


Figure 4.11 Screen of simulator during the experiment
– In case of maze with one exit –

(2) Average Time to Find Out Each Crossing

Watabe indicated exponential relation between each crossing and average time to find out in his experiment. Therefore, regression lines which indicated the relation between each crossing and average time to find out in each crossing in order to compare the result of this experiment and that of Watabe's experiment are shown in Figure 4.12. "Random wayfindings" in Figure 4.12 means the result of testees who had no plan to walk, and "wayfindings along walls" in Figure 4.12 means the result of testees who walked regularly along walls of the maze in Watabe's experiment. From the relation of 3 regression lines, the result of simulator is indicated in the range between "random wayfindings" and "wayfindings along walls" but drawn closer to "wayfindings along walls".

As mentioned above, it is found that the result of the experiment by using the simulator is almost the same as that of Watabe's experiment.

(3) Routes of Testees' Wayfindings

Typical patterns of routes of testees' wayfindings are shown in Figure 4.13. The result of testees' wayfindings when they got lost in a route during evacuation is indicated in Figure (a) and that of testee's route when they evacuated regularly is indicated in Figure (b). In case of Figure (a), testee lost the route to exit G and noticed that he already passed crossing 2

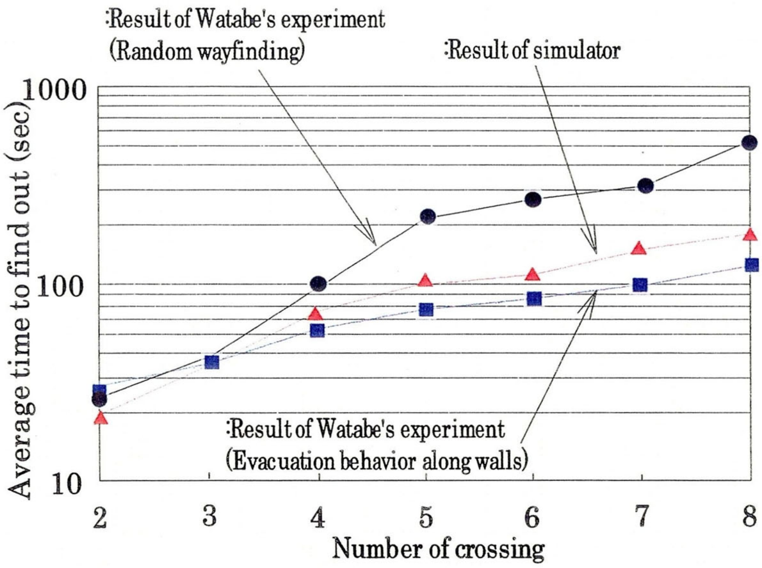
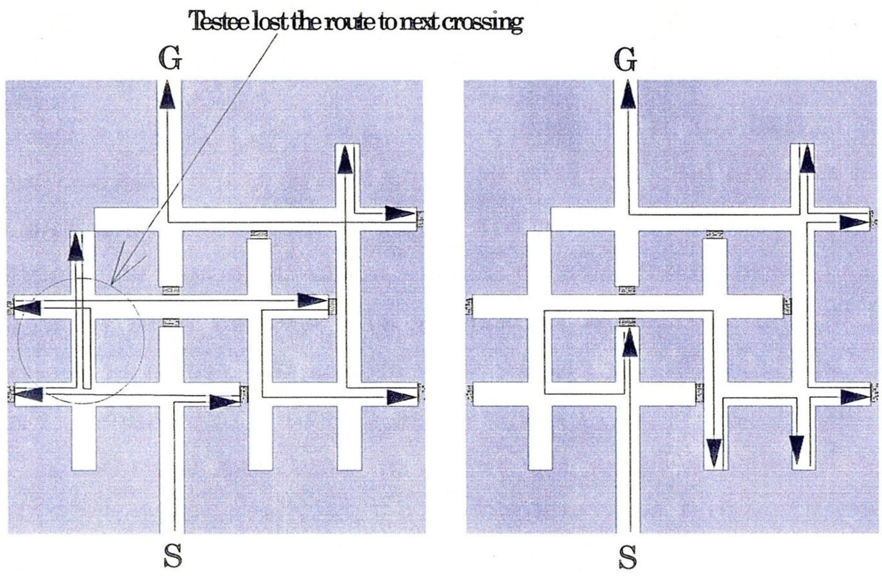


Figure 4.12 Relation between average time to find out crossing and each crossing



(a) Example of testee that evacuated without plan for evacuation

(b) Example of testee that evacuated along right-hand side walls

Figure 4.13 Differences of testees' wayfinding behavior

when he saw the mark in crossing 2. After testee found crossing 3, he tried to search for a way to the exit without any clear plan for evacuation. The testee succeeded in reaching exit G without being lost in a route after he was back to crossing 3. In case of Figure (b), testee continued to evacuate

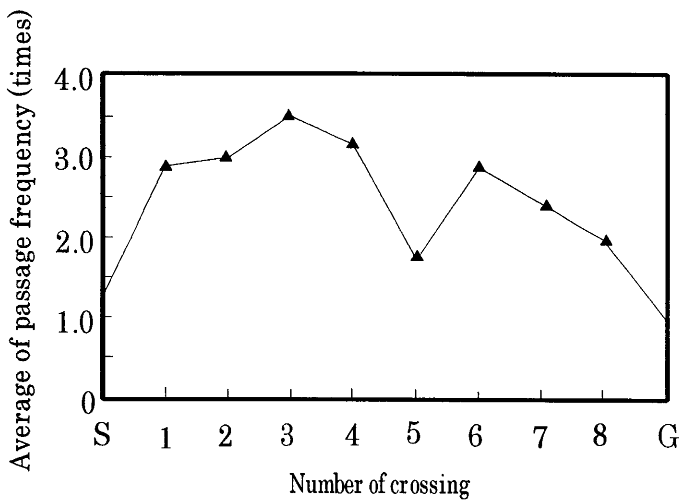


Figure 4.14 Average of passage frequency in each crossing

according to his clear policy to go along right wall in the maze and completed evacuation without being lost in a route. From these results and the result of hearing to the testees, it is found that difference of pattern of wayfindings depends on policy to evacuate.

(4) Passage Frequency in Each Crossing

Passage frequencies of all testees are investigated because passage frequency increased at a crossing where many teestees lost their way to an exit. The result of passage frequency is shown in Figure 4.14. This figure is shown as below.

Two peaks at crossings 3 and 6 and the minimum at crossing 5 appear in Figure. The reason is that there are a few search frequencies at crossing 5 which has only two ways where testees could go, less other crossings and where a mark could be found to search for a route to the exit. Moreover, it is also found that passage frequency decreased at the center of the maze, such as, crossings 3, 4, 5 and 6 where testees were not easily lost because of crossing 5.

(5) Cumulative Percentage of Finding Crossings

The author also investigated time to find each crossing. The cumulative percentage of finding crossings that divided testees who find the crossing by time T by all testees is shown in Figure 4.15. As testees approached the exit G, it took a long time for them to find the crossing.

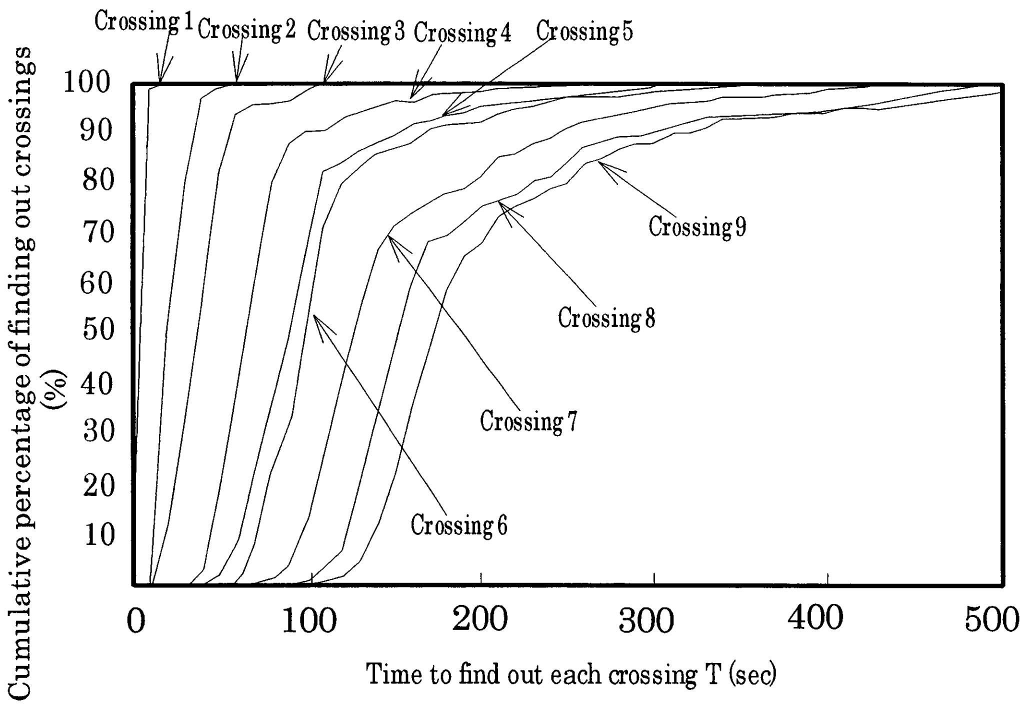


Figure 4.15 Relation between cumulative percentage of finding each crossing and time to find out each crossing

Moreover, it took a long time to find crossing 4 after finding crossing 3 and crossing 7 after finding crossing 6 from the viewpoint of time to find the next crossing after finding one crossing. This is the reason why testees took a long time to search the next crossing because of long distance, especially from crossings 3 to 4 and from crossings 6 to 7 considering much passage frequency at crossing 3 and 6 as shown in Figure 4.14. On the other hand, it took a short time to find crossings 6 after finding crossing 5 because there were a few passage frequency at crossing 5 as shown in Figure 4.14.

From these results, students can grasp characteristics of their wayfindings by using this simulator themselves instead of a fire drill. Furthermore, students also may simply construct many virtual structures and practice evacuation from these structures by making use of the simulator that the author developed.

4.4 Summary

In this chapter, the author presents the development of evacuation simulation software on a 3 dimensional image by using a personal computer in order that students grasp their behavior tendency during a disaster. This simulation software consists of "data editor" by which users can simply construct simulated spaces such as underground shopping centers or department stores, and "simulator" by which users can simulate evacuation in the spaces which are constructed by the data editor.

To evaluate this software, the author tried to explore wayfinding behavior by experiment using two kinds of mazes that were constructed by data editor. One is the maze with many exits and the other was constructed based on the actual maze with one exit that was used in Watabe's experiment.

As the result of the former maze experiment, it is found that three typical characteristics of wayfinding behavior were derived: first, tendency to go straight; second, tendency to turn frequently; and third, tendency to choose paths where they walked before.

As the result of latter maze experiment, it is found that tendencies of the simulator is the same as that of Watabe's experiment from the point of view of the relation between crossings and average time to find out each crossing. Furthermore, the author also found out a part of the maze where evacuees have a difficulty to evacuate due to the result of evacuees' passage frequency.

This simulation software that the author developed can be a useful tool to simply practice evacuations and grasp students' characteristics of wayfinding behavior without being an actual situation.

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CHAPTER 5

Simulation Software of Students Behavior at a Disaster

5.1 Introduction

Teachers can have knowledge about mechanism of an earthquake and preparation for an earthquake and can teach students that knowledge by using the software that the author developed as mentioned in the previous chapter. However, teachers may play an important role not only before an earthquake but also after an earthquake. If a fire breaks out or severe damage caused by an earthquake, students have to escape from school buildings. Furthermore, students may happen to encounter an earthquake in complexes, such as, an underground shopping center when they go on a school excursion. Then it is very important that teachers as guides in such a place must lead students to exit safely and quickly. In order to achieve this, teachers should know the characteristics of students' behavior and the way of conduct for students beforehand. Accordingly, teachers conduct students to practice fire drills at school repeatedly. However, it is impossible to practice a fire drill in an actual structure, such as, an underground shopping center.

Therefore, the author developed computational simulation software of evacuation that teachers can use. Recently, many simulation models of evacuees' conduct in emergency situations have been proposed by using computers.[1),2),3)] These simulation models, however, are focused only on evacuees' conduct. The simulation method should take into account the role of guides such as teachers, because the time to complete the evacuation depends not only on the quick reaction of evacuees but also on better instructions given by guides. In order to simulate the conduct of evacuees and guides in a situation of fire preceded by an earthquake, the author developed a simulation model by using chained codes used in the field of information processing.

In this chapter, the development of the simulation model considering not only the conduct of guides and evacuees but also the reaction of evacuees' conduct to guide's instructions is described. Furthermore, the author also simulates evacuation in an underground shopping center by using a model and considers the result of the simulation.

5.2 Procedure of Simulation Model

The simulation model that the author proposes consists of a floor, fire and human models. Each content of the modeling is described below.

5.2.1 Floor Model

It is difficult and complex to represent space for places such as underground shopping centers, etc., in a computational model. So for the floor modeling, the spaces where people move in, such as, passages and crossings are simply represented with a network of nodes connected by links[1)]. An example of the floor model is shown in Figure 5.1. Nodes and links indicate crossings and passages, respectively. Dots represent the human model which can move on these links.

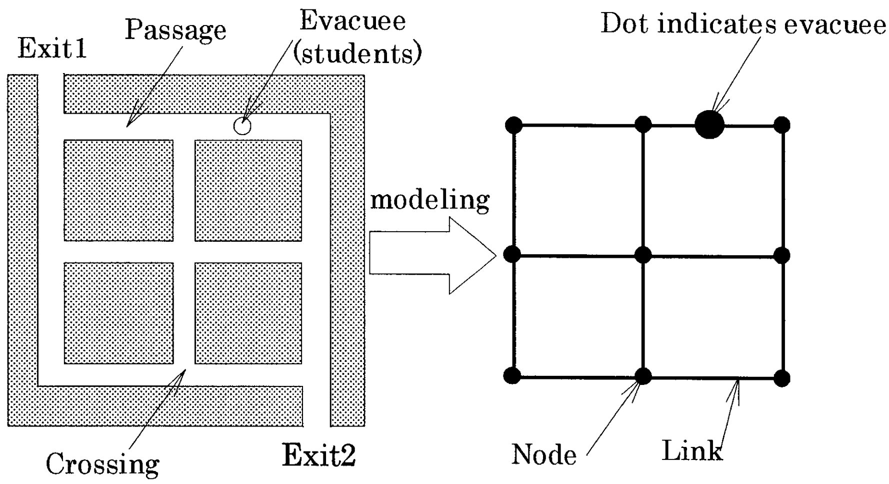


Figure 5.1 Model of floor

5.2.2 Fire Model

Spreading of fire and smoke is a very complex phenomenon. Therefore, for the fire model, the author assumed that the fire can only break out on a node and smoke simply spreads in coaxial circles as shown in Figure 5.2. Harmless smoke spreads at first and then poisonous smoke spreads at the velocity of 0.5 m/s after the break out of fire. In this model, the fire does not break out in numerous places simultaneously right after an earthquake but in specific area.

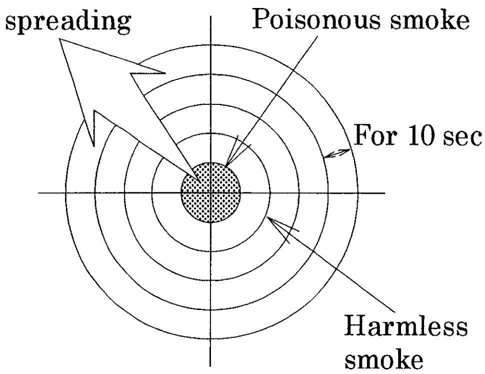


Figure 5.2 Model of fire

5.2.3 Human Model

There are two types of human model. One is the evacuee model and the other is the guide model which represents an teachers. Each model is described bellow.

Some people stroll through the underground shopping center often and others seldom do. So for the evacuee model, the author propose two typical models of evacuee due to their different reaction in an emergency, namely, one could know routes to all exits and the other would not know any route to exit at all.

The way of determining evacuees' conduct is as follows.

(1) Evacuees move in accordance with potential value Ω given by random number before a fire breaks out in an earthquake. This means that evacuees walk randomly at the velocity of 1.3 m/s.

(2) After a fire breaks out, potential value at the point where the fire breaks out, Ω is assumed to be zero and the area of potential value 0 spreading in a coaxial circular manner represents smoke. Evacuees cannot approach this area of fire because the potential values in this area are greater than the rest of the area.

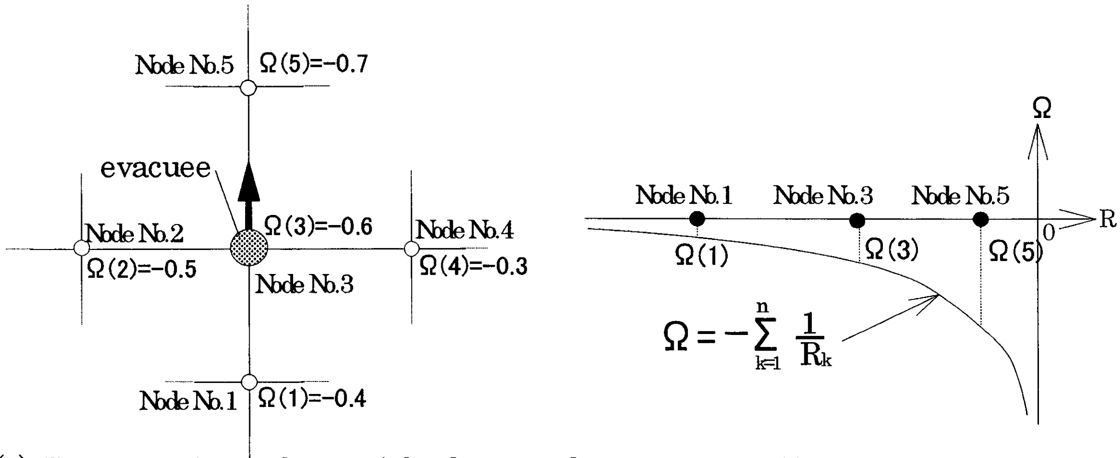
(3) The evacuees who are familiar with the place move in the direction is determined by the potential Ω given in eq.(5.1).

$$\Omega = -\sum_{k=1}^{n} \frac{1}{R_k} \qquad \cdot\cdot\cdot\cdot (5.1)$$

Where R_k denotes a distance from the position of evacuee under consideration to exit k. An example how an evacuee determines the direction is illustrated in Figure 5.3. In this case, an evacuee at node No.3 compares the potential value of his node with those of other joint nodes which are obtained by eq.(5.1) and he moves in the direction of node No.5 because it was the lowest potential value. Whenever the evacuee reaches the next node in a new position, the potential values Ω are calculated.

(4) Some of the evacuees continue to walk randomly if they are confused and forget the exit routes or they are not familiar with the place.

(5) When evacuees get caught in a fire, they could die of suffocation within 90 seconds.



(a) Human motion and potential value at nodes (b) Potential curve

Figure 5.3 Rule for the determining the direction of motion based on the potential value

(6) If evacuees gather in front of an exit, they can pass through the exit without stopping by an arch action.

5.2.4 Guide Model

Guides give evacuees information about the way to the nearest exit when the former encounters the latter. The author introduces two kinds of guide. One is the stationary guide who gives evacuees information about way to the nearest exit and the other is the mobile guide who gives information to evacuees during his patrol in the area. The way of conducting by the guide is as follows.

(1) Stationary guides are stationed at the node where they can see at least one exit and on the circumference of the floor model.
(2) Mobile guides patrol clockwise along rectangular links as shown in Figure 5.4.
(3) The velocity of guides' movement is at 2.0 m/s.
(4) Guides give the evacuees information about the route to the nearest exit when the evacuee is within 5 m. Then the evacuee's speed of movement changes from 1.3 m/s to 2.3m/s.
(5) Guides stop giving evacuees information and start to escape by taking

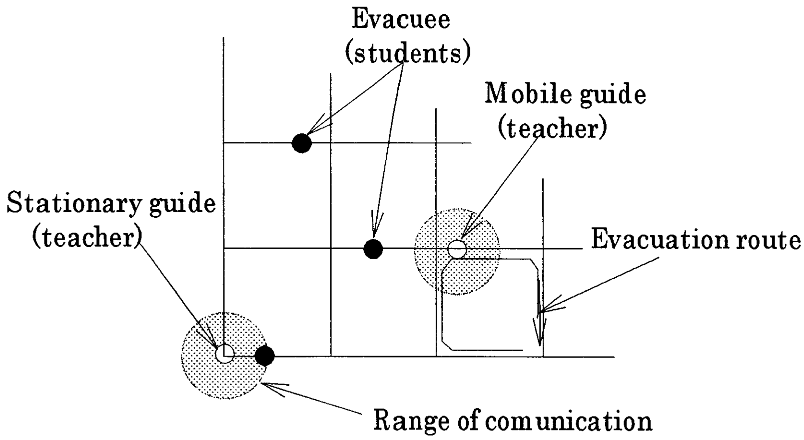
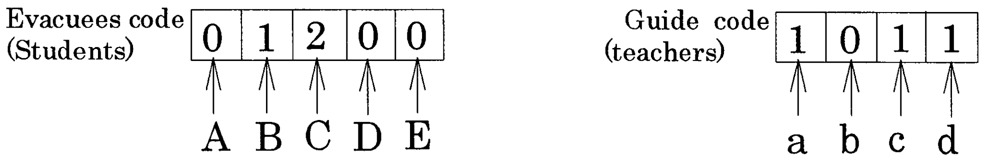


Figure 5.4 Example of stationary and mobile guide

the route to the nearest exit when the guides enter in the smoke area.

5.2.5 Encoding Information about Condition of Evacuees and Guides

The simulation and character of the evacuation and guides are described in chained codes in the field of image processing. Contents of these codes are shown in Figure 5.5.



Code:
- A: whether the evacuee has met guide or not.
- B: whether the evacuee saw a fire or not.
- C: how long the evacuee stayed in fire.
- D: whether the evacuee arrives at exit or not.
- E: whether the evacuee has information about the routes to exits or not.

Code:
- a: kind of guides.
- b: whether guide should begin to evacuate or not.
- c: choice of routes to exits.
- d: whether the guide has information about routes to exits or not.

Figure 5.5 Composition of the codes

The evacuees have five codes from A to E and the guide have four codes from a to d. They are summarized in Table 5.1. For example, the evacuee in Figure 5.5 has not a guide yet, saw a fire, stayed in the area of fire from 30 to 59 seconds, has not arrived at an exit yet and has not obtained any information from a guide. The guide in Figure 5.5 is a mobile guide, does not begin to evacuate yet, plans his escape on route number 1

Table 5.1 The summary of the codes

Evacuees		Guides	
A	Yes: 1, No: 0	a	Stationary guide: 0 Mobile guide: 1
B	Yes: 1, No: 0		
C	0 sec: 0	b	Yes: 1, No: 0
	0-29 sec: 1	c	Number of route
	30-59 sec: 2	d	Yes:1
	60-89 sec: 3		
	90 sec: 4		
D	Yes: 1, No: 0		
E	Yes: 1, No: 0		

and has information about routes to exits.

5.2.6 Transmitting Guides' Information to Evacuees

When a guide sees evacuees after the fire breaks out, he gives evacuees his instruction to the nearest exit. The way of conveying the information is shown in Figure 5.6. At that moment, the guide's code d that indicates information about the route to the exit replaces the corresponding evacuee's code E resulting in the evacuee's new knowledge. Then the evacuee's code A changes from 0 to 1 by getting new information.

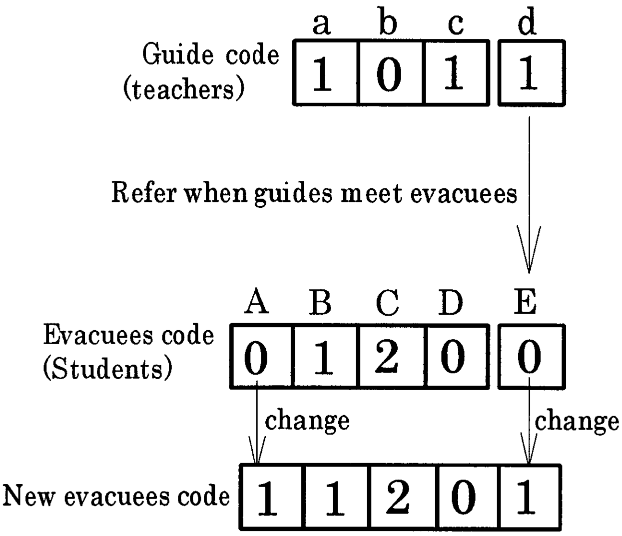
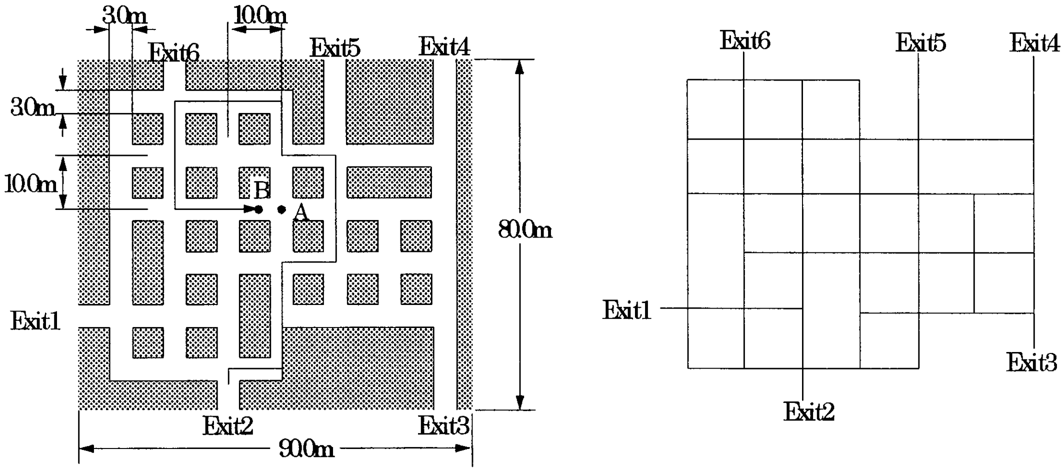


Figure 5.6 Example of the transmission of information

5.3 Example of Simulation

5.3.1 Simulation Condition

The author applied this simulation model to an actual underground shopping center in Tokyo. This model is shown in Figure 5.7.



(a) An actual underground shopping center (b) Simulation model

Figure 5.7 Model analyzed

The process of the simulation is explained as follows along the flowchart in Figure 5.8.

(1) The number of evacuees is 10, 20, 40, 60, 80 and 100.
(2) Fire breaks out at point A in Figure 3.7 30sec after the beginning of simulation.
(3) As soon as fire breaks out, evacuees begin to evacuate and guides start to assist evacuees.
(4) Simulation stops when the last evacuee succeeded in evacuating or failed to evacuate resulting in death from fire or smoke inhalation.
(5) The time for evacuation is defined as the time when the very last evacuee reaches an exit.

The author calculated the number of evacuees who could be killed and the actual time of complete evacuation altered by changes in the percentage of evacuees who know the way to the exits and the number of

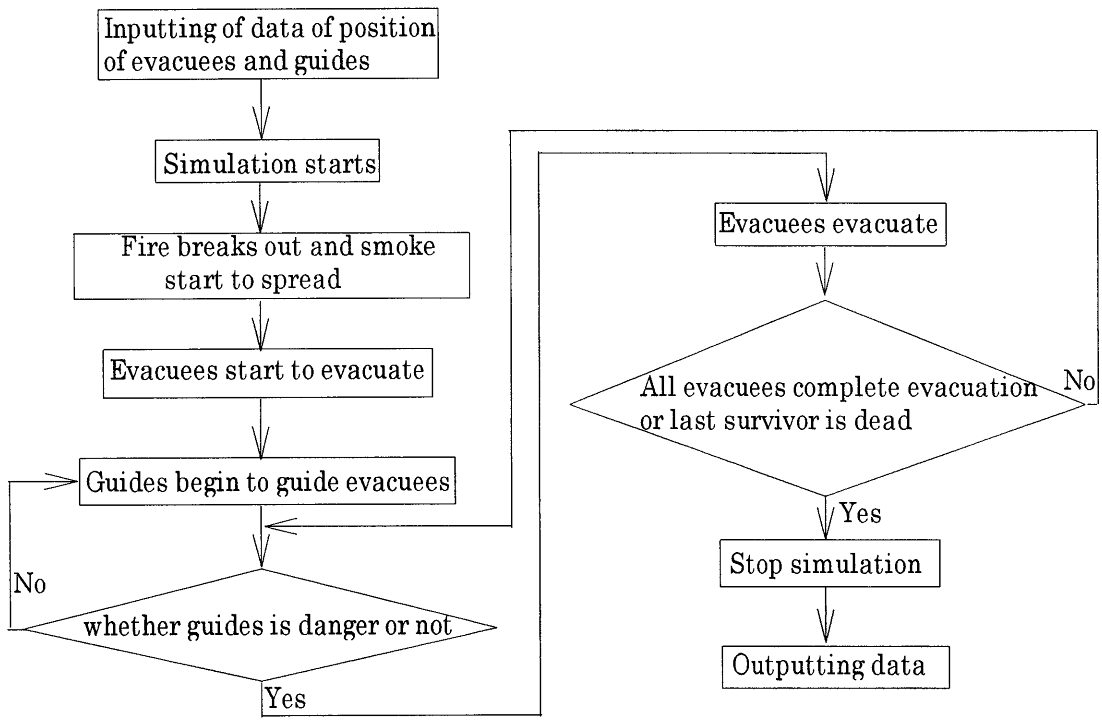


Figure 5.8 Flowchart of simulation

Table 5.2 Cases for simulation

		Percentage of evacuees who know the way to exits(5)		
		0	50	100
Number of guids	0	ST / MO	ST / MO	ST / MO
	2	ST / MO	ST / MO	ST / MO
	4	ST / MO	ST / MO	ST / MO
	6	ST / MO	ST / MO	ST / MO
	8	ST / MO	ST / MO	ST / MO
	10	ST / MO	ST / MO	ST / MO

ST: A case of stationary guide

MO: A case of mobile guide

guides. The percentage and number are listed in Table 5.2 and the aut hor also calculated all cases 10 times.

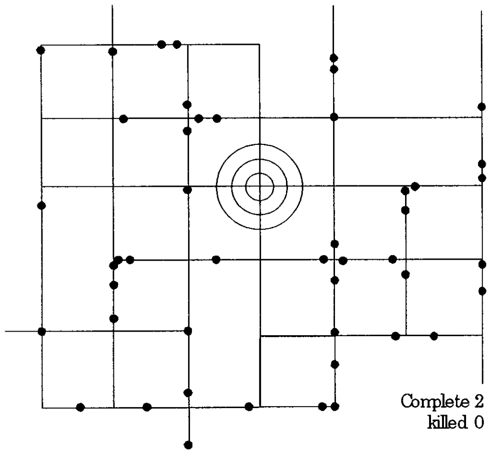
5.3.2 Result of Simulation

The simulations of evacuees after 50 and 150 seconds of the beginning of simulation are shown in Figure 5.8 and 5.9. Figure 5.8 shows the situations without guide and Figure 5.9 with 10 mobile guides. In both cases, the percentage of evacuees who know the route to exits is 50 %. Symbols ● and ○ represent evacuees and guides respectively, and smoke and fire are shown in coaxial colorless or gray circles in these figures. It can be seen that evacuees can evacuate more quickly in Figure 5.9 than in Figure 5.8 in the same simulation time due to the aid of the guide.

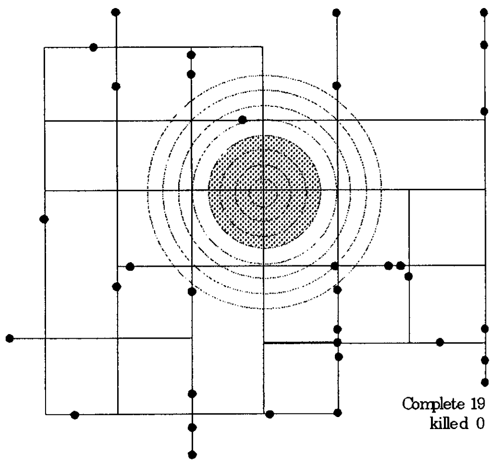
Figure 5.10 shows the relation between the number of success in evacuation and the time to complete the evacuation by changing the number of guides. Figure 5.10(a) is the result from the cases with stationary guides and Figure 10(b) with mobile guides. The percentage of evacuees who know the route to exits is 50 % in the same condition as in Figure 5.8 and Figure 3.9. It is found that with more guide's assistance, more evacuees can complete evacuation, and a mobile guide is more effective than a stationary guide.

Figure 5.11 illustrates the difference in the number of evacuees killed with the changes in the number of guides and evacuees who know the way to the exits. Figure 5.11(a) is the case of a stationary guide and Figure 11(b) is the case of a mobile guide. From both figures, it can be seen that the more the guides assist evacuees, the higher the percentage of evacuees who could know the route to the exits, and the more evacuees could complete evacuation. Moreover, it is found that a mobile guide is more effective than a stationary guide in terms of reducing the death rate.

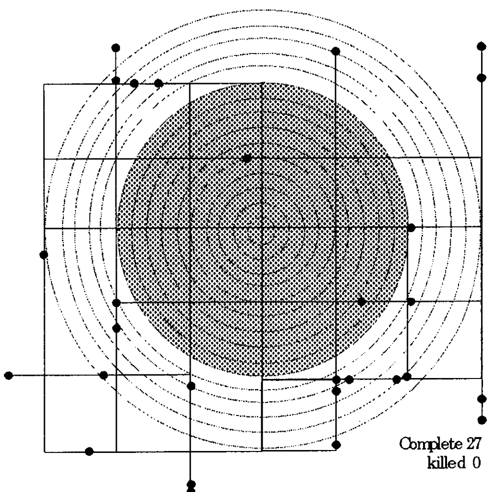
The difference in time span to complete evacuation with the dangers in the number of guides and evacuees who know the way to the exits is shown in Figure 5.12. Figure 5.12(a) is the case of a stationary guide and Figure 12(b) is the case of a mobile guide. These figures indicate that the higher the rate of evacuees who know the route to the exits, the more quickly the evacuation is completed. When the number of guides is zero and the percentage of evacuees who know the way to exits is low, the time to complete evacuation decreases contrary to the author's expectation in these figures. This is only because the time to complete evacuation here is defined as the time when the very last evacuee reaches an exit. By no means is this an effective evacuation but a rather poor one because evacuees are mostly killed as shown in Figure 5.11(b).



(a) Simulation at 50 sec

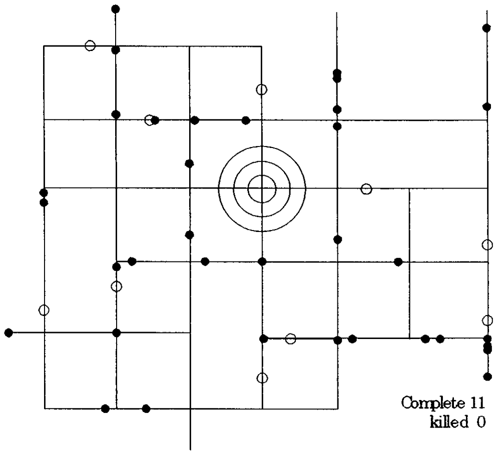


(b) Simulation at 100 sec

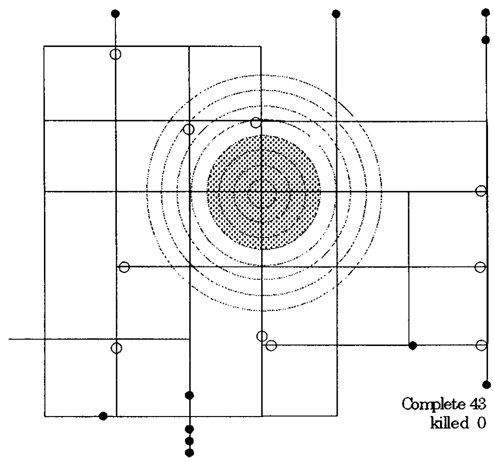


(c) Simulation at 200 sec

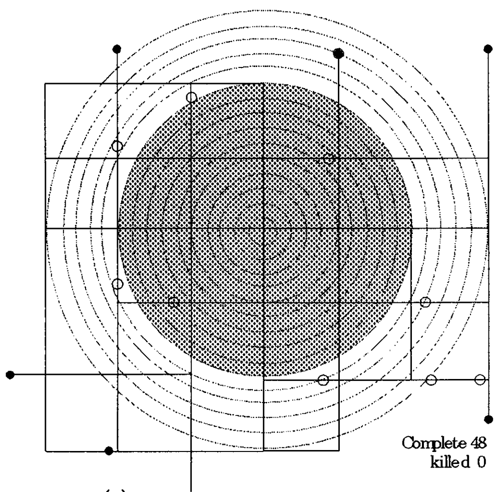
Figure 5.9 Simulation of evacuees without guide



(a) Simulation at 50 sec



(b) Simulation at 100 sec



(c) Simulation at 200 sec

Figure 5.10 Simulation of evacuees with 10 mobile guide

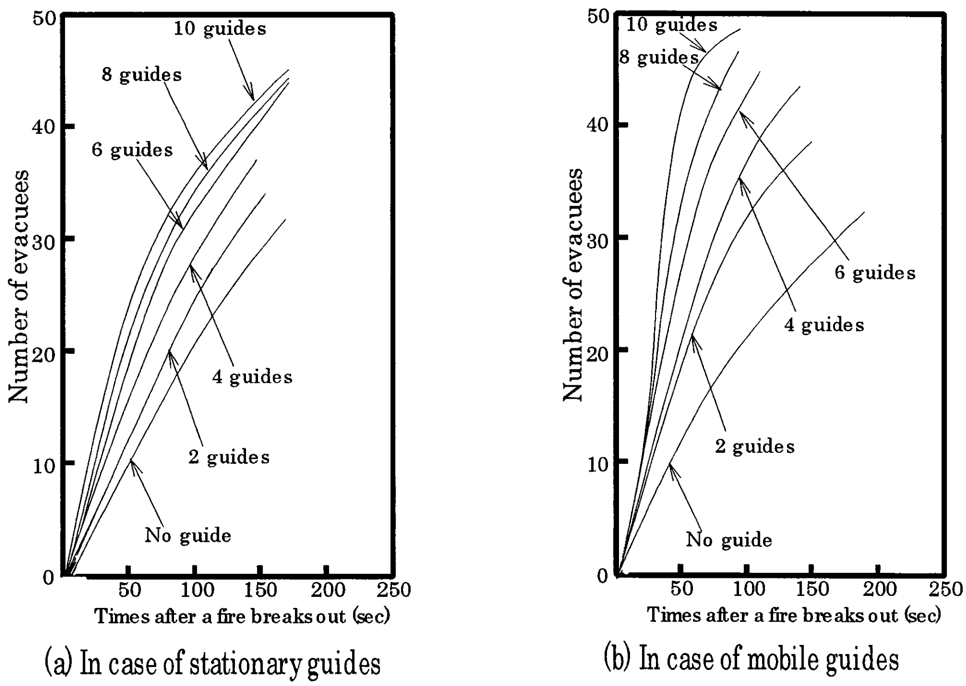


Figure 5.11 Comparison of the number of evacuees who completed evacuation

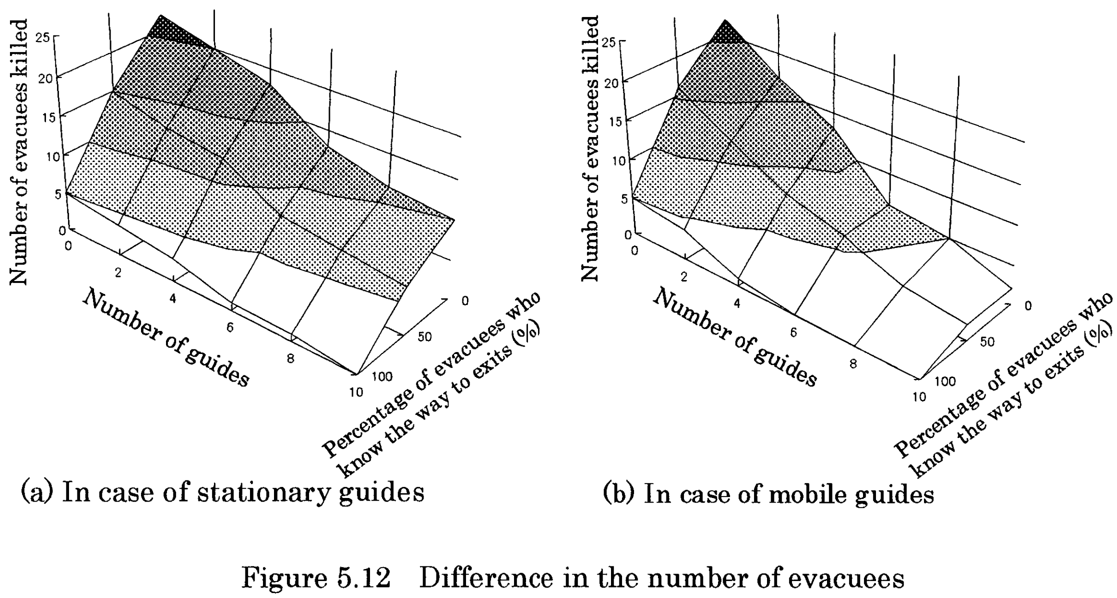
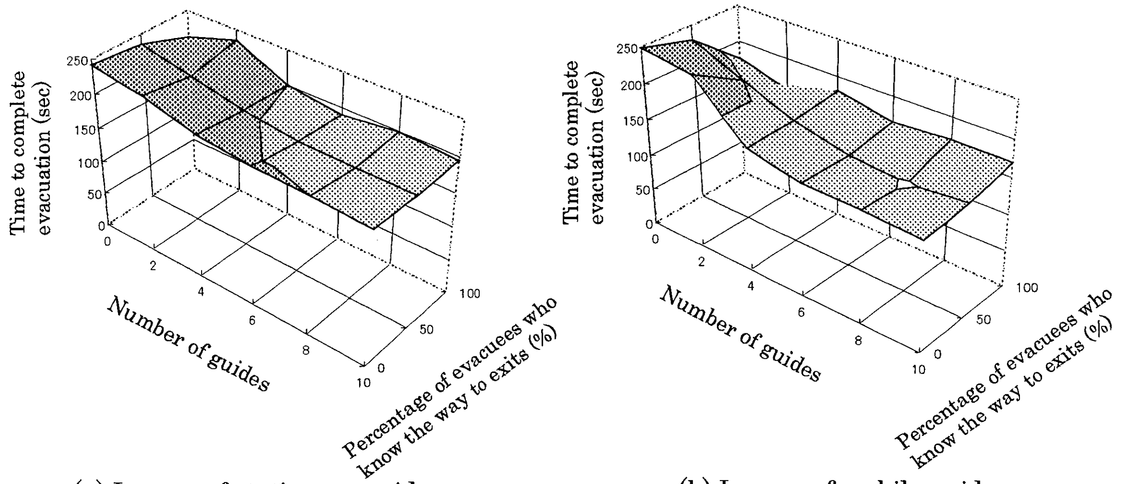


Figure 5.12 Difference in the number of evacuees who are killed with guides' assistance



(a) In case of stationary guides (b) In case of mobile guides

Figure 5.13 Difference in time span to complete evacuation with guides' assistance

Finally, Figure 5.13 shows a plot of the changes in the time to complete evacuation and percentage of evacuees killed under the condition that the ratio of guides and evacuees is kept constant at 1 to 10 with the changes in the number of guides from 10 to 2. It is found that the percentage of evacuees killed and the time to complete evacuation tend to increase with decreasing the number of guides even if the ratio is kept constant.

5.4 Summary

In this chapter, a computational simulation model at the reaction of evacuees to guide's instruction is first developed. Then the author also tried to apply this simulation model to the actual underground shopping center in Tokyo and met with the following results.

(1) It was found that the more guides assist, the more evacuees could evacuate.
(2) Instructions provided by mobile guides is more effective than that of stationary guides.

(3) There is an influence on safe evacuation based on the number of guides even if the percentage of guide and evacuees is the same.

From these result of the simulation, the author think that it is very important for teachers to instruct students the evacuation route when an earthquake occurs. Therefore, teachers should consider the emergency management for their instructions and the education of disaster preparedness for teachers when they draw up a plan or devise disaster prevention plans in their school by using this program of the simulation model.

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CHAPTER 6

Conclusion and Direction for Future Research

6.1 Conclusion

The study in this dissertation was done in order to develop some computational software for disaster preparedness education for teachers and schoolchildren in elementary and junior high schools. Summary and conclusion for each software that was developed are described as follows.

In chapter1, the author found that there was no appropriate teaching materials for earthquake preparedness even if many teachers strongly felt the necessity of earthquake preparedness education in schools in reference to 1987 Naruse's questionnaire survey. Furthermore, a questionnaire was distributed to elementary schools and junior high schools in Shizuoka and Yamaguchi prefectures in order to investigate teachers' requirement of teaching materials and tools for earthquake preparedness. As a result, the author suggested three kinds of software for earthquake preparedness education: "Education software for earthquake preparedness", "Simulator for evacuation by using 3 dimensional images" and "Simulation software for evacuation."

In chapter 2, the author thought education software for earthquake preparedness for teachers on a personal computer is needed first because teachers must play an important role in an earthquake. Therefore, the software for teachers was developed based on Hypertext used in education software. Before developing the software, curriculum was made and divided into three modules: "Understanding earthquake", "Earthquake disasters and survival" and "Preparation for earthquake hazards" referring to the result of questionnaires in Shizuoka and Yamaguchi Prefectures. After developing the software, it was distributed to 26 teachers in order to evaluate the software's effectiveness. As a result, it is found that all the modules, particularly in "Preparation for earthquake hazards" were improved after the software was introduced. Moreover, most of the teachers felt it was the appropriate level of difficulty for each model for them to study. From these results of the evaluation, the software can be a useful education software for learning earthquake prevention.

In chapter 3, education software for earthquake preparedness for students was developed. Before developing the software, the curriculum that was made in chapter 2 was reconstructed to change appropriate contents suitable for students by using the brain writing technique and the KJ method. The author also introduced S-P curve, Caution Index and IRS analysis that were used in the field of educational technology in order to evaluate visually and quantitatively the improvement of knowledge of earthquake preparedness. After developing the software, it was distributed to an elementary school and a junior high school. As a result, the improvement of knowledge of earthquake preparedness can be confirmed from the result of S-P curve and Caution index. Moreover, the new version software was evaluated again after the curriculum was reconstructed by using IRS analysis. After this evaluation, it is found that there was an improvement of effectiveness in learning earthquake preparedness.

From these results, it can be useful for students to use the software and for us to evaluate its effectiveness easily.

In chapter 4, a 3 dimensional image evacuation simulation using a personal computer was developed in order that teachers and students can grasp the tendency of their behavior during a disaster. After developing it, wayfinding behavior by experiment using two kinds of mazes was explored.

As a result, it is found that tendencies of the simulator is the same as that of the actual experiment. From these results, learners can practice a fire drill by using this simulator.

In chapter 5, the author thought it is also an important for teachers to know students' evacuation behavior. Especially, teachers should not only grasp their behavior but also know how to discipline them quickly when they go on school excursions or off-campus trainings. The author developed the model that simulates not only the conduct of teachers and evacuees but also the reaction of school children's conduct to guides' instructions. To perform the reaction of evacuees' conduct to guides' instructions, evacuees' code was expressed by using chained codes.

The simulation model was applied to an actual underground shopping center. As a result, it was found that the more guides for assistance, the more evacuees could evacuate quickly and a mobile guide was especially more effective than that of a stationary guide. Teachers can simulate evacuation behavior and conducts of schoolchildren by the simulation model in anticipation of school events, such as, a school excursion.

6.2 Direction for Future Research

The author independently developed and evaluated four kinds of software. However, people often simultaneously need knowledge about earthquake and evacuation during an earthquake disaster in view of past earthquake disasters. Therefore, it is necessary to combine four kinds of software and generally evaluate children's diminishing fear of earthquakes from the viewpoint of knowledge and tendency of evacuation behaviors.

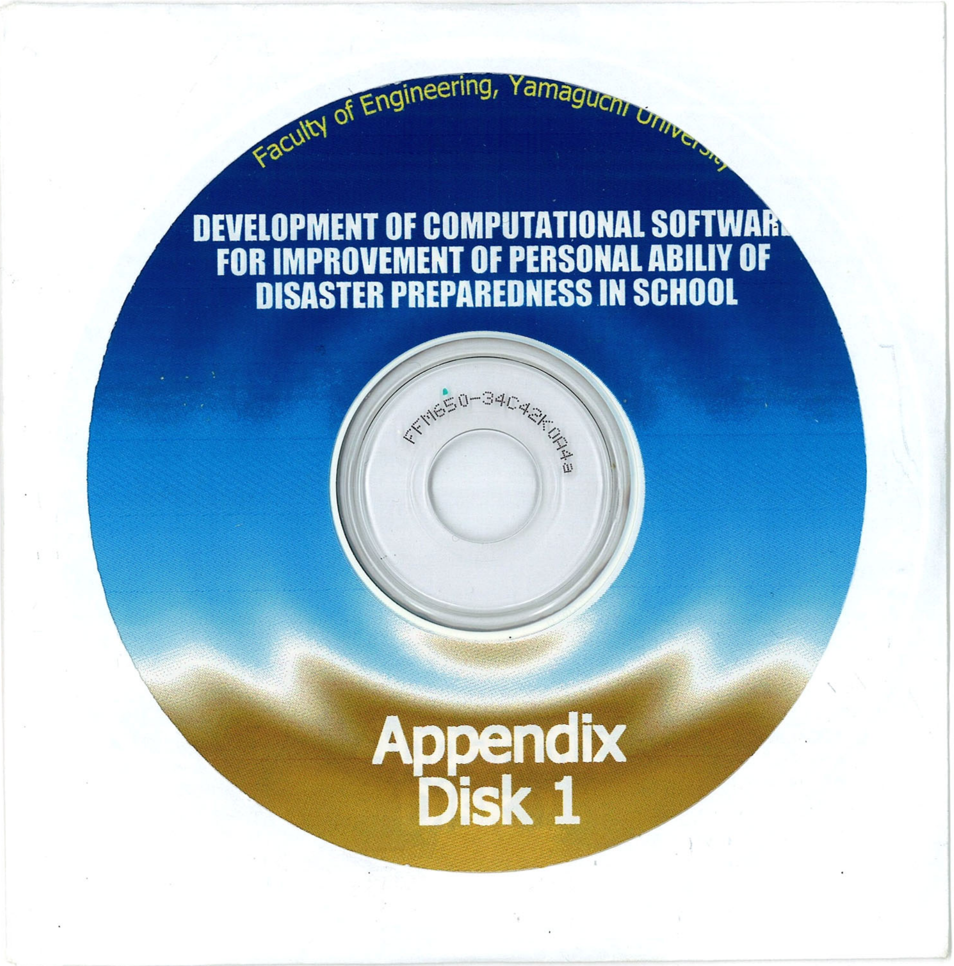
As for the continuance of this study, direction for future research is described as follows.

1. The author needs to distribute his developed software to many schools and evaluate its effectiveness on a long term basis.

2. The author needs to evaluate the use of 3D image evacuation simulation software, which has influence on students' awareness of earthquake preparedness.
3. Curriculums for earthquake preparedness education for school children have been constructed by using KJ method. However, the curriculum should be constructed based on a formative processing of knowledge and awareness about earthquake preparedness. Therefore, the field of educational psychology should be introduced in order that school children can learn about earthquake prevention more effectively.
4. Method of evaluating student's ability against disasters by using the software that the author developed should be suggested.

Finally, the author will continue to improve and evaluate the software that was developed in this dissertation considering these points as mentioned above in the future.

APPENDIX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Appendix
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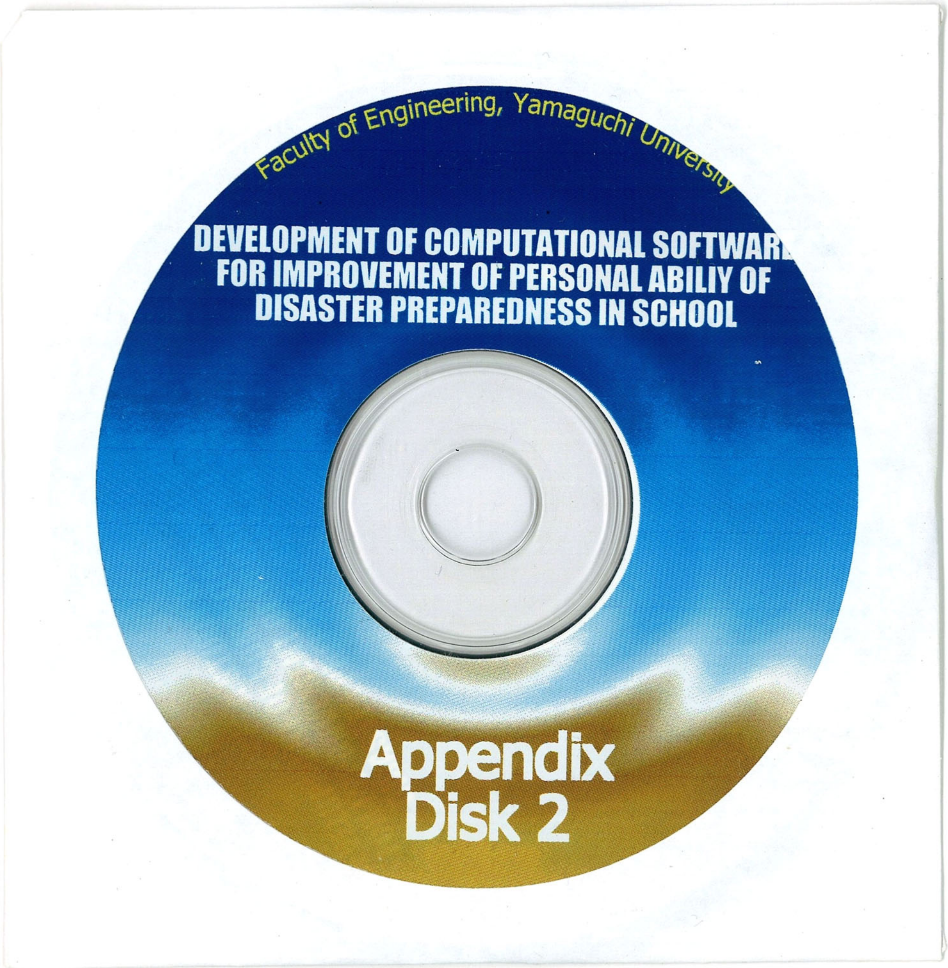
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Disk 2