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Development of a Web Based Environment for Task Centered Learning of Relative Motion

상대 운동의 과제 중심 학습을 위한 웹 기반 환경 개발

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이 논문을 교육학 박사 학위 논문으로 제출함

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박철호의 박사 학위 논문을 인준함

2001년 6월

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Abstract

The purpose of this research is to develop a Web based science learning environment. To accomplish this purpose, developmental goals were specified, learning strategy was devised, structure and functions of the Web based learning environment were designed and developed, and the instructional effect was evaluated.

Developmental goals were specified by analyzing two researchers' reflections on their experience in Web based science learning environment. Their reflections were classified into four categories: content, learner, instructor, and system. The goals were (1) to provide differentiated learning tasks, (2) to encourage learners to express their conceptions, (3) to assist instructors to observe and guide students, and (4) to make integrated structure and functions in the Web based learning environment.

Task centered learning strategy was devised to achieve the goals. Elements of two learning strategies were adopted: "problems from everyday contexts" and "self-directed learning in group" of the problem based learning, and "learning units" and "individualized feedback" of the mastery learning. In the Web based learning environment, learning tasks are given. Learners are permitted to attempt the task if they pass diagnostic test. They make use of learning materials and discuss with others to fulfill the task. After fulfilling the task, they report about it. If the report is accepted by instructor, they are given a task fulfillment certificate. If not, they get feedback and revise the report.

Structure and functions of the Web based learning environment were designed and developed for task centered learning. In the process, the developer considered content, learner, instructor, and system simultaneously and comprehensively. Four "rooms" (Library, Laboratory, Conference Room, and Workshop) were developed. They are integrated that participants' interactions are arranged systematically. Learners' activities are recorded automatically so that instructors can easily observe them. Functions such as diagnosis pass approval, task fulfillment certification, and privilege to write on learners' private board were developed to help instructors to guide learners.

After the development, instructional effect of the Web based learning environment was evaluated. Students' utterances in the Web based learning environment were classified and compared with known preconceptions. Diagnostic test, discussion in the Conference Room, and task fulfillment report encouraged the students to express their conceptions. The Relativity of Motion Questionnaire was used to examine the students' conceptions before and after their participation. Students of lower score made conceptual changes, but larger sample is needed to confirm this finding. Students and experts evaluated the Web based learning environment according to a criteria. Students appreciated the Web based learning environment as being interesting and helpful, and asked more learning materials and privileges. Experts appreciated it as being effective in instructor's observation and guidance, and suggested improvement to be practical in the current school situation.

The Web based learning environment was developed adopting task centered learning strategy. It was effective in students' expression of conceptions and conceptual changes, and in instructors' observation and guidance.

Key words: Web based learning environment, task centered learning, relative motion, developmental research

Student number: 98717-804

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Ⅰ. Introduction

1. Background

Relative motion has been studied in the history of physics from Galileo to Einstein, and it encompasses basic concepts of kinematics such as displacement, velocity, frames of reference, etc. However, students have misconceptions of relative motion and have difficulties in understanding the concept (Aguirre and Erickson, 1984; Park, 1992; Bowden et al., 1992; Walsh et al., 1993; Panse et al., 1994; Oh, 1998). Researchers suggested instructional strategies such as "metacognitive activities (Park, 1992)" and "structured contrastive activities (Oh, 1998)" to help learners to have scientific conceptions. These instructional strategies will support learning of relative motion.

Learning is, in the constructivist view, constructing the learner's own knowledge through interacting with the surrounding environment. Constructivist learning environment is a place where learners may work together and support each other as they use a variety of tools and information resources in their guided pursuit of learning goals and problem-solving activities (Wilson, 1996). In such a learning environment, if the guidance is systematically provided, learners will actively participate in learning process and harvest fruitful learning outcomes.

One way to realize this learning environment is to develop a Web based learning environment. The Web was developed as one of the Internet services to share information among collaborating people. Now it surpasses other Internet services in flexibility and usability, and prevails throughout the world. Its flexibility, usability and prevalence are adequate conditions for a learning environment, and there have been efforts to design and develop Web based learning environments around the world (Khan, 1997).

However, the Web is so open a system that it is hard to keep track of learners' activities, and to let them stay long and visit frequently. It needs technical and instructional solutions. Technical solution is to make the Web based learning environment powered by server-side technologies, such as server-side scripts and database management systems. Maximum use of server-side technologies will keep every track of the learners.

On the other hand, to let them stay long and visit frequently is another problem. It requires instructional strategies. One of the strategies is task centered learning, which consists of diagnostic tests, learning tasks, task fulfillment report, and instructional feedback. Instructors help learners reach the goal of learning tasks. The tasks are selected from everyday context or novel situation so that learners can have interest and authentic learning experience. The learners share their feelings and informations with others while they are attempting the task.

Development of a Web based learning environment is a kind of instructional systems development (ISD). This can be guided by ISD models (eg. Dick & Carey, 1996; Willis, 1995). But development is more than simple application of a theory or a model. Developers' or practitioners' activities are characterized by 'reflection-in-action' (Schön, 1983), because every situation where they have to tackle problem is often too unique to apply existing theories or models. They also need "systems thinking" because a real situation consists of many or uncountable variables interacting with one another. It will be helpful for them to have in mind a systems diagram of the situation and seek leverages which are the key to the problem (Senge, 1993). In this research, the developer reflected on his practice and consider various aspects of the Web based learning environment simultaneously and comprehensively by help of the Design Matrix (Table Ⅲ-1).

2. Purpose

The purpose of this research is to develop a Web based environment for task centered learning of relative motion. The following tasks are tackled in this research.

1) Goal specification

(1) What are the developmental goals of a Web based learning environment?

2) Design and development

(1) What learning strategy is required for a Web based learning environment to achieve the developmental goals?
(2) What structure and functions are required for a Web based learning environment to achieve the developmental goals?

3) Evaluation

(1) Is the Web based learning environment effective in students' expressing and changing their conceptions of relative motion?
(2) Is the Web based learning environment effective in instructors' observing and guiding students?

3. Methods

1) Goal specification

Researchers' reflection on their experience in Web based science learning environment was classified into four categories: content, learner, instructor, and system.

2) Design and development

The Web based learning environment adopted task centered learning strategy. Structure and functions of the Web based environment for task centered learning were designed and developed. The structure and functions were integrated so that learners and instructors could work effectively in the Web based learning environment.

The development procedure emphasized recursion and reflection. This emphasis is similar to Willis' (1995) R2D2 model. In the development process, the developer recursively reflected on the development and revised it. The Design Matrix (Table Ⅲ-1) was devised to help the developer to consider interactions among the structural components of the Web based learning environment simultaneously and comprehensively.

3) Evaluation

The instructional effects of the Web based learning environment was evaluated as follows:

(1) Students' conceptions of relative motion expressed in the Web based learning environment were classified and compared with known preconceptions..

(2) Students' conceptual changes was measured by the Relativity of Motion Questionnaire (Oh, 1998; Pak et al., 2001).

(3) Students' feedbacks about the Web based learning environment were classified.

(4) Physics education experts evaluated the effectiveness of the Web based learning environment in instructors' observing and guiding the students.

4. Limitations

The students were working as volunteers in the Web based learning environment. The result might be different if the participation were compulsory.

The sample was small. To generalize the instructional effects of the Web based learning environment requires large sample.

This research did not separate variables to make experiment which variables affects students' learning, rather various aspects are considered simultaneously and comprehensively in the development process.

Information technologies develop so fast that the state-of-the-art Web technologies used in the Web based learning environment might became obsolete in a short time.

Ⅱ. Literature Review

1. Task centered learning

Structure and functions of a learning environment reflect learning strategies. The Web based learning environment is intended to help individual students obtain scientific conceptions about relative motion through active interaction. This intention leads to task centered learning strategy. Task centered learning strategy in this Web based learning environment is to learn by fulfilling authentic tasks by help of individualized feedback.

Learning by fulfilling authentic tasks is similar to the problem based learning (PBL). It was developed in medical education in the mid-1950's and since that time it has been refined and implemented in over sixty medical schools. The eight principles of PBL are as follows: (1) Anchor all learning activities to a larger tasks or problem. (2) Support the learner in developing ownership for the overall problem or tasks. (3) Design an authentic task. (4) Design the task and the learning environment to reflect the complexity of the environment they should be able to function in at the end of learning. (5) Give the learner ownership of the process used to develop a solution. (6) Design the learning environment to support and challenge the learner's thinking. (7) Encourage testing ideas against alternative views and alternative contexts. (8) Provide opportunity for and support reflection on both the content learned and the learning process (Savery and Duffy, 1996). A general scenario of PBL in medical school is as follows: (1) Students are divided into groups of five, and then presented a real problem. (2) They discuss the problem, generating hypotheses based on whatever experience or knowledge they have, identifying relevant facts in the case, and identifying learning issues (objectives generation). (3) After that, they gather the information from the available medical library and computer database resources (self-directed learning). (4) After self-directed learning, they meet again and work on the problem with this new level of understanding. (5) This cycle repeats itself if new learning issues arise (Barrows, 1992; Savery and Duffy, 1996).

Individualized feedback of task centered learning is similar to mastery learning. The characteristics of mastery learning are as follows (Fuchs et al., 1986): (1) Material to be learned is divided into smaller units, and performance criteria are established. (2) Following instruction on each learning unit, a test is administered, the result of which provides feedback to teacher and student regarding mastery of the unit and necessary corrective strategies (formative testing). (3) The teacher provides corrective feedback until the student achieves mastery of the learning unit (systematic correction). (4) The student then progresses to the next skill in the learning hierarchy. From meta-analysis result of 108 research papers on mastery learning, Kulik et al. (1990) concluded that mastery learning program have positive effects on student achievement. Although mastery learning focuses on individual learners, it does not prohibit their interactions. Mevarech (1991), and Mevarech and Susak (1993) reported that cooperative-mastery learning group of 3rd and 4th grade children performed better in questioning behavior and in mathematics than cooperative-only group. Lazarowitz et al. (1994) reported that academic achievements of cooperative-mastery learning group of 11th and 12th grade students was higher than individualized-mastery group.

PBL emphasizes authentic problems from everyday context, students' generating objectives and self-directed learning in group. However, it is usually applied to higher education like medical education, for learning tasks from complex real situation might be too hard for primary or secondary students to fulfill. Mastery learning can complement PBL by individualized feedback during the task fulfillment process. Task centered learning is synergic combination of PBL and mastery learning.

Contexts for learning tasks must be carefully selected because learners respond differently according to contexts and skills. Song and Black (1991) found that Korean secondary school students showed better performance in the interpretation skill in everyday contexts while they showed better application skill in scientific contexts. However, task fulfillment requires both interpretation and prediction skills and more. The decision between everyday and scientific contexts are not simple. This research decided to employ both everyday contexts and scientific or novel situations.

2. Web based learning environment

Learning experience consists of interactions between content, student and teacher, which are affected by society and school (Chung, 1971). Figure Ⅱ-1 shows the relationship between these five components (Kim et al., 1988). These are structural components of a learning environment.

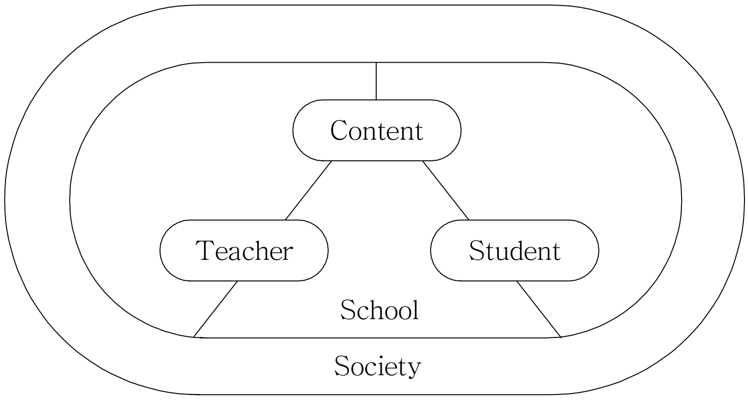


Figure Ⅱ-1. The learning experience model (Kim et al., 1988)

Wilson (1996) gave a definition of a constructivist learning environment: a place where learners may work together and support each other as they use a variety of tools and information resources in their guided pursuit of learning goals and problem-solving activities. Learners are given 'rooms' to explore. They work together on projects, supporting and learning from one another, as well as from their environment. They are given generous access to tools and information resources, and also proper support and guidance. Under this condition, learning is fostered and supported, but not controlled nor dictated.

Perkins (1991) suggested that all learning environments, including traditional classrooms, include the following functional components:

Information banks, Symbol pads, Phenomenaria, Construction kits and Task manager. Information banks are sources of information, such as textbooks, teachers, encyclopedia, videotapes, etc. Symbol pads are surfaces for the construction and manipulation of symbols and language, such as student notebooks, word processors, drawing programs, etc. Phenomenaria are areas for presenting, observing and manipulating phenomena, such as aquariums, instructional simulations, etc. Construction kits are packaged collections of content components for assembly and manipulation, such as learning logs, math-manipulation software, or authoring tools. Task managers are those elements of the environment that set tasks and provide guidance, feedback and changes in direction, such as assignments within textbooks, grading programs, etc.

Park (1997) developed a Web based learning environment, NetClass, and guided senior high school students discussion on science-related subjects. The Web based learning environment consisted of Library, Conference Room, and Workshop. Figure Ⅱ-2 shows the first page of NetClass. (It is no longer available.) At first, it had only a Conference Room. The Conference Room was based on a Web forum system, NetForum[1]. It had hierarchical structure: Forum > Topic > Message > Reply. In a forum, participants suggested a topic, and then wrote messages about the topic. The other participants wrote replies to messages. But as the computer-mediated communication went on, student-originated topics turned out to be ineffective and basic information about topic and a place to synthesize discussions became necessary. Then Workshop and Library

1) NetForum was made by a group in the Department of Biostatistics and Medical Informatics, University of Wisconsin, but is no longer available.

were made. A topic was suggested in the Workshop and basic information about force and motion concepts was provided in the Library.

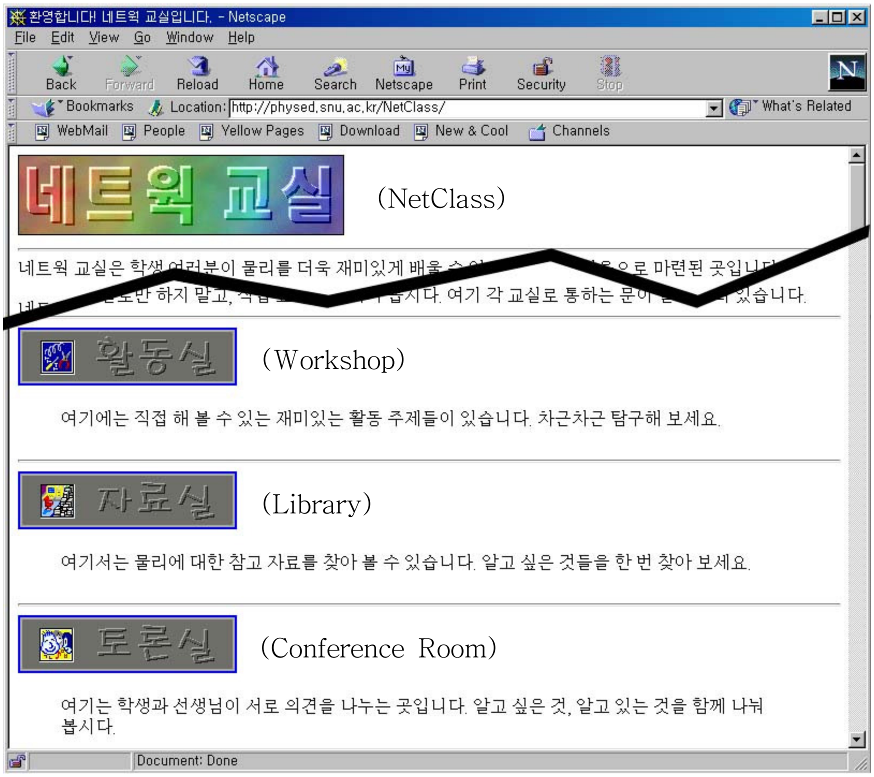


Figure Ⅱ-2. NetClass

However, NetClass had some shortcomings. First, it did not keep records of learners' message reading. The instructor did not see if his message was read by a certain student. He had difficulties in communicating with the students. Second, the 'rooms' or functions were not integrated effectively. For example, information in the Library could not be referred directly in the Conference Room. Because the Web based learning environment was based on a foreign product, there were limits in adapting the product for specific purposes. Finally, information in the

Library was insufficient. It was only the summary of concepts and formulas in textbook. Furthermore, there was no evidence in the discussion that learners had looked up this information.

After reflecting on these, Park and Pak (2000) suggested another prototype of a Web based learning environment, i*dle, which integrates Library, Laboratory, Conference Room, and Workshop.

3. Relative motion

Aguirre and Erickson (1984) interviewed American 10th grade students regarding conceptions about ten implicit vector characteristics by analysis of interview records. They found 'inferred rules,' which are consistent conceptions that a subject appears to be using on a given occasion to deal with a particular aspect of an interview situation.

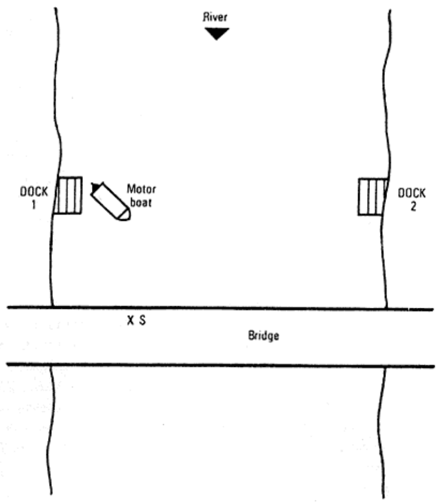


Figure Ⅱ-3. The motorboat problem
(Aguirre and Erickson, 1984)

For example, students were asked to describe a motion of a motorboat on the river by an observer on the bridge, and their answers were categorized into inferred rules: RPM-1 (student does not distinguish movements relative to a stationary and relative to a moving body), RPM-2 (student distinguishes movement relative to an implicit reference point and relative to a moving body), and RPM-3 (student distinguishes movement relative to several stationary bodies and relative to a moving body). The situation is shown in Figure Ⅱ-3. These inferred rules were used to analyze students' answers to diagnostic tests and task fulfillment reports, and to plan instructional feedback in the Web based learning environment.

Park (1992) investigated Korean college students' conceptual change in the basic theory of relativity. He proposed a model of conceptual change through metacognitive activities. He found that students had various ideas about relativity and the ratio of conceptual change after instruction was 45%. Most students thought that metacognitive activities were helpful for their learning and it was also observed that students actively participated in learning. In the Web based learning environment, instructor discussed with learners regarding their activities and asked them to reflect on their thinking, which was a kind of metacognitive activity.

Bowden et al. (1992) and Walsh et al. (1993) analyzed American 10th grade students' and college students' solving problems regarding frame of reference and relative speed by the method of phenomenography, and presented the categories of description. For example, students were asked to compare the times taken for a motorboat to cross a river when the river is flowing and when it is not, which is adapted from Aguirre and Erickson (1984). Their answers were analyzed through iterative process of phenomenography to produce final categories of descriptions (Table Ⅱ-1). These categories of descriptions helped analyze students' task fulfillment report in the Web based learning environment.

Table Ⅱ-1. Categories of description about the motorboat problem (Bowden et al., 1992)

Category	Description	Student focus
Rd	Longer distance relative to river, same speed relative to river, therefore longer time	Distance relative to river, distinguishing frames of reference
V	Smaller velocity, same distance, therefore longer time	Velocity, combination of velocities
Dp	Longer distance, therefore longer time	Distance; path traveled parabolic or discontinuous (speed of boat unaffected by flow of river)
D	Same distance, therefore same time	Distance (speed of boat unaffected by flow of river)
F	Less pushing force left, therefore longer time	Force, power, etc (linear relation to speed and distance [same] taken for granted)

Oh (1998) investigated Korean junior high school students' conceptual change in force and motion. He proposed a model of conceptual change through contrastive activity. The contrastive activity proved to be helpful for them to recognize the limit of their naive ideas and accept the scientific concepts. He also developed questionnaire to examine students' conceptions about relativity of motion. His contrastive activity is based on cognitive conflict models. In the Web based learning environment, students were given novel or unfamiliar situations through video clips or still pictures and asked to discuss about the materials, which were expected to cause cognitive conflicts.

Pak et al. (2001) investigated Korean secondary school students' conception about relativity of motion. They found that secondary students describe motion relative to outside the frame when the motion is in an opened frame, while they describe motion relative to inside the frame when the motion is in a closed frame. And they found that students do not see object's motion relative to frame when the frame is opened to the background and the object is observed from outside the frame. They also found that students seem to assume a kind of force in the same direction of motion of frame acting on an object moving in the opposite direction of the frame when the frame is closed from the background and the motion is observed inside the frame. They used the Relativity of Motion Questionnaire to examine students' conception, which was adapted from Oh (1998). This questionnaire was also used in this research to compare students' conceptions before and after their participation.

Panse et al. (1994) found Indian college students' seven alternative conceptions (AC's) about frame of reference. For example, when small bodies are located on a larger body and moving relative to it, their motion is ignored, as they are part of the larger frame (AC-3); some motions are real and some apparent (AC-5); descriptions in a given frame may vary among different observers, but they are equivalent, according to the principle of relativity (AC-7, Pseudorelativism). These categories were taken into consideration to identify students' conceptions observed in the Web based learning environment.

PSSC (Physical Science Study Committee, 1965) and HPP (Harvard Project Physics. Holton, G. et al., 1970) are physics curricula in 1960's, and they affected many physics curricula afterwards (Physics Learning Research Group, 2000). PSSC had the following sections related to relative motion: [6-8] The Description of Motion; Frames of Reference, [20-9] Experimental Frames of Reference, [20-10] Fictitious Forces in Accelerated Frames, and [20-11] Newton's Law and the Rotation of the Earth. HPP has the following sections related to relative motion: [3.5] Newton's first law of motion, [3.6] The significance of the first law, [4.4] Moving frames of reference. These contents can be classified into the two categories of relative motion: relative velocity and frame of reference. Relative velocity is related to vector analysis of relative motion, and frame of reference is related to conceptual understanding of relative motion.

PSSC accompanied an instructional film about relative motion, named 'Frames of Reference.' And there is a reflection note on this film written by one of the experts in the film, Ivey, along with another researcher (Steyn-Ross & Ivey, 1992). This reflection also provides the film script, of which the contents are as follows: (1) You're upside-down! (2) All motion is relative. (3) Defining a frame of reference. (4) Equivalence of inertial frames. (5) Choosing the reference frame which simplifies the description. (6) Galilean velocity transformation. (7) An accelerated frame of reference. (8) Another accelerated frame. (9) The Earth as an inertial frame of reference. (10) Summary. Some of the learning materials in the Web based learning environment were based on the film and the script.

4. Instructional systems development

Instructional systems development (ISD) is the process of determining what to teach and how to teach it (Dick, 1996). Development of a Web based learning environment is a kind of ISD, because it has contents to teach and instructional strategies determined by instructor. ISD procedure is illustrated by ISD model. Figure Ⅱ-4 shows the Dick and Carey model (Dick & Carey, 1996), which guides systematic designs of instruction.

Some researchers in ISD like Willis (1995) criticized the Dick and Carey model as originating from behavioral, objective-rational tradition. He showed eight family characteristics of objective-rational ISD models: (1) The process is sequential and linear; (2) Planning is top down and 'systematic'; (3) objectives guide development; (4) Experts, who have special knowledge, are critical to ID work; (5) Careful sequencing and the teaching of subskills are important; (6) The goal is delivery of preselected knowledge; (7) Summative evaluation is critical; (8) Objective data are critical. Then he suggested seven family characteristics of constructivist-interpretivist ISD models: (1) The ID process is recursive, non-linear, and sometimes chaotic; (2) Planning is organic, developmental, reflective, and collaborative; (3) Objectives emerge from design and development work; (4) General ID experts don't exist; (5) The goal is personal understanding within meaningful contexts; (6) Formative evaluation is critical; (7) Subjective data may be the most valuable. He suggested alternative ISD model which follows this constructivist-interpretivist tradition: R2D2(Recursive, Reflective Design and Development) model. It is represented graphically in Figure Ⅱ-5.

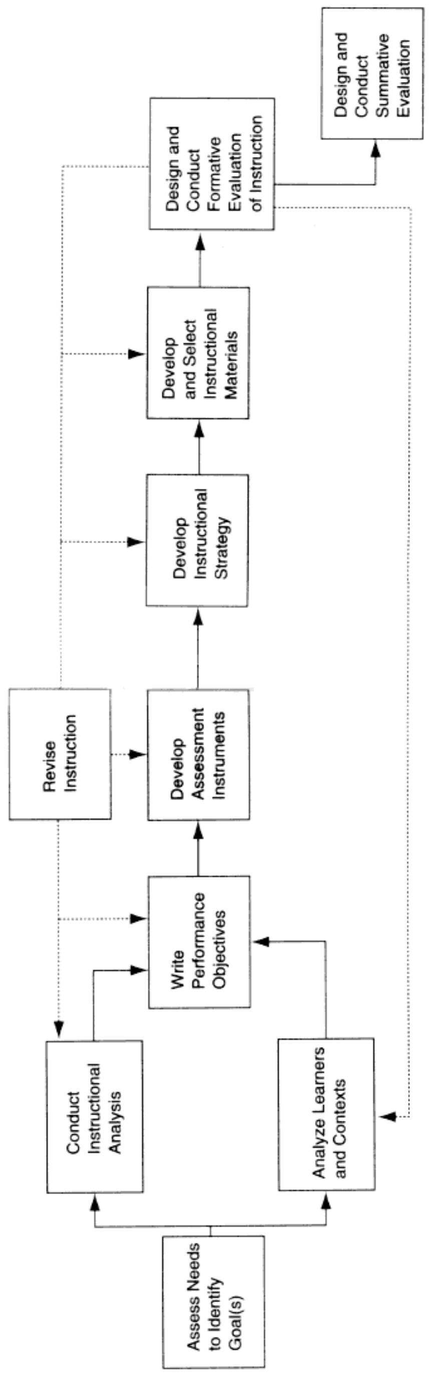


Figure Ⅱ-4. Dick and Carey model

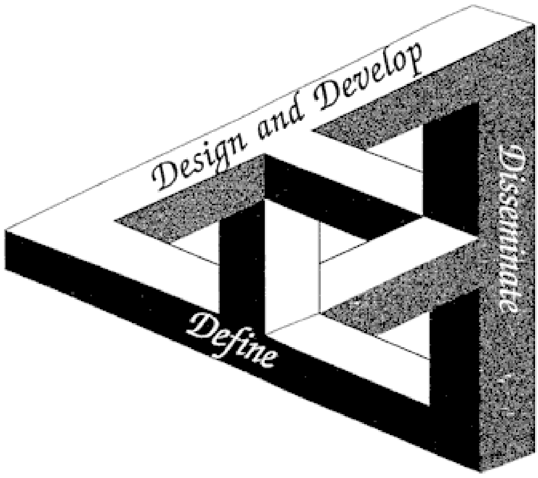


Figure Ⅱ-5. R2D2 model

But dichotomy between the two models are not so clear as might be said. Even objective-rational models, which are criticized as being linear, have formative evaluation and revision cycles that are recursive, while constructivist-interpretivist models look linear when they are proceduralized. Even though constructivist-interpretivist models do not state specific behavioral objectives, general goal of instruction is set early and specific objectives evolve naturally from the process of development. On the other hand, performance objectives of objective-rational models are not that rigid because they might be revised according to the result of formative evaluation. As Dick (1996) have said, there are many more similarities than differences between the two models. Willis (1995) commented that recursive approaches can be taken to extremes that are both frustrating and nonproductive. A developer could take R2D2 model as a basis with respect to its recursive and reflective characteristics, but should ensure its productivity by, for example, stating explicit instructional objectives as soon as possible. Table Ⅱ-2 shows R2D2 stages and tasks.

Table Ⅱ-2. R2D2 stages and tasks

Stage	Tasks
Definition	Front-end analysis Learner analysis Task and concept analysis Specifying instructional objectives
Design & Development	Media and format selection Selection of a development environment Product design and development Evaluation strategy
Dissemination	Summative evaluation Final packaging Diffusion Adoption

There are guides and criteria for design, development, and evaluation of educational product. Lee et al. (2000) gave an educational contents development guide. This guide advises how to design and implement educational contents, user interfaces and Web services. It suggests a Web site which is composed of help desk, lecture room, public archives, private room, mail box, question & answer, communication channel, and administration mode. But it does not consider the components' integration, which would help learners navigate effectively. Integration aspect needs to be added to the guide. KERIS (2001) provided educational Web site evaluation criteria. By the criteria, instructional Web site is evaluated considering three aspects: content (validity, significance, relevance, etc.), instructional design (controllability, context, navigation, usability, etc.), and educational environment (educational meaning, copyright, etc.). Squires and McDougall (1994) wrote a teacher's guide to choosing and using educational software. It illustrates a perspectives interactions paradigm for studying educational software (Figure Ⅱ-6). They argued the problems of checklist approaches and framework approaches (classification of software by application type, educational role, or educational rationale) of choosing and using educational software. They then identified three 'actors' in the design and use of educational software: the student(s), the teacher and the designer, and the interactions between the perspectives of the actors in the computer-based educational environment.

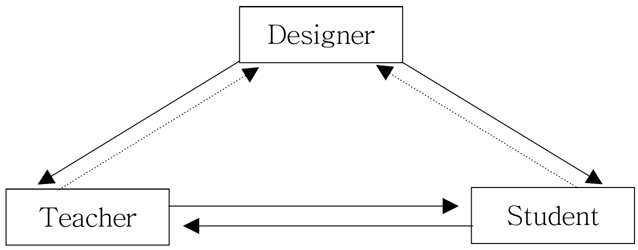


Figure Ⅱ-6. The perspectives interactions paradigm

They asserted that this paradigm enables a more comprehensive treatment of the area, and moves the emphasis in discussion away from consideration of the technical attributes of educational software packages, and toward consideration of more educational issues such as learning processes, classroom activities, teacher roles, curriculum issues, student responsibility for learning, etc. They also maintained that it is generative, for by considering the interactions between the perspectives of the actors, the evaluator adopts a comprehensive view of the design and use of the educational software, and identifies issues that are significant in the context of the perceived use of the software. This paradigm is useful not only in choosing and using educational software, but also in designing and developing it, in that every design and development of a product expects to be chosen and used.

5. Developmental research

Richey and Nelson (1996) gave a definition of developmental research: a situation in which someone is performing instructional design, development or evaluation activities and studying the process at the same time; the study of the impact of someone else's instructional design and development efforts; the study of the instructional design, development and evaluation process as a whole, or of particular process components. They classified developmental researches as Type 1 and Type 2. Table Ⅱ-3 portrays the relationships between the two types. This research is more Type 1 than Type 2, because it describes design, development, and evaluation of a specific Web based learning environment, and shows lessons learned from the process.

Table Ⅱ-3. Two types of developmental research (Richey and Nelson, 1996)

	Type 1	Type 2
Emphasis	studies of specific product or program design, development and/or evaluation projects	studies of design, development or evaluation process, tools, or models
Product	lessons learned from developing specific products and analyzing the condition that facilitate their use	new design, development, evaluation procedures and/or models, and conditions that facilitate their use
Conclusion	Context-specific	Generalized

Diesing (1991) has noted that social science produces at least three kinds of knowledge: (1) systems of laws, which describes interconnected regularities in society; (2) descriptions, from the inside, of a way of life, community, person, belief system, or scientific community's beliefs; (3) structural models, mathematical or verbal, of dynamic processes exemplified in particular cases. The third type of knowledge is process knowledge presented in model form. This is usually of great interest to instructional designers and developers. When inquiry procedures result in this type of knowledge, theses endeavors can legitimately be placed in the research realm (Richey & Nelson, 1996). In fact, this research does not provide a new model, but suggests a new technique such as the Design Matrix. In this way, this research can contribute to the knowledge base of Web based learning environment development.

van den Akker (1999) said that formative evaluation holds a prominent place in developmental research. He gave a few typical characteristics of formative evaluation within the context of developmental research. The first one is priority on information richness. Formative evaluation within developmental research generate suggestions in how to improve the instructional systems, which is more productive than standardization of methods to collect and analyze data. The other one is shifting emphasis in quality criteria. During development processes, the emphasis in criteria for quality usually shifts from validity, to practicality, to effectiveness. Practicality refers to the extent that users and other experts consider the instructional systems as appealing and usable in normal condition. Effectiveness refers to the extent that the experiences and outcomes with the instruction are consistent with the intended aims.

In this research, formative evaluation is important too. Instructors and students participated as evaluators and they gave suggestions how to improve the Web based learning environment. Their suggestions were mainly related to practicality and effectiveness of the Web based learning environment.

van den Akker also noted three dilemmas in developmental research. The first one is tension in role division between development and research. Designers are eager to pursue their ideals in creating innovative instructional systems, while researchers tend to critically seek for correctness of decisions and empirical proof of outcomes. He suggested that progress is helped by a dominance of the creative designers' perspective in earlier stages, and then a shift to a stronger voice for the more critical researchers' position. The second one is isolating critical variables versus comprehensive and complex design. It is hard to isolate, manipulate and measure separate variables in a developmental research. On the contrary, it is the very nature of formative developmental research to investigate comprehensive instruction that deal with many interrelated elements at the same time. However, experimental approaches are not entirely impossible in the context of developmental research. Summative evaluation via experimental methods may be appropriate and feasible at the end of the development procedure. The last one is generalization of findings. Since data collection in formative research is usually limited to small and purposive samples, efforts to generalize findings cannot be based on statistical techniques. However, reports on formative research can facilitate analogical reasoning by a clear theoretical articulation of the design principles applied and by a careful description of both the evaluation procedures as well as the implementation context. Especially a 'thick' description of the process-in-context may increase the 'ecological' validity of the finding, so that other can estimate in what respects and to what extent transfer from the reported situation to their own is possible.

All the three dilemmas apply to this research. The researcher was at the same time the developer in this research. The conflict was not between two parties but inside the sole person. The researcher made a compromise with himself that he would be a developer in the first phase of the development, and then a researcher in the last phase. The researcher as a developer tried as much as possible learning materials and Web technologies in the Web based learning environment to make it comprehensive at the cost of isolation, manipulation and measurement of critical variables. But at the end of the development, students' conceptual change was measured to evaluate the instructional effect of the Web based learning environment, which would compensate for the cost. It was hard to generalize the findings of this research. But this research provides as rich information as possible so that it can be applied to other development situation by analogical reasoning.

6. Web technologies

Web technologies can be classified as server-side and client-side regarding where the programs are executed. Server-side technology is what is executed inside a server computer that contains all the information of a Web based learning environment, and client-side technology is executed on the Web browser of user computer (Park, 2000).

Figure Ⅱ-7 shows how Web technologies work. In this figure, rectangles are hypertext documents (along with multimedia), normal circles are executable programs and bold circles are programs that are running. Arrows represent transmission through the Internet or output inside the computer.

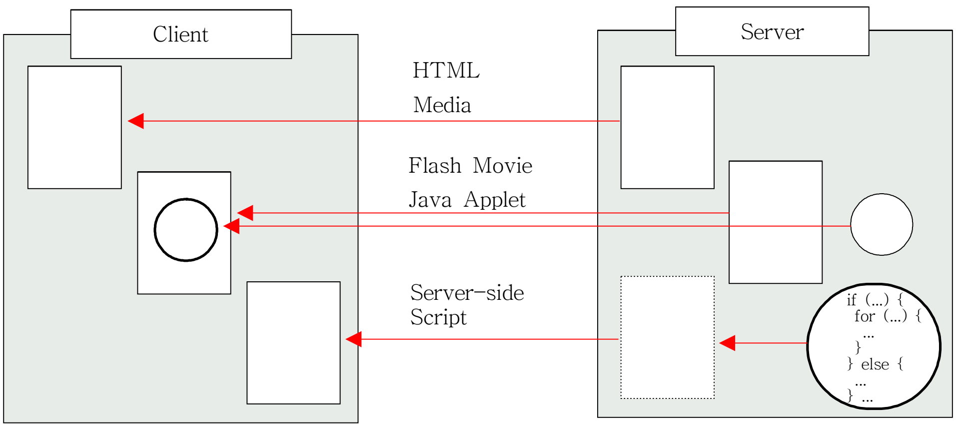


Figure Ⅱ-7. Web technologies

Normal hypertext documents and media (image, sound or video) files are stored in the server and transmitted as they are. They are useful as static information which do not have to be interactive or updated frequently. Even if media look active, they are also static information, in that they are neither programmed nor executed, but just edited and played.

Flash movie or Java Applet is transmitted along with hypertext document and executed inside the user computer. This is useful as instructional simulation. Flash movie is famous for its interactivity and optimization for the Web, with its high graphic quality and small file size. And it is relatively easy to make a Flash movie through the Flash authoring tool. But it lacks some mathematical functions, such as sine, cosine and tangent. Therefore, if a realtime calculated simulation is needed, Java Applet must be used. Java Applet is made through the original Java Development Kit (JDK) from Sun Microsystems, Inc. or other third-party Java development environments.

Server-side script is executed inside the server and the output is transmitted to the user computer in the form of hypertext document. This is useful as search engine, bulletin board, etc. that stores and retrieves information from the server. It can be categorized as Common Gateway Interface (CGI) and Web server module. CGI is the server-side script that is running as an independent process in the server. Web server module is running as a part of the Web server process. Web server module is usually more efficient than CGI.

Software components of Web systems are Web server, Web programming language and database management system (DBMS). These components were selected according to the recommendation in expert sites on the Internet. And the combination of Apache (Web server), PHP (Web programming language), and MySQL (DBMS) is evaluated by experts to be highly optimized. Apache is the most popular Web server that is serving more than 60% of the Web sites in the world[2)]. PHP is the most popular

Apache Web server module[3]. It is faster than traditional CGI scripts. And MySQL is a mid-range DBMS. It is faster than commercial DBMS's and as reliable as safely handles more than 50 million records[4]. All these are free or open-source softwares.

Web server is responding according to user request. DBMS stores every information of the Web based learning environment. Interfaces between user, Web server and DBMS are made in the form of server-side scripts written in Web programming language. The key activity of the Web system production is to design database and make the server-side scripts.

Most DBMS's are managing relational database (RDB), which store data in tables. Table structure is determined after data characteristics are analyzed. Every table represents an 'entity,' and the table column represents attributes of the entity. For example, in the Web based learning environment, there are entities like user and message. A user has attributes like name, school, grade, etc. and a message has attributes like writer, title, contents, etc. Entities have relation to each other. For example, user makes several messages, and every message has a writer.

While designing database, entities, attributes of entity and relation between entities are analyzed. Tables are made according to the result of the analysis. Once the tables are made, data are stored in table rows. Each row represents an instance of the entity. For example, one row in user table represents a specific person, and one row in message table represents a message. Stored data can be retrieved by special language called SQL

2) http://www.netcraft.com/survey/
3) http://www.securityspace.com/s_survey/data/man.200104/apachemods.html
4) http://www.mysql.com/doc/F/e/Features.html

(Structured Query Language). For example, names of Year 8 students are searched like this:

```
SELECT name FROM user WHERE year = 8;
```

More complicated data can be retrieved. For example, alphabetically ordered names of Year 8 students who wrote no messages at all are searched like this:

```
SELECT user.name
FROM user
LEFT JOIN message ON user.name = message.name
WHERE user.year = 8 AND message.name IS NULL
GROUP BY user.name
ORDER BY user.name;
```

Server-side scripts that interface between user, Web server and DBMS are made of these SQL statement, programming logic and graphical user interface (GUI), which are written in Web programming language as well as HTML and JavaScript.

The Web based learning environment was developed on these technological bases. There are no static HTML documents in the Web based learning environment because every page must be dynamically produced according to user input. Even a small learning material first identifies the user if he or she has passed the diagnostic test. If not, they are not permitted to see the material. This is implemented by Apache, PHP, and MySQL. The video clips in the Library are captured from videotapes and converted into streaming media to be used on the Internet. And the instructional simulations in the Laboratory are made through Flash.

Ⅲ. Procedure

1. Goal specification

Two researchers reflected on their experience in Web based science learning environment (Park, 1997; Kim, 1998). They wrote down their experience of old Web based learning environments and request for a new one. The form below was used to gather opinions.

Name:
Organization:
Email:

1. In which Web-based learning environment, what kind of research or teaching have you done? (Name of the Web-based learning environment; purposes, methods, etc. of the research or instruction)

2. Describe briefly the structure and function of the Web-based learning environment.

3. What did the Web-based learning environment need to be improved?

(1) In consideration of contents

(2) In consideration of learners (students)

(3) In consideration of instructors (teacher)

(4) In consideration of Web systems (computer, network, etc.)

Their opinions were classified into the structural components of Web based learning environment: content, learner, instructor, and system.

2. Design and development

The Web based learning environment adopted task centered learning strategy. Structure and functions for task centered learning were designed and developed. The structure and functions were integrated so that learners and instructors can work effectively in the Web based learning environment.

The development procedure emphasized reflection and recursion in design and development. In the development process, the developer recursively reflected on the development and revised it. This procedure is similar to Willis' (1995) R2D2 model. The Design Matrix (Table Ⅲ-1) was devised and used for the developer to consider interactions among the structural components of the Web based learning environment simultaneously and comprehensively. The development procedure follows two stages of R2D2 model: Definition stage, and Design and Development stage. The Dissemination stage was omitted because this development did not aim at final packaging, diffusion, or adoption, but at producing a working prototype and testing its effectiveness. Tasks for the Definition stage are need analysis, learner analysis, task analysis, and instructional objectives specification. Tasks for the Design and Development stage are media and format selection, selection of a development environment, product design and development, and feedback.

1) Learner analysis

Students' conceptions about relative motion was gathered from the literature on relative motion. Conceptions revealed in students' answer to diagnostic tests, discussion in the Conference Room, and task fulfillment reports were also analyzed and applied to the development.

2) Task analysis

Learning tasks of relative motion can be classified into two categories: relative velocity and frame of reference. The former is related to vector analysis of relative motion, and the latter is related to qualitative understanding of relative motion. The learning tasks and materials were selected from everyday contexts or novel situations, such as subway train, motorboat, space station, and moving background. Prerequisites for the tasks were analyzed to make diagnostic tests.

3) Media and format selection

The Web based learning environment incorporates various media and formats, such as still images and video clips in the Library, instructional simulations in the Laboratory, and communication channel such as Web board. Video is required because learning relative motion will be facilitated by watching real motion. Video clips are captured from instructional films, TV programs, or self-taken videos. Instructional simulations complement video clips' non-interactivity. Students can observe motion from different frames of reference through the simulations. Communication channel is necessary for students and instructors to discuss topics. Understanding relative motion needs metacognition, which can be promoted by discussion on the Web board.

4) Selection of a development environment

Still images are captured by scanner and image capturing software or downloaded from the Internet, and edited by retouching software. Video clips are captured from videotapes by video capture card and video editing software, and converted into streaming media by converting software. Instructional simulations are made by Flash authoring tool. The PHP scripts for the Web based learning environment were written right on the server. Development environment was ordinary 'vi' editor. The output was examined on a PC Web browser. MySQL DBMS and Apache Web server are also maintained on the server.

5) Product design and development

The design and development process was a course of simultaneous and comprehensive consideration of the components of the Web based learning environment. The Design Matrix (Table Ⅲ-1) was devised to keep balance in the design phase. It shows interactions among the structural components of the Web based learning environment: content, learner, instructor, and system. It is based on the learning experience model (Figure Ⅱ-1) and the perspectives interactions paradigm for studying educational software (Figure Ⅱ-6). In the learning experience model, the school (and the society) becomes the system in a Web based learning environment. Therefore, content, learner (student), instructor (teacher), and system are the components of a Web based learning environment. In the perspectives interactions paradigm, the designer is not apparently shown in a Web based learning environment, but his or her intention is revealed through the content and the system. Therefore, the designer perspective in the paradigm can be divided into the content and the system, and the dashed arrows become normal arrows. Then the components' interaction in a Web based learning environment can be shown as Figure Ⅲ-1.

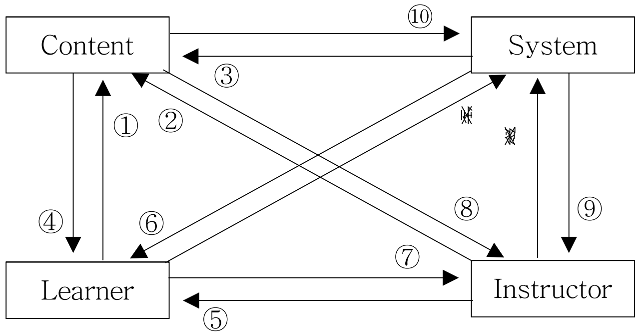


Figure Ⅲ-1. Components' interactions

The twelve arrows of the components' interaction make twelve cells in the Design Matrix. Every component in Figure Ⅲ-1 has three arrows from other components. This represents the relationship between the focus and the surroundings in the Design Matrix.

Table Ⅲ-1. The Design Matrix

Surrounding \ Focus	Content	Learner	Instructor	System
Content		④ achieving goal, having interest	⑦ evaluating validity, requesting revision	⑩ light traffic, light system requirements, Web browser compatibility
Learner	① differentiated task, diagnostic test, task fulfillment certificate, scientific info, everyday context, simple, vivid, amusing		⑧ guiding learners, no control or dictatorship	[illegible] easy to communicate, easy to use, open to revision request
Instructor	② clear objectives	⑤ asking questions, requesting guidance		[illegible] providing necessary records, open to revision request
System	③ appropriate technology supported	⑥ communicating with others, fully using, requesting revision	⑨ watching learners, requesting revision	

The matrix helped the developer to consider each component in relation to the others simultaneously and comprehensively while designing the Web based learning environment. For example, when the content was under consideration, it was designed to have differentiated tasks (as to the learner), clear objectives (as to the instructor), and appropriate technology supports (as to the system). When the learners were under consideration, they were expected to achieve goals of the tasks (as to the content), ask questions to the instructor (as to the instructor), and request revision of the Web based learning environment (as to the system). When the learner or the instructor, namely the subject, was under consideration, activities of the subject were gathered. When the content or the system, namely the object, was under consideration, functions of the object were designed according to the subjects' activities.

3. Evaluation

At the end of the development, instructional effect of the Web based learning environment was evaluated.

Three experts, eight secondary students (five from a female junior high school, and three from a male senior high school), and eighteen observer students participated in the Web based learning environment. Experts evaluated it concerning content, learner, instructor and system, and students gave feedback concerning learner and system (Table Ⅲ-2). Their feedback was also used to revise the Web based learning environment.

Table Ⅲ-2. Evaluator role

Component / Evaluator	Content	Learner	Instructor	System
Expert	○	○	○	○
Student		○		○

The observer students had no obligation to feedback. Their participation could test the capacity of the Web based learning environment. However, one of the observer students was actively engaged in fulfilling the tasks and gave appreciable feedbacks to the developer.

What follows are evaluation criteria reconstructed from the elements of educational Web site evaluation criteria (KERIS, 2001) and other development guides.

Content. Does it deal with all the needed concepts of relative motion for secondary school physics? If not, what is left out or what is unnecessary?

Does it have scientific information about relative motion? If not, what is the wrong information?

Learner. Is it easy for you (learners) to learn here? What makes it easy or difficult?

Is it interesting for you (learners) to learn here? What is interesting and what is not (for learners)?

Do you think you (learners) learned something here? What did you (learners) learn?

Instructor. Are you able to effectively observe the learners' activities here? What makes it effective or ineffective?

Are you able to effectively evaluate learners' performance here? What makes it effective or ineffective?

Are you able to effectively guide learners here? What makes it effective or ineffective?

System. Is it easy to use the functions of the Web based learning environment? What makes it easy or difficult?

Is it stable enough? What is the reason of the stability or unstability?

Is it using state-of-the-art technologies? What is sate-of- the-art, and what is not?

1) Expression of conceptions

Students' conceptions of relative motion are gathered from their answer to diagnostic tests, discussion between students and instructors, and the task fulfillment reports. These conceptions were compared with other research findings to see if they were consistent with research findings.

2) Conceptual change

Eight secondary school students' conceptions about relative motion before and after their participation in the Web based learning environment were compared. Five of them were female junior high school students and three of them were male senior high school students. The Relativity of Motion Questionnaire (Oh, 1998; Pak et al., 2001) was used to examine the students' conceptions. This questionnaire consists of 17 questions. The situations are escalator (1-6), subway train (7-14), and motorboat (15-17).

3) Students' feedback

Students gave feedback about the Web based learning environment. Their feedback was classified according the evaluation criteria.

4) Observation and guidance

Two instructors who had observed and guided students in the Web based learning environment and another expert who has Ph. D. in physics education evaluated if the Web based learning environment was effective in observing and guiding the students. He reflected on the interactions in the Web based learning environment, examined the functions for instructors, and evaluated the effectiveness.

Ⅳ. Result

1. Specified goals

Two researchers reflected on their experience in Web based learning environment. Their reflection was classified into the structural components of Web based learning environment as follows:

Content. Differentiated tasks are needed.

Relevant topics are needed.

Quantity of materials needs not be too much.

Materials needs to be categorized.

Learner. Students need to make inquiries by themselves.

Assignments are needed to activate interaction among learners.

Instructor. Assistants to help instructor are needed.

System. Learner activities (login, reading messages, manipulating simulations, etc.) need to be traced easily by instructors.

Components of the Web based learning environment needs to be integrated.

System management needs to be easy.

Messages need to be thread-enabled.

Edited messages need to be notified.

All learners need to use networked PC.

The hierarchy of the Web based learning environment needs to be simple.

From their reflection, three developmental goals were specified as follows:

(1) Provide differentiated learning tasks
(2) Encourage students to express their conceptions
(3) Assist instructors to observe and guide students
(4) Make integrated structure and functions in the Web based learning environment

2. The Web based learning environment

1) Analysis results

(1) Learner analysis result

From the literature on relative motion, various information about students' conceptions of relative motion was found. For example, students often describe motion relative to the ground when the motion is in an opened frame, while they describe motion relative to inside the frame when the motion is in a closed frame. Students do not observe an object's motion relative to a frame, when the frame is opened to the background and the object is observed from outside the frame. Students seem to assume a kind of force in the same direction of motion of frame acting on an object moving in the opposite direction of the frame when the frame is closed from the background and the motion is observed inside the frame.

From the messages in diagnostic tests, task related discussion, and task fulfillment report, such information about students' conceptions was found too. For example, a student thought that if a car is approaching her, the driver observes her as standing still, which can be inferred that she thought the driver observes her with respect not to the car but to the ground. And another student thought that when she jumps up in a moving train she will land on a place away from the starting point, which might be because she did not distinguish inertial from non-inertial frame of reference.

(2) Task analysis result

The concepts related to relative motion were classified into two categories: relative velocity and frame of reference, and each category is divided into four levels (Table Ⅳ-1 & Ⅳ-2). The levels of each category were determined by the complexity of the situation. For relative velocity, the situation is simple when there are only two observers, while the situation is complex when there is the third observer and the relative motion is not in a line but on a plane. For frame of reference, the situation is simple when there are no other frames except the observer's one, while the situation is complex when there are two frames which are accelerated relative to each other.

Table Ⅳ-1. Categories of relative motion: relative velocity

Level	Description
1	Speed of B relative to A, vice versa. There is no third observer. (e.g., A is on the ground and B is in a running car.)
2	A and B move in the same direction and observed by C. Speed of B relative to A, vice versa. (e.g., C is on a bridge. A is in a train running on the bridge and B is in a car running in the same direction as A.)
3	A and B move in the opposite directions and observed by C. Speed of B relative to A, vice versa. (e.g., C is on a bridge. A is in a train running on the bridge and B is in a car running in the opposite direction as A.)
4	A and B move in different directions and observed by C. Velocity of B relative to A, vice versa. (e.g., C is on a bridge. A is flowing along with the river and B is crossing the river.)

Table Ⅳ-2. Categories of relative motion: frame of reference

Level	Description
1	Motion of an object in my frame of reference without any other frames of reference (e.g., throwing up and catching a ball in a room alone)
2	Motion of an object in a frame of reference which is moving relative to my frame of reference (e.g., a person on the ground observes the other person who is throwing up and catching a ball on a horizontal escalator)
3	Equivalence of inertial frames of reference (e.g., free fall motion of an object cannot be discriminated if it is observed on the ground or in a frame of reference which is moving at a constant velocity relative to the ground.)
4	- Frame of reference which is moving with constant acceleration (e.g., motion of an object which falls in a cart pulled by constant force) - Frame of reference which is rotating with constant angular velocity (e.g., motion of a ball which is thrown on a rotating disc)

2) Design

In the Web based learning environment, every participant has to sign up and make the unique ID. The ID is required in entering the Web based learning environment. It has three main areas, Task Park, Plaza and My Rooms, as shown in Figure Ⅳ-1.

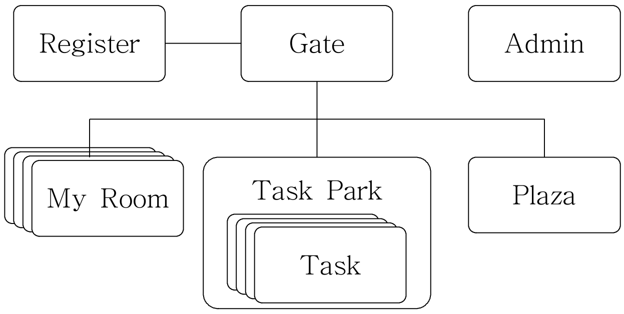


Figure Ⅳ-1. Design of main areas

Task Park is the central area of the Web based learning environment, where learners choose a learning task and attempt it. Figure Ⅳ-2 is an illustration of a learning task.

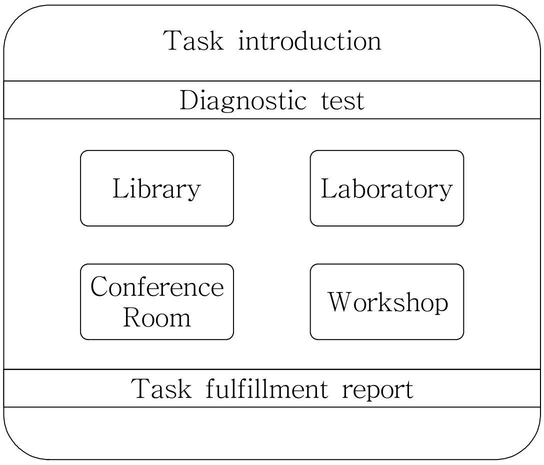


Figure Ⅳ-2. Design of a learning task

Each task unit consists of a task introduction, diagnostic tests, four 'rooms,' and a task fulfillment report. Before attempting the task, learners have to pass the diagnostic tests. If they do not pass the test, they have to state why they answered so in the diagnoses. They are guided by instructors according to the test results. After the guidance, if they are recognized by instructors as being prepared to attempt the task, they are given access into the rooms, or they have to tackle another task. If they get permission into the task, they look up materials, make experiments, discuss with each other and try the task. If they have an answer to the task, they report it. If the report reaches the intended goal, they are given task fulfillment certificate. If not, they are guided by instructors in fulfilling the task. Figure Ⅳ-3 shows the process.

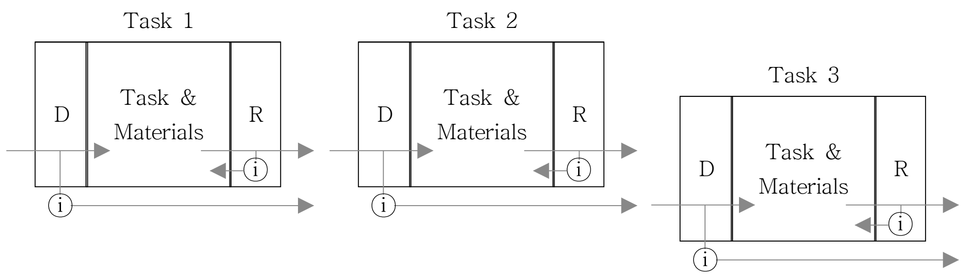


Figure Ⅳ-3. Task flow (D: diagnostic test, R: task fulfillment report, i: guidance)

In the Library, learners look up materials related to the task and talk about them. In the Laboratory, they make experiments with instructional simulations and talk about them. In the Conference Room, they discuss with other learners and instructors about the task. All the communication in the Library and the Laboratory is also gathered automatically into the Conference Room. The Conference Room provides a task-wide integration of messages. The discussion in the Conference Room is carefully structured in the Workshop and becomes a collaborative report about the task. This process is illustrated in Figure Ⅳ-4. The integration of Library, Laboratory, Conference Room, and Workshop is to facilitate active interaction among participants.

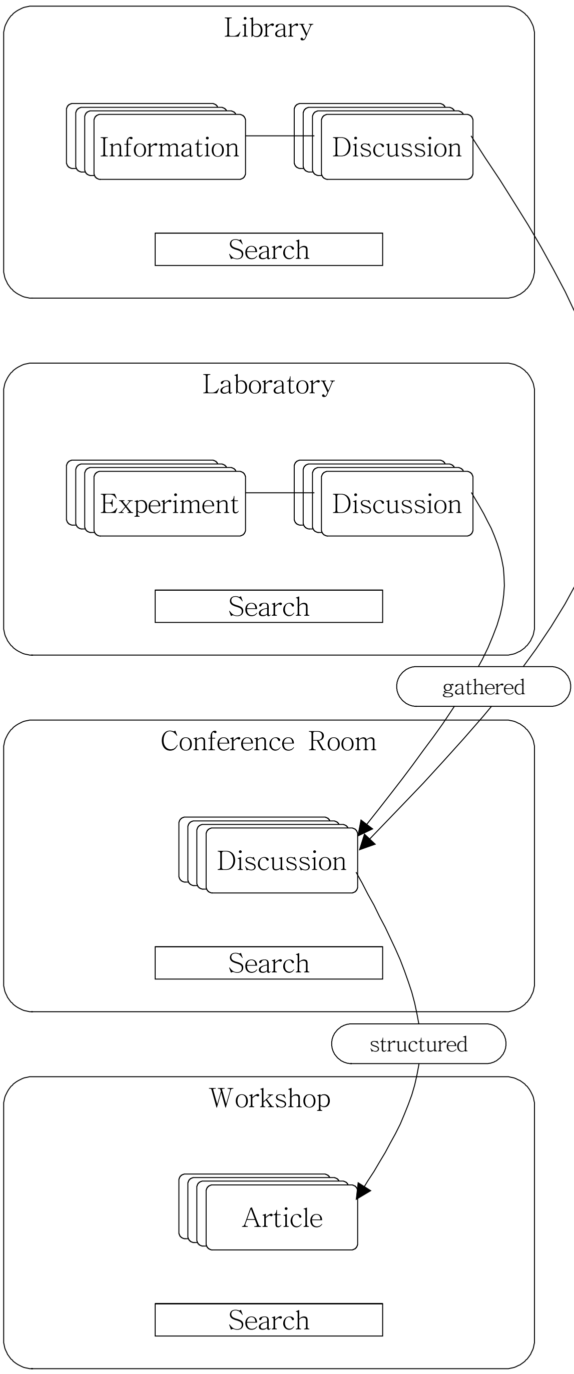


Figure Ⅳ-4. Relation of the four rooms

Plaza contains bulletin boards where participants in the Web based learning environment get help, request improvement, ask questions, answer questions and talk free. It also has Hall of Fame where task fulfillment records of all the students in the Web based learning environment are arranged by student and by task (Figure Ⅳ-5).

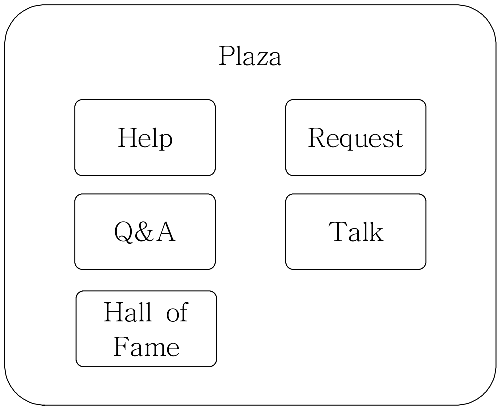


Figure Ⅳ-5. Design of Plaza

My Room is a private place owned by a single participant. Diagnosis results and task fulfillment certificates are stored, personal information can be changed, the owner of the room privately discuss with instructors, and all the messages in the boards that the owner has access to in the Web based learning environment are shown in My Room (Figure Ⅳ-6). The Board Assembly complements the scattered boards in the Web based learning environment and provides an environment-wide integration of messages, while the Conference Room of a task provides a task-wide integration.

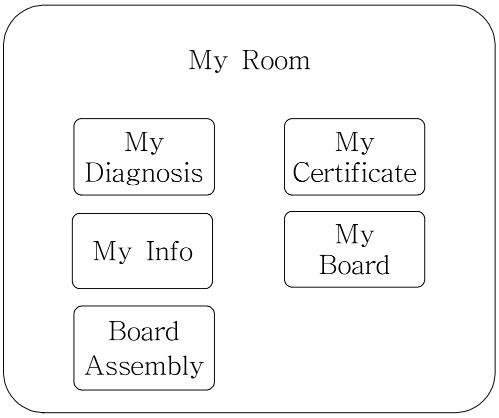


Figure Ⅳ-6. Design of My Room

3) Product

(1) Main areas

All participants have to identify themselves before entering the main areas of the Web based learning environment (Figure Ⅳ-7).

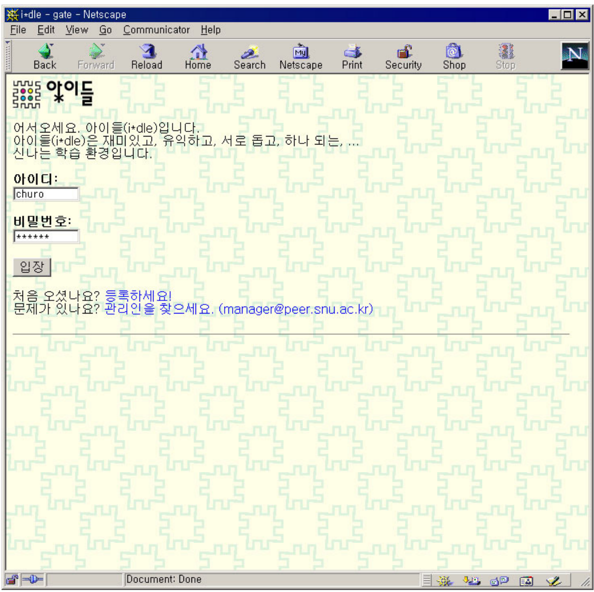


Figure Ⅳ-7. Gate

The main areas of the Web based learning environment are Task Park, Plaza, and My Room. The Task Park is the central area of the Web based learning environment, where learners choose a learning task and attempt it. Figure Ⅳ-8 shows introduction page of a task.

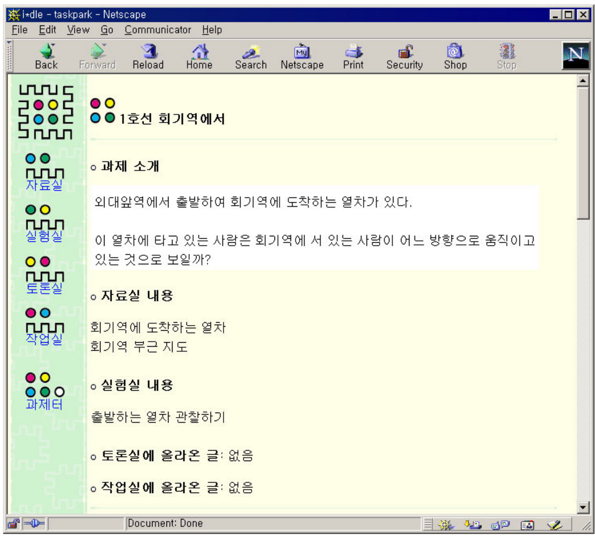


Figure Ⅳ-8. Task introduction

Plaza (Figure Ⅳ-9) contains bulletin boards where participants in the Web based learning environment get help, request improvement, ask questions, answer questions and talk free. It also has Hall of Fame where task fulfillment records of all the students in the Web based learning environment are arranged by student and by task.

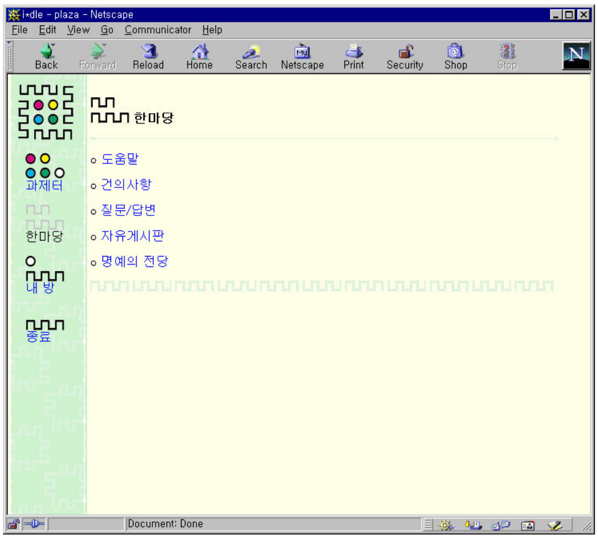


Figure Ⅳ-9. Plaza

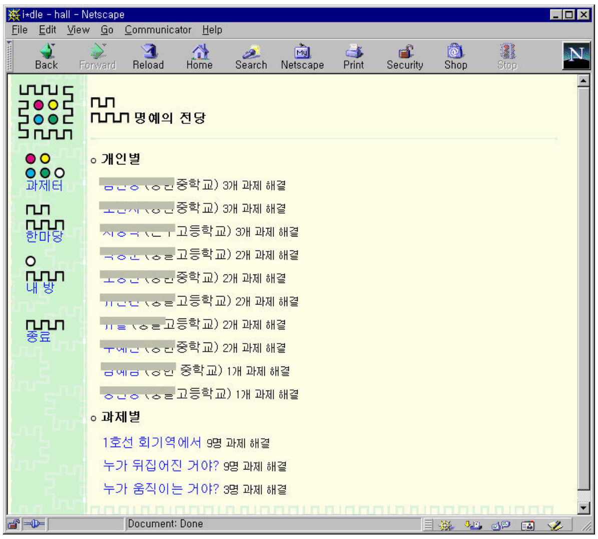


Figure Ⅳ-10. Hall of Fame

My Room (Figure Ⅳ-11) is a private place owned by a single participant. Diagnosis results and task fulfillment certificates are stored in My Diagnosis (Figure Ⅳ-12) and My Certificate (Figure Ⅳ-13) respectively. Personal information can be changed in My Info, and the information of other participants can be searched in People Search. The owner of the room privately discuss with instructors on My Board, and all the messages in the boards that the owner have access to are shown in Board Assembly (Figure Ⅳ-14).

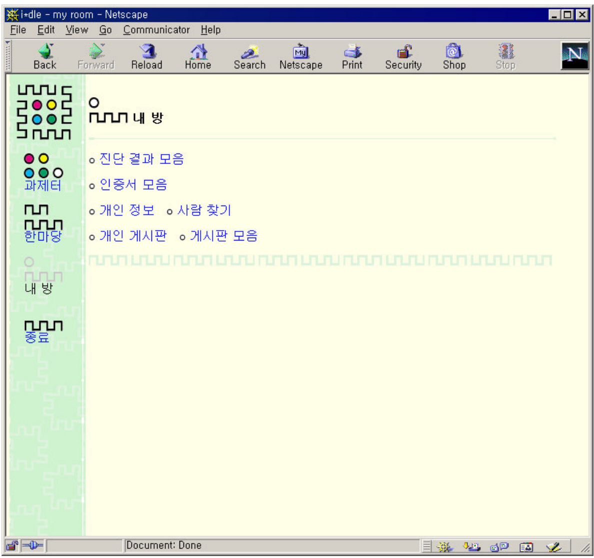


Figure Ⅳ-11. My Room

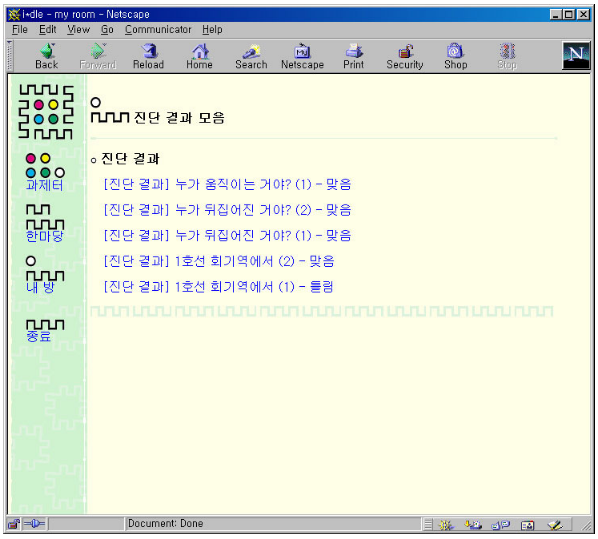


Figure Ⅳ-12. My Diagnosis

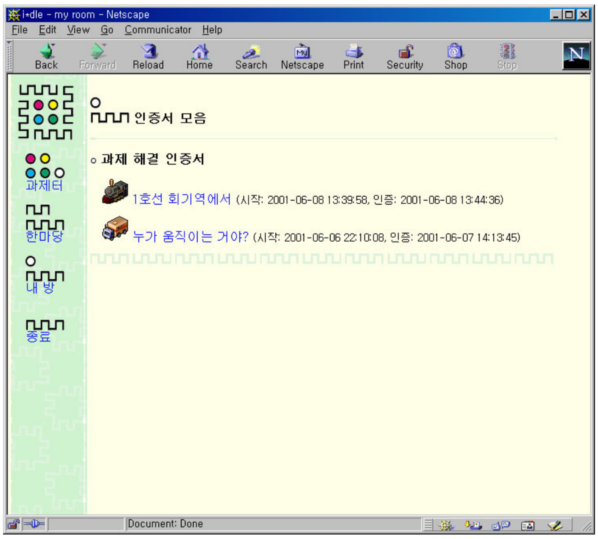


Figure Ⅳ-13. My Certificate

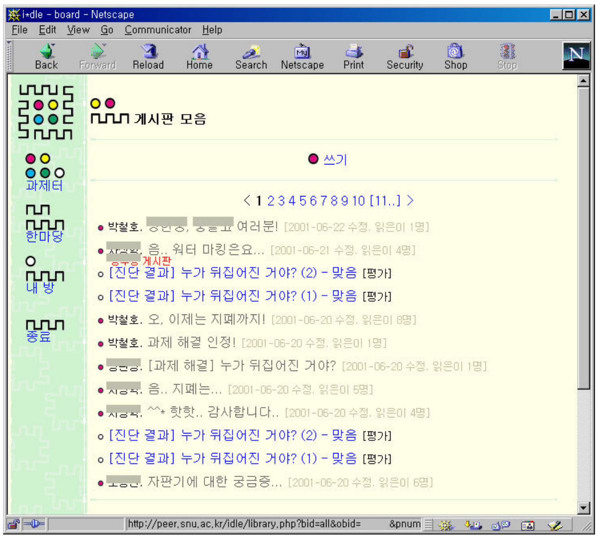


Figure Ⅳ-14. Board Assembly

(2) Learning tasks and materials

Three learning tasks are developed. The tasks are based on the categories of relative motion (Table Ⅳ-1, Ⅳ-2). Each task accompanies diagnostic tests, task related materials in the Library, and instructional simulations in the Laboratory, which are selected and constructed from everyday contexts or novel situations. Table Ⅳ-3 through Table Ⅳ-5 show the specifications of the tasks.

Table Ⅳ-3. Materials of a task unit: at Hoegi station

Classification	Relative velocity 1
Task name	At Hoegi station
Introduction	A train is arriving at Hoegi station. In which direction is a person standing on the station moving relative to the other person in the arriving train?
Goal	To infer direction of motion of the ground frame relative to the moving frame.
Diagnostic Test	1. Finding direction in a map 2. How do I look moving relative to a person in a car approaching me from the front?
Library	1. Map around Hoegi station (graphic file) 2. Train arriving at Hoegi station (video clip)
Laboratory	1. Observing leaving train

Table Ⅳ-4. Materials of a task unit: who is upside-down?

Classification	Frame of reference 1
Task name	Who is upside-down?
Introduction	There are two video clips in Library of two persons who are upside-down each other. Find similarity and difference between the two cases.
Goal	To know that the position looks different relative to observers. (The concepts of up and down are possible because of gravity.)
Diagnostic Evaluation	1. What if you drop an object on the earth? 2. What if you drop an object in a space station?
Library	1. Two persons upside-down each other in a space station 2. PSSC 'Frames of Reference': A. You're upside-down!
Laboratory	1. Rotating a person

Table Ⅳ-5. Materials of a task unit: who is moving?

Classification	Frame of reference 1
Task name	Who is moving?
Introduction	Who is moving in the video clip? How can you tell that?
Goal	To know that motion of an object is recognized against the background.
Diagnostic Evaluation	1. In which direction is the train moving?
Library	1. One of the two trains which stayed parallel are leaving. 2. PSSC 'Frames of Reference': B. All motion is relative 3. Moving background while taking a movie
Laboratory	1. Moving background in the experiment ‘Observing leaving train.'

Figure Ⅳ-15 through Ⅳ-17 is a screen shots of diagnostic test, Library and Laboratory.

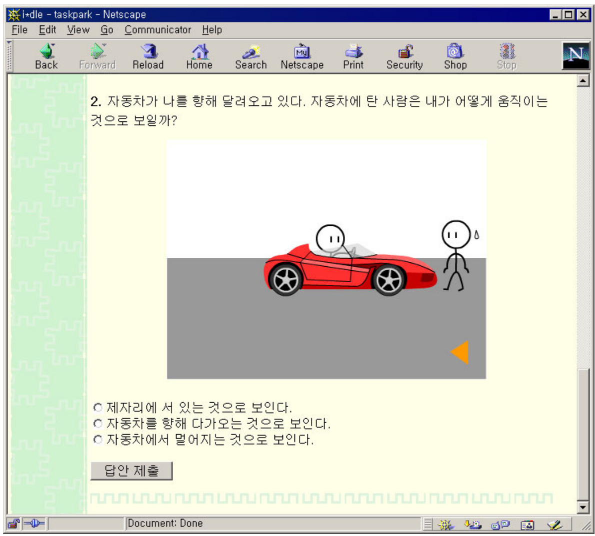


Figure Ⅳ-15. Diagnostic test item

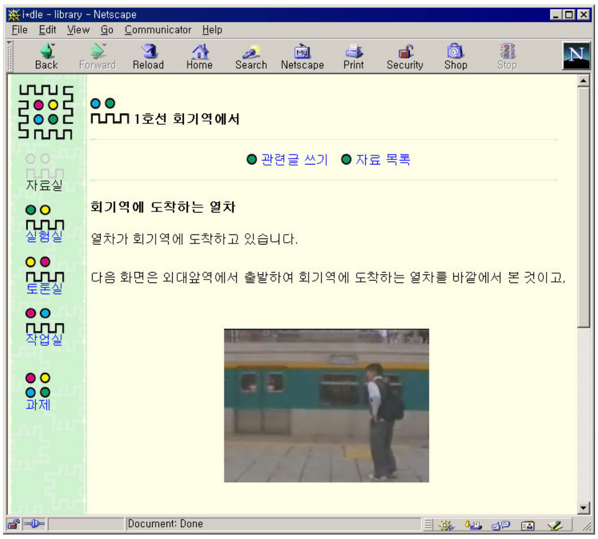


Figure Ⅳ-16. Library: video clip

Figure Ⅳ-17. Laboratory: Flash movie

(3) Functions for instructors

Functions for instructors are the student list in the instructor's private room (Figure Ⅳ-18), diagnosis pass approval (Figure Ⅳ-19), and task fulfillment certification (Figure Ⅳ-20). Instructors have privileges to write on students' private boards so that they can discuss the diagnostic test results and task fulfillment reports with the students.

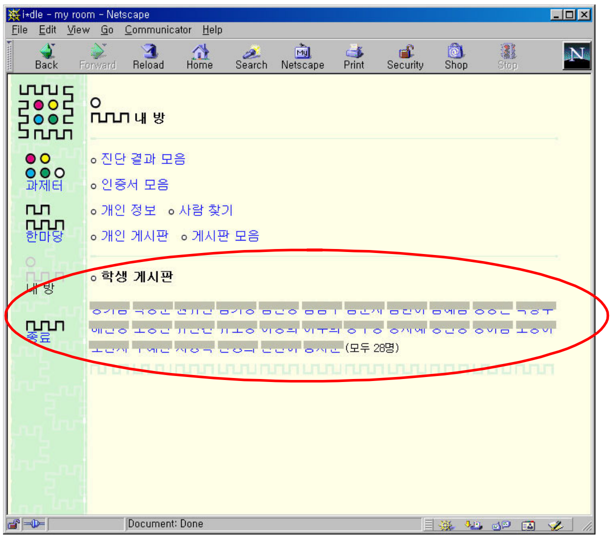


Figure Ⅳ-18. My Room for instructor

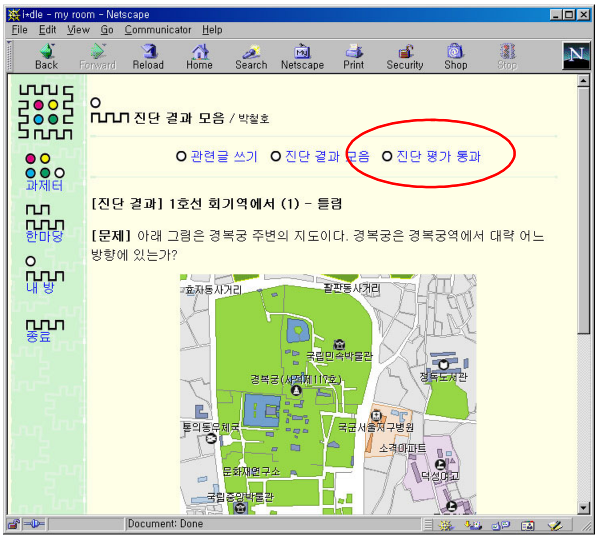


Figure Ⅳ-19. Diagnosis pass approval

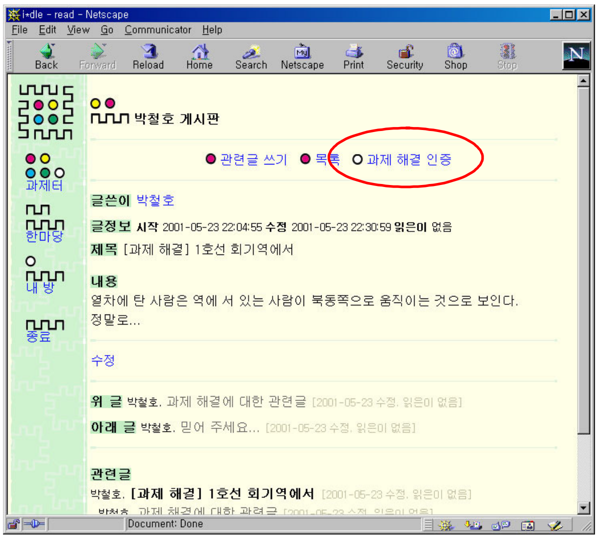


Figure Ⅳ-20. Task fulfillment certification

These functions helped instructors observe students and guide them properly.

(4) The Web systems

The hardware and software specifications of the server is listed in Table Ⅳ-6.

Table Ⅳ-6. Server specifications

CPU	Intel PentiumⅡ 233MHz
Memory	64MB
Hard disk	6GB
Operating system	Linux (kernel 2.4.3)
Web server	Apache 1.3.20
Web programming language	PHP 4.0.6
DBMS	MySQL 3.23.39

The hardware components of the server are even lower in capacity than those of average desktop PC nowadays (2001) but stable enough to handle thousands of clicks per day.

Database tables are designed considering the entities in the Web based learning environment. Table Ⅳ-7 shows the table names and the entities.

Table Ⅳ-7. Database tables

Name	Entity
admission	admission to task or board
attach	attached file information
board	message board
login	login record
message	message
reader	reader record
record	task attempt record
task	task information
user	user information

Server-side scripts that interfaces user, Web server and DBMS are written in PHP. The names and functions of PHP scripts are listed in Table Ⅳ-8. Total number of lines of the scripts is about 6,000. Part of a script is shown in Figure Ⅳ-21.

Table Ⅳ-8. PHP scripts

Name	Function
board.php	message board in Conference room
conference.php	Conference main
count.php	reader list
gate.php	login gate
info.php	user information
laboratory.php	Laboratory main
library.php	Library main
main.php	introduction
myroom.php	My room main
plaza.php	Plaza main
read.php	message read
register.php	user registration
taskpark.php	Task park main
transfer.php	attached file transfer
workshop.php	Workshop main
write.php	message write

```
        list($bname, $btype) = mysql_fetch_row($result);

// writeheader
        writeheader($bi, $btype);

// writebody
        $result = mysql_query("select
title, content, ref, url, mtype, depth
from message
where bid = '$bi' and number = '$num'");

        list($title, $content, $ref, $url, $mtype, $depth)
        = mysql_fetch_row($result);

        $content = str_replace("<br>", "", $content);

        $result = mysql_query("select aid, filename, aorder
from attach
where bid = '$bi' and number = '$num'
order by aorder");

        while ($a = mysql_fetch_row($result)) {
                $attach[] = $a;
        }

        echo("<form enctype=multipart/form-data action=$PHP_SELF
method=post onSubmit=₩"return writeverify(this)₩">₩n");
```

Figure Ⅳ-21. Part of a script

3. Evaluation

1) Expression of conceptions

Expression of conceptions is basis for conceptual change. Students revealed their conceptions of relative motion in the discussion with the other students and the instructor, and recognized what they were thinking about relative motion.

(1) Diagnostic Tests

If students give correct answers to diagnostic tests, there are no more interactions between the students and the instructor regarding the tests. But if they do not pass the diagnostic tests, they have to explain why they choose the option. Then instructor guide them to right answer. In this way, students' conceptions can be expressed and corrected. But the discussion on the Web has limitations. Students usually repeat what they have said, not getting deeper in reflection on their thought. Here is an example:

[Question] A car is approaching me. Where do I look going with respect to the driver?

↓

[Student] I look like standing still. (wrong answer)

↓

[Student] I just think that I look like standing still, so I chose the answer. But it's wrong. I'll do my best later.

↓

[Instructor] Then how do you think now? Where do I look going if seen by the driver? If you answer this question, you will pass the diagnosis. See you soon.

↓

[Student] Maybe I am going ahead to the car? I don't seem to look going away from the car. Don't I?

↓

[Instructor] OK, You don't seem to look going away from the car. It's a nice reasoning. You pass!

(2) Task Fulfillment

There were eight student evaluators. Five of them are female junior high students, three of them are male senior high students. And there were eighteen observer students who worked without any obligation. The student evaluators passed all the diagnostic tests, and in average they fulfilled 2 out of 3 tasks. Sixty-one percent of the observer students passed any one of the diagnostic tests, and only one of them fulfilled the tasks but all of the tasks. The task 'Who is moving?' was hard to be approved. Only three of them fulfilled the task. Task fulfillment process is task fulfillment report, instructional feedback, revision, and task fulfillment approval. Here is an example of the process:

[Task] Is it easy to tell what is at rest and what is moving? Find out how we can tell what is at rest and whit is moving.

↓

[Student] We make a great mass of decision instantly by our mysterious intuition. But in this case, the intuition makes confusion. Maybe this confusion is from the intuition depending only on the sight.

↓

[Instructor] Then, what kind of intuition makes us confused in the case of two parallel trains and the two doctors' movie? How do we depend on the sight?

↓

[Student] Maybe from the preconception that one is moving and the other is at rest; the wall is at rest; or I am at rest.... If I feel inertial force or hear machinery noise I can judge correctly.

↓

[Instructor] Good. "One is at rest and the other is moving." "The wall is not moving." "I am at rest." All these are intuition related to the sight? OK, you are approved.

(3) Discussion about tasks

Instructor gave questions about learning materials and tasks, and students answered the questions and talked about their thought. One of the long discussions in the Conference Room was about a video clip in the task 'Who is moving?' A student told that if she jumps up in a moving train she will land on a point away from the starting point. The instructor asked if she had made an experiment on it. Then she did it herself and talked about it. The instructor summarized the talks and asked related questions and other students gave their opinions. Here is the discussion:

[Instructor] Two trains are passing each other in a subway station. If the platform-side window of the other train is curtained so that the opposite platform cannot be seen from this train, is it possible to distinguish which train is moving?

↓

[Student 1] I can tell if my train moving or not. If I jump up in the train and land on the point where I jumped up, the train is not moving, but if away from the point, the train is moving. Isn't it?

↓

[Instructor] It's plausible. Have you ever done that yourself? If you have, tell us the story. What do others think?

↓

[Student 1] I got on a subway train with my friends and talked about this with them. Half of them agreed with me, and the other half didn't. So we jumped up together. We landed on the same point. The jumping height was not high enough, the duration was too short, the direction was not exactly vertical, and the train was not moving fast enough. I think because of those reasons I was not able to get the intended result. Isn't it so?

↓

[Student 2] I thought as she thought. But in reality there was no difference. Wasn't it because of the height? If the height is high enough, will there be any difference? I'm so confused...

↓

[Instructor] (To Student 1) You pointed out the limitations of the experiment: (1) jumping height, (2) duration in the air, (3) jumping direction, and (4) speed of the train. Isn't there some other way or place to make an experiment without these limitations?

↓

[Student 3] I think I cannot tell if the train is moving or not. If you jump up in a moving train you will land on the same place. You can catch the ball thrown up at the same place. If the train is moving and you jump up in the train, you will move along at the same speed of the train and land on the same place. If you would like to distinguish by jumping, you have to jump right before the train starts to move; if you land on the same place, the other train is moving, and if away from the place, your train is moving. And when a train looks like moving, if you feel a force by inertia, your train is moving, and if not, the other train is moving.

↓

[Instructor] Good approach! You discriminate between the two cases: (1) when the train starts to move, and (2) while the train is moving. In the first case, you can tell if the train is moving or not by jumping or feeling inertial force, but in the second case, you cannot. How do you others think about that?

↓

[Student 1] Even when the train is moving, not starts to move, don't you feel your body is pushed forward or pulled backward? One day I stood on a carpet and my friends pulled it. When I jumped up a while, I landed on a different place from the starting point. What is the difference between the train and the carpet? When I get on a train later, I'll make experiments with a small ball.

↓

[Instructor] Carpet? It's a very interesting situation. How about considering the two cases of motion. And you're going to make an experiment with a small ball? Great! Make sure to discriminate between the two cases.

(4) Discussion about topics

Students brought discussion topics on the Talk board and other students and instructors took part in the discussion. It was not intended by the researcher, but the students had much interest in the topics: How vending machine work? Is there water in Mars? The instructors did not give direct answers in the discussion, rather they summarized the talks and asked related questions. Here is a excerpt from the "vending machine discussion":

[Student 1] How does vending machine distinguish coins? First I thought that it will measure the falling speed of the coin. That will be different by coin size and weight. But it seems not enough... Coins are different in color. That is, the substances may be different. What do you think about that?

↓

[Instructor 1] Student A told us the variables: size, weight, speed, and substances. Any other variables?

↓

[Student 2] One day I asked EBS about that. They answered that the metal content is measured by electric current, and then the speed is measured by magnet.

↓

[Instructor 1] Oh, did you asked EBS? Wonderful! Then, how can we measure metal content? How is magnet used to measure speed?

↓

[Instructor 2] Magnet is used for attracting iron. But as to the vending machine too? If you find another example of magnet + nonferrous metal + electric current, you will get a better idea. How about making an experiment and inferring the inner structure?

↓

[Student 3] I know that it is determined by weight and size. But isn't it difficult to distinguish a coin by materials? If it were, electric conductivity had to be measured, but this seems not practical.

↓

[Instructor 1] By electric conductivity you can tell what the material is? Good idea! Then isn't there any practical method to measure the conductivity?

↓

[Student 2] Doesn't the electric current flow differently according to metal substances? And the speed is measured not only by magnet but also by photo sensor. I don't know how. Besides, is there some other usage of photo sensor than vending machine?

↓

[Instructor 1] What is the relation between metal substances and electric current? How can I measure the speed of a coin by the magnet and photo sensor? Did you ask where is photo sensor used? It's near you. Photo sensors are in your mouse. Then what do the photo sensors do in the mouse?

↓

[Student 3] Oh, No! After I read your message, I tried to disassemble my mouse. I took off front and back cover, but the top was sticked to a small pole in the middle of the mouse. I tried to twist the top, but it broke... However I saw the photo sensor, but don't know how to assemble the mouse...

↓

[Instructor 2] Disassembly! That's satisfying curiosity and fostering scientific insights. That's what made me science teacher. I have been disassembling things since I was five year old. Miniature tank, electric razor, camera, laptop computer, etc. When I disassembled my father's electric razor, I could not assemble it back and was scolded. ... For me, disassembly is fun and inquiry process. However, you should seek the reason when something is uneasy to disassemble.

↓

[Student 3] Oh, I have such painful memories too. When I was little, I disassembled my father's watch but could not assemble back and was scolded hard. But this mouse was much simpler case... After the accident I found a small screw hidden by a label. My poor mouse... Anyway thank you for your advice. Take care.

Students' conceptions found in the Web based learning environment were various and they were closely related to their everyday experiences. When they felt some cognitive conflicts or curiosities in the discussion, they actively make experiments and do practices to test their conceptions or knowledge. The Web based learning environment was effective in students' expressing their conceptions of relative motion.

2) Conceptual change

At the end of the development, five female junior high school students and three male high school students participated in the Web based learning environment and had attempted the tasks for about four weeks. Their conceptions before and after their participation were compared (Table Ⅳ-9).

Table Ⅳ-9. Students' score before and after participation

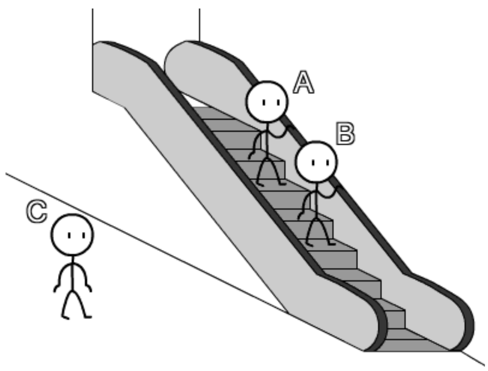
<table>
<tr><th colspan="2" rowspan="2">Student</th><th colspan="3">Pre-test</th><th colspan="3">Post-test</th></tr>
<tr><th>Score (%)</th><th colspan="2">Average (%)</th><th>Score (%)</th><th colspan="2">Average (%)</th></tr>
<tr><td rowspan="5">Junior high</td><td>A</td><td>9 (53)</td><td rowspan="5">7.0 (41)</td><td rowspan="8">9.1 (54)</td><td>8 (47)</td><td rowspan="5">8.0 (47)</td><td rowspan="8">10.0 (59)</td></tr>
<tr><td>B</td><td>9 (53)</td><td>11 (65)</td></tr>
<tr><td>C</td><td>7 (41)</td><td>7 (41)</td></tr>
<tr><td>D</td><td>4 (24)</td><td>8 (47)</td></tr>
<tr><td>E</td><td>6 (35)</td><td>6 (35)</td></tr>
<tr><td rowspan="3">Senior high</td><td>F</td><td>16 (94)</td><td rowspan="3">12.7 (75)</td><td>17 (100)</td><td rowspan="3">13.3 (78)</td></tr>
<tr><td>G</td><td>15 (88)</td><td>14 (82)</td></tr>
<tr><td>H</td><td>7 (41)</td><td>9 (53)</td></tr>
</table>

These students were selected from the sample schools of Pak et al.'s

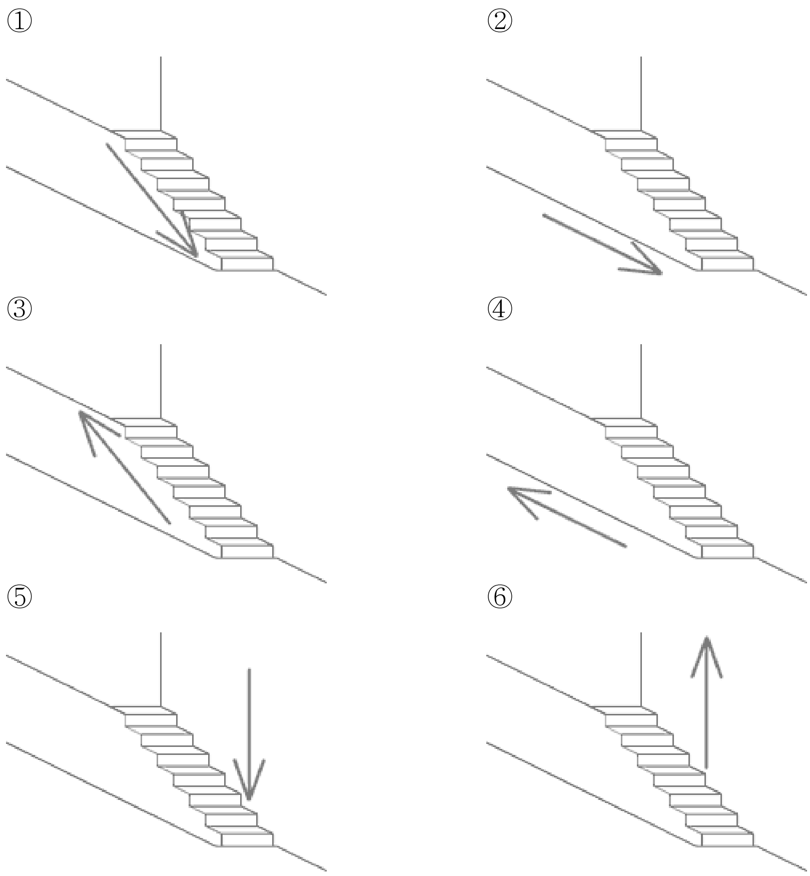
(2001) survey. The average score of the sample schools were 6.04 (35.5%) for junior high and 9.26 (54.5%) for senior high. Student A, B, and C's scores were higher than the average of the female junior high, Student D's was lower, and Student E's was as same. Student F and G's score were higher than the average of the male senior high, and Student H's was lower. There were no distinct changes among the students of higher or average score. But students of lower score (Student D and H) show changes.

The questions and students' answers before and after participation are as follows. Correct answers have asterisks (*).

[1-2] A and B are standing on a descending escalator. C is observing them outside of the escalator.



(Figures below are the options for questions 1 through 6.)



1. How is A moving relative to B?

Table Ⅳ-10. Answers to question 1

Motion	Before (J/S)	After (J/S)
(1) No motion *	6 (3/3)	6 (3/3)
(2) As fast as escalator in direction ②	1 (1/0)	0 (0/0)
(3) As fast as escalator in direction ⑤	1 (1/0)	1 (1/0)
(4) As fast as escalator in direction ①	0 (0/0)	1 (1/0)

Table Ⅳ-11. Each student's answer to question 1

Student		Before	After
Junior high	A	(1)	(1)
	B	(1)	(1)
	C	(1)	(4)
	D	(2)	(1)
	E	(3)	(3)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(1)	(1)

2. How is A moving relative to C?

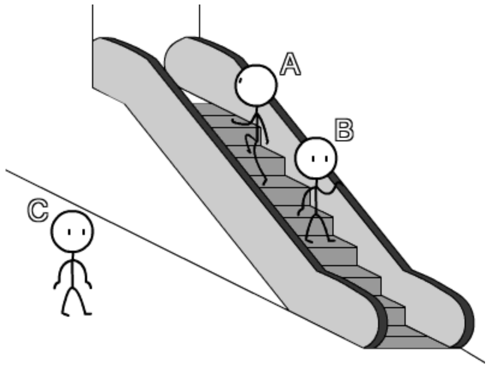
Table Ⅳ-12. Answers to question 2

Motion	Before (J/S)	After (J/S)
(1) As fast as escalator in direction ① *	5 (2/3)	6 (3/3)
(2) Faster than escalator in direction ①	1 (1/0)	1 (1/0)
(3) Faster than escalator in between ①, ②	1 (1/0)	0 (0/0)
(4) Faster than escalator in between ③, ④	1 (1/0)	0 (0/0)
(5) Faster than escalator in ⑤	0 (0/0)	1 (1/0)

Table Ⅳ-13. Each student's answer to question 2

Student		Before	After
Junior high	A	(1)	(1)
	B	(3)	(1)
	C	(1)	(5)
	D	(2)	(1)
	E	(4)	(2)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(1)	(1)

[3-4] A is running up at the same speed of the escalator.



3. How is A moving relative to B?

Table Ⅳ-14. Answers to question 3

Motion	Before (J/S)	After (J/S)
(1) Slower than escalator in direction ③	3 (3/0)	0 (0/0)
(2) As fast as escalator in direction ③ *	2 (0/2)	2 (0/2)
(3) As fast as escalator in direction ①	1 (1/0)	0 (0/0)
(4) Faster than escalator in direction ⑥	1 (1/0)	1 (1/0)
(5) Slower than escalator in direction ⑥	1 (0/1)	1 (0/1)
(6) No motion	0 (0/0)	1 (1/0)
(7) Faster than escalator in direction ③	0 (0/0)	1 (1/0)
(8) Slower than escalator in direction ④	0 (0/0)	1 (1/0)
(9) Slower than escalator in between ③, ④	0 (0/0)	1 (1/0)

Table Ⅳ-15. Each student's answer to question 3

Student		Before	After
Junior high	A	(4)	(9)
	B	(1)	(6)
	C	(1)	(8)
	D	(1)	(7)
	E	(3)	(4)
Senior high	F	(2)	(2)
	G	(2)	(2)
	H	(5)	(5)

4. How is A moving relative to C?

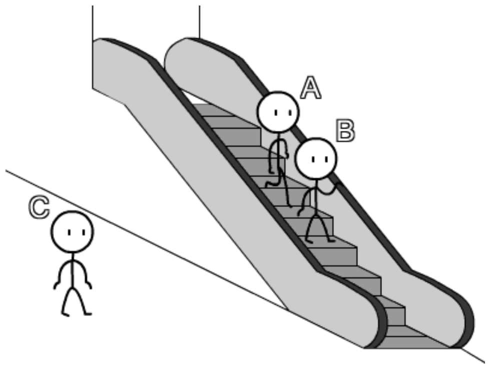
Table Ⅳ-16. Answers to question 4

Movement	Before (J/S)	After (J/S)
(1) No motion *	4 (2/2)	5 (3/2)
(2) As fast as escalator in direction ③	2 (1/1)	1 (1/0)
(3) Faster than escalator in direction ⑥	1 (1/0)	0 (0/0)
(4) Slower than escalator in between ①, ②	1 (1/0)	0 (0/0)
(5) Faster than escalator in direction ③	0 (0/0)	1 (0/1)
(6) Slower than escalator in direction ⑥	0 (0/0)	1 (1/0)

Table Ⅳ-17. Each student's answer to question 4

Student		Before	After
Junior high	A	(2)	(2)
	B	(1)	(1)
	C	(3)	(1)
	D	(1)	(6)
	E	(4)	(1)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(2)	(5)

[5-6] A is running down at the same speed of the escalator.



5. How is A moving relative to B?

Table Ⅳ-18. Answers to question 5

Movement	Before (J/S)	After (J/S)
(1) As fast as escalator in direction ① *	4 (2/2)	2 (0/2)
(2) Faster than escalator in direction ①	1 (0/1)	2 (2/0)
(3) Faster than escalator in direction ②	1 (1/0)	0 (0/0)
(4) Faster than escalator in between ①, ②	1 (1/0)	2 (1/1)
(5) Faster than escalator in direction ⑤	1 (1/0)	2 (2/0)

Table Ⅳ-19. Each student's answer to question 5

Student		Before	After
Junior high	A	(4)	(4)
	B	(1)	(2)
	C	(5)	(5)
	D	(3)	(2)
	E	(1)	(5)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(2)	(4)

6. How is A moving relative to C?

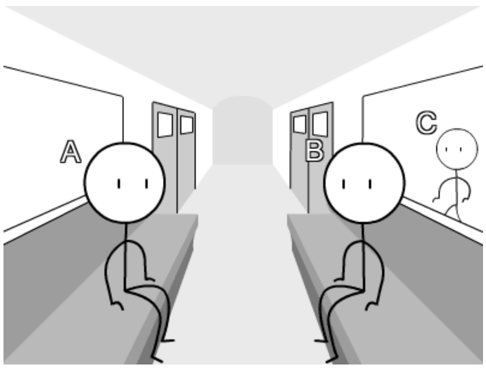
Table Ⅳ-20. Answers to question 6

Motion	Before (J/S)	After (J/S)
(1) Faster than escalator in direction ① *	4 (2/2)	6 (3/3)
(2) Faster than escalator in direction ⑤	3 (2/1)	0 (0/0)
(3) As fast as escalator in direction ①	1 (1/0)	1 (1/0)
(4) No motion	0 (0/0)	1 (1/0)

Table Ⅳ-21. Each student's answer to question 6

Student		Before	After
Junior high	A	(3)	(3)
	B	(1)	(1)
	C	(2)	(4)
	D	(1)	(1)
	E	(2)	(1)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(2)	(1)

[7-8] Subway train is leaving the station slowly. A and B are seated in the train in front of each other. C is observing them outside of the train.



7. How is A moving relative to B?

Table Ⅳ-22. Answers to question 7

Motion	Before (J/S)	After (J/S)
(1) No motion *	7 (4/3)	7 (4/3)
(2) Slower than train, opposite direction	1 (1/0)	0 (0/0)
(3) As fast as train, opposite direction	0 (0/0)	1 (1/0)

Table Ⅳ-23. Each student's answer to question 7

Student		Before	After
Junior high	A	(1)	(1)
	B	(2)	(1)
	C	(1)	(1)
	D	(1)	(1)
	E	(1)	(3)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(1)	(1)

8. How is A moving relative to C?

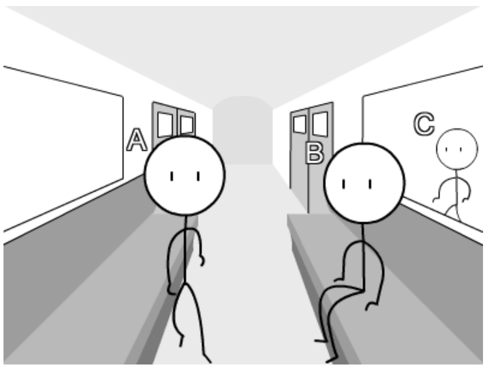
Table Ⅳ-24. Answers to question 8

Motion	Before (J/S)	After (J/S)
(1) As fast as train, same direction *	5 (2/3)	4 (1/3)
(2) As fast as train, similar to same	1 (1/0)	1 (1/0)
(3) As fast as train, opposite direction	1 (1/0)	0 (0/0)
(4) Faster than train, same direction	1 (1/0)	2 (2/0)
(5) As fast as train, etc.	0 (0/0)	1 (1/0)

Table Ⅳ-25. Each student's answer to question 8

Student		Before	After
Junior high	A	(1)	(1)
	B	(1)	(5)
	C	(2)	(2)
	D	(4)	(4)
	E	(3)	(4)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(1)	(1)

[9-10] When the train is leaving slowly, A stands up and an is walking in the opposite direction at the same speed of the train. C is observing them outside of the train.



9. How is A moving relative to B?

Table Ⅳ-26. Answers to question 9

Motion	Before (J/S)	After (J/S)
(1) As fast as train, opposite direction *	3 (1/2)	2 (0/2)
(2) No motion	1 (1/0)	2 (2/0)
(3) Faster than train, same direction	1 (1/0)	1 (0/1)
(4) Faster than train, similar to same	1 (0/1)	0 (0/0)
(5) Faster than train, opposite direction	1 (1/0)	0 (0/0)
(6) Slower than train, similar to opposite	1 (1/0)	0 (0/0)
(7) As fast as train, same direction	0 (0/0)	1 (1/0)
(8) Slower than train, opposite direction	0 (0/0)	2 (2/0)

Table Ⅳ-27. Each student's answer to question 9

Student		Before	After
Junior high	A	(5)	(8)
	B	(2)	(2)
	C	(6)	(2)
	D	(3)	(8)
	E	(1)	(7)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(4)	(3)

10. How is A moving relative to C?

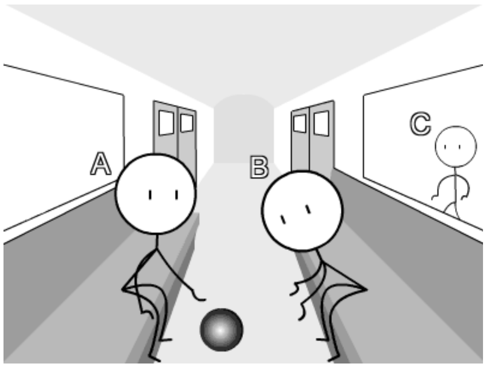
Table Ⅳ-28. Answers to question 10

Motion	Before (J/S)	After (J/S)
(1) No motion *	2 (0/2)	3 (1/2)
(2) Faster than train, opposite direction	2 (2/0)	0 (0/0)
(3) Faster than train, same direction	1 (1/0)	1 (1/0)
(4) Faster than train, similar to opposite	1 (0/1)	0 (0/0)
(5) Slower than train, same direction	1 (1/0)	0 (0/0)
(6) Slower than train, opposite direction	1 (1/0)	0 (0/0)
(7) As fast as train, opposite direction	0 (0/0)	1 (1/0)
(8) As fast as train, similar to opposite	0 (0/0)	1 (1/0)
(9) Faster than train, similar to same	0 (0/0)	1 (0/1)
(10) Slower than train, similar to same	0 (0/0)	1 (1/0)

Table Ⅳ-29. Each student's answer to question 10

Student		Before	After
Junior high	A	(6)	(7)
	B	(5)	(1)
	C	(2)	(8)
	D	(3)	(10)
	E	(2)	(3)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(4)	(9)

[11-12] Subway train stopped at a station. A and B are seated in the train in front of each other. C is observing them outside of the train.



11. If A rolls a ball to B, in which direction is the ball moving relative to B? (The train stopped at the station.)

Table Ⅳ-30. Answers to question 11

Direction	Before (J/S)	After (J/S)
(1) Same as rolling *	7 (4/3)	8 (5/3)
(2) Between train moving and ball rolling	1 (1/0)	0 (0/0)

Table Ⅳ-31. Each student's answer to question 11

Student		Before	After
Junior high	A	(1)	(1)
	B	(1)	(1)
	C	(1)	(1)
	D	(2)	(1)
	E	(1)	(1)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(1)	(1)

12. In which direction is the ball moving relative to C? (The train stopped at the station.)

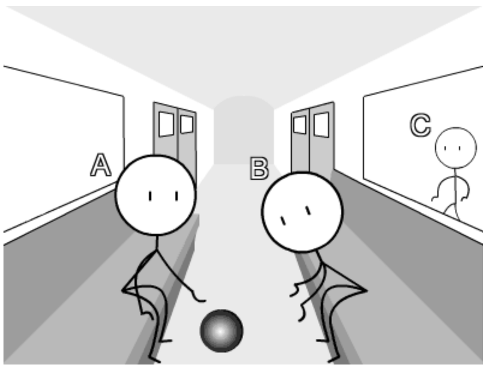
Table Ⅳ-32. Answers to question 12

Direction	Before (J/S)	After (J/S)
(1) Same as rolling *	6 (3/3)	8 (5/3)
(2) Between train moving and opposite to ball rolling	1 (1/0)	0 (0/0)
(3) Between opposite to train moving and same as ball rolling	1 (1/0)	0 (0/0)

Table Ⅳ-33. Each student's answer to question 12

Student		Before	After
Junior high	A	(1)	(1)
	B	(1)	(1)
	C	(1)	(1)
	D	(2)	(1)
	E	(3)	(1)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(1)	(1)

[13-14] Subway train is leaving the station at a constant speed. A and B are seated in the train in front of each other. C is observing them outside of the train.



13. If A rolls a ball to B, in which direction is the ball moving relative to B?

Table Ⅳ-34. Answers to question 13

Direction	Before (J/S)	After (J/S)
(1) Between opposite to train moving and same as ball rolling	4 (2/2)	4 (2/2)
(2) Same as rolling *	3 (2/1)	3 (2/1)
(3) Between train moving and opposite to ball rolling	1 (1/0)	0 (0/0)
(4) Between opposite to train moving and opposite to ball rolling	0 (0/0)	1 (1/0)

Table Ⅳ-35. Each student's answer to question 13

Student		Before	After
Junior high	A	(2)	(1)
	B	(3)	(1)
	C	(1)	(4)
	D	(2)	(2)
	E	(1)	(2)
Senior high	F	(2)	(2)
	G	(1)	(1)
	H	(1)	(1)

14. In which direction is the ball moving relative to C?

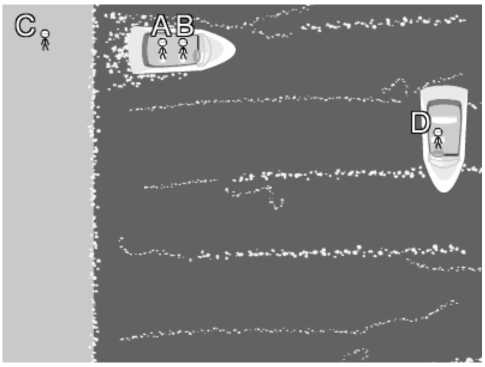
Table Ⅳ-36. Answers to question 14

Direction	Before (J/S)	After (J/S)
(1) Between train moving and opposite to ball rolling	4 (2/2)	0 (0/0)
(2) Between opposite to train moving and same as ball rolling	3 (2/1)	3 (2/1)
(3) Between train moving and ball rolling *	1 (1/0)	2 (1/1)
(4) Same as rolling	0 (0/0)	1 (1/0)
(5) Opposite to train moving	0 (0/0)	1 (1/0)
(6) Between opposite to train moving and opposite to ball rolling	0 (0/0)	1 (0/1)

Table Ⅳ-37. Each student's answer to question 14

Student		Before	After
Junior high	A	(3)	(2)
	B	(1)	(5)
	C	(2)	(2)
	D	(1)	(3)
	E	(2)	(4)
Senior high	F	(1)	(3)
	G	(2)	(2)
	H	(1)	(6)

[15-17] A river flows southwards. D flows along the river in a motorboat with its engine turned down. A and B are crossing the river in another motorboat with its engine running constantly pointing east. C is observing them on the bank.



15. In which direction is A moving relative to B?

Table Ⅳ-38. Answers to question 15

Direction	Before (J/S)	After (J/S)
(1) No motion *	7 (4/3)	6 (3/3)
(2) Between river flow and opposite to engine push	1 (1/0)	0 (0/0)
(3) Same as engine push	0 (0/0)	2 (2/0)

Table Ⅳ-39. Each student's answer to question 15

Student		Before	After
Junior high	A	(1)	(1)
	B	(1)	(1)
	C	(1)	(1)
	D	(2)	(3)
	E	(1)	(3)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(1)	(1)

16. In which direction is A moving relative to C?

Table Ⅳ-40. Answers to question 16

Direction	Before (J/S)	After (J/S)
(1) Between river flow and engine push *	4 (2/2)	6 (3/3)
(2) Same as engine push	2 (1/1)	1 (1/0)
(3) Opposite to engine push	1 (1/0)	0 (0/0)
(4) Between river flow and opposite to engine push	1 (1/0)	0 (0/0)
(5) Same as river flow	0 (0/0)	1 (1/0)

Table Ⅳ-41. Each student's answer to question 16

Student		Before	After
Junior high	A	(4)	(1)
	B	(2)	(1)
	C	(1)	(1)
	D	(3)	(5)
	E	(1)	(2)
Senior high	F	(1)	(1)
	G	(1)	(1)
	H	(2)	(1)

17. In which direction is A moving relative to D?

Table Ⅳ-42. Answers to question 17

Direction	Before (J/S)	After (J/S)
(1) Same as engine push *	4 (2/2)	4 (3/1)
(2) Between opposite to river flow and engine push	2 (2/0)	3 (1/2)
(3) Between river flow and engine push	2 (1/1)	1 (1/0)

Table Ⅳ-43. Each student's answer to question 17

Student		Before	After
Junior high	A	(2)	(2)
	B	(1)	(1)
	C	(3)	(1)
	D	(2)	(3)
	E	(1)	(1)
Senior high	F	(1)	(1)
	G	(1)	(2)
	H	(3)	(2)

3) Students' feedbacks

Students gave feedbacks about the Web based learning environment freely or according to the evaluation criteria as follows:

Learner. Flash movies were novel for observing motions.
It is interesting to discuss tasks with friends.
Active participation was encouraged.
It was hard to know how to use the learning materials to solve a task.
It needs more materials.
It would be better to have different level of tasks for different level of students.

System. It was convenient that the Laboratory and the Library was closely connected for a task.
Board Assembly was convenient to use.
Learning materials on the Laboratory and the Library was easy to use.
It was fast and stable.
It is simple and well-structured.
Privilege to read friends' private boards is needed.

They evaluated the Web based learning environment as being interesting and helpful, and asked more materials to look up and more privilege to observer other friends.

4) Observation and guidance

Two instructors who had observed and guided students in the Web based learning environment and another physics education expert evaluated if the Web based learning environment was effective in observing and guiding the students. They reflected on the interactions in the Web based learning environment, examined the functions for instructors, and evaluated the Web based learning environment as follows:

Content. An introductory task to show why it is important to learn relative motion is needed.

More learning tasks and materials are needed.

Learner. It was interesting for students to have their own room where their learning records and certificates are stored.

It was interesting for students to discuss with their friends and teachers.

Prompt response makes students more interested in the activities.

It was good to make students think about tasks and construct their own solution, though it is difficult for students.

It is necessary to develop amusing factors because students nowadays prefer games.

Text-only communication could hinder active and persistent participation. Charts or audio-visual communication might be helpful.

Instructor. Certification system was good for observing and guiding students.

It was hard for teachers to respond to every diagnosis test result and task fulfillment report.

It is needed to compare all the students at once.

It would be good to have student assistants who can help instructors by responding to requests from their fellow students.

System. It was fairly stable.

To grant appropriate privilege to teachers and students was good.

Automation to handle many students and teachers is needed.

Instructional simulations by Flash were more effective than common movie clips.

Message sort by edited date was good.

Movie clips from everyday contexts were good.

The system is well-structured but hard to adapt myself to.

They appreciated the functions for observation and guidance such as threaded messages, reader record, diagnostic test, and task fulfillment certification. They were able to infer the evolution of students' thoughts by tracing the threaded messages in the discussion about a topic if students wrote properly using the threading function. They could see whether a student had read a certain message by looking up the reader record. They were also able to look up individual students' diagnosis results and task fulfillment reports, and guide them to correction and revision.

They suggested improvement of the Web based learning environment.

More learning materials are needed because the present ones were not enough for the Web based learning environment to be self-sufficient. Another efficient way of feedback is needed. It was not efficient for instructors to reply to every utterance of students to guide them, because every teacher in school have to deal with hundreds of students. The interaction type needs to be extended from text to audio-visual way so that students may express their thoughts more freely and participate in the learning process more actively.

Ⅴ. Summary and Conclusion

The purpose of this research is to develop a Web based science learning environment. To accomplish this purpose, developmental goals were specified, learning strategy was devised, structure and functions of the Web based learning environment were designed and developed, and the instructional effect was evaluated.

The developmental goals were (1) to provide differentiated learning tasks, (2) to encourage students to express their conceptions, (3) to assist instructors to observe and guide students, and (4) to make integrated structure and functions in the Web based learning environment. The goals originated from two researchers' reflection on their experience in Web based science learning environment. Their reflection was classified into four categories: content, learner, instructor, and system.

Task centered learning strategy was devised to achieve the goals. Elements of two learning strategies were adopted: "problems from everyday contexts" and "self-directed learning in group" of the problem based learning, and "learning units" and "individualized feedback" of the mastery learning. The learning tasks and materials were selected from everyday contexts or novel situations according to the two categories of relative motion: relative velocity and frame of reference. The process of task centered learning is that learners take diagnostic test, attempt the task, and report task fulfillment to be certificated. Learners are permitted to attempt the task if they pass diagnostic test. They make use of learning materials and discuss with others to fulfill the task. After fulfilling the task, they report about it. If the report is accepted by instructor, they are given a task fulfillment certificate. If not, they get feedback from the instructor and revise the report.

Structure and functions of the Web based learning environment were designed and developed for task centered learning. In the process, the developer considered content, learner, instructor, and system, simultaneously and comprehensively by help of a tool named "Design Matrix." This tool shows interactions among the structural components of Web based learning environment. The Web based learning environment has three main areas, Task Park, Plaza, and My Room. Each task in the Task Park consists of diagnostic tests, four "rooms," and task fulfillment report. Learners endeavor a task in the four rooms. In the "Library," they look up video clips, images, and texts related to the task. In the "Laboratory," they make experiments through instructional simulations. In the "Conference Room," they discuss the task. Their discussion in the Library and the Laboratory is also automatically gathered in the Conference Room. In the "Workshop," they synthesize the discussion into a document. The rooms are integrated that participants' interactions are not scattered but arranged systematically. Learners' activities are automatically recorded so that instructors can easily observe them. Functions for instructors, such as diagnosis pass approval, task fulfillment certification, and privilege to write on learners' private board, were developed to help instructors to guide learners. During the development, eight secondary students and three experts participated in the Web based learning environment.

After the development, instructional effect of the Web based learning environment was evaluated. Students' utterances in the Web based learning environment were classified and compared with known preconceptions.

Diagnostic test, discussion in the Conference Room, and task fulfillment report encouraged the students to express their conceptions. The Relativity of Motion Questionnaire was used to examine the students' conceptions before and after their participation. Students of lower score made conceptual changes, but larger sample is needed to confirm this finding. Students and experts evaluated the Web based learning environment according to a criteria. Students appreciated the Web based learning environment as being interesting and helpful, and asked more learning materials and privileges. Experts appreciated it as being effective in instructor's observation and guidance, and suggested improvement to be practical in the current school situation.

The Web based learning environment was developed adopting task centered learning strategy. It was effective in students' expression of conceptions and conceptual changes, and in instructors' observation and guidance.

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Linux operating system

http://klpd.org/

http://linux.sarang.net/

Apache Web server

http://httpd.apache.org/

PHP Web programming language

http://www.php.net/

http://www.phpschool.com/

MySQL database management system

http://www.mysql.com/

국문 초록

본 연구의 목적은 상대 운동의 과제 중심 학습을 위한 웹 기반 환경을 개발하는 것이다. 이를 위해, 개발 목표를 상세화하고, 학습 방략을 고안하며, 웹 기반 학습 환경의 구조와 기능을 설계 및 개발하고, 학습 지도 효과를 평가하였다.

개발 목표는 두 명의 연구자들이 웹 기반 학습 환경에 대한 자신의 경험을 회고한 내용을 분석하여 상세화하였다. 이들의 회고는 내용, 학생, 교사, 시스템, 이렇게 네 가지 범주로 분류되었다. 개발 목표는 다음과 같다. (1) 개별화된 학습 과제를 제공한다. (2) 학생이 자신의 개념을 쉽게 표현할 수 있게 한다. (3) 교사가 학생을 효과적으로 관찰하고 안내할 수 있게 한다. (4) 통합된 구조와 기능을 가진 웹 기반 학습 환경을 구성한다.

이 목표를 달성하기 위해 과제 중심 학습 방략이 고안되었다. 이것은 두 가지 학습 방략의 요소들을 채택하였는데, “일상 상황의 문제”와 “자기 주도적 협동 학습”의 요소는 문제 기반 학습에서, “학습 단위”와 “개별화된 반응”의 요소는 완전 학습에서 채택한 것이다. 본 웹 기반 학습 환경에서는 학습 과제가 제공된다. 학생은 진단 평가를 통과해야 과제 해결 활동을 할 수 있는 권한을 받는다. 학생은 과제를 해결하기 위해 학습 자료를 이용하고 다른 사람들과 토론하며, 과제를 해결한 후 과제 해결 보고서를 작성한다. 보고서가 교사의 승인을 받으면 학생들은 과제 해결 인증서를 받고, 그렇지 못할 경우, 학생은 교사의 안내를 받으며 보고서를 보완하게 된다.

과제 중심 학습 방략을 구현하기 위해 웹 기반 학습 환경의 구조와 기능이 설계 및 개발되었는데, 그 과정에서 개발자는 내용, 학생, 교사, 시스템을 동시적, 포괄적으로 고려했다. 과제 해결 활동을 위한 네 개의 “방”, 즉 자료실, 실험실, 토론실, 작업실이 설계되었다. 이 방들은 통합되어 있어서 참여한 학생과 교사의 활동 내용이 체계적으로 정리된다. 학생들의 활동은 자동으로

기록되어 교사가 쉽게 관찰할 수 있다. 교사가 학생들을 안내하는 데에 도움이 되도록, 진단 통과 허가, 과제 해결 인증, 학습자의 개인 게시판에 쓰기 권한 등의 기능들이 개발되었다.

개발을 마친 후에, 본 웹 기반 학습 환경의 학습 지도 효과가 평가되었다. 학생들이 본 웹 기반 학습 환경에서 발언한 내용을 분류하여 기존에 알려져 있는 학생의 선개념들과 비교하였다. 학생들은 진단 평가, 과제에 대한 토론, 과제 해결 보고서 등의 다양한 기회를 통해 자신의 개념을 표현할 수 있었다. 운동의 상대성 개념 검사지를 사용하여 참여 전후의 학생의 개념 변화를 조사한 결과, 사전 검사에서 낮은 점수를 받은 학생들이 개념 변화를 보였다. 학생과 전문가가 평가 기준에 따라 본 웹 기반 학습 환경을 평가하였다. 학생들은 본 웹 기반 학습 환경이 흥미있고 유익했다고 평가하였고, 더욱 많은 자료를 준비하고 학생의 권한을 확대할 필요가 있다고 요청하였다. 전문가들은 본 웹 기반 학습 환경이 교사의 학생 관찰과 안내에 효과적이라고 평가하였으며, 현재의 학교 상황에서 실용적으로 사용되기 위해 필요한 개선점들을 제안하였다.

본 웹 기반 학습 환경은 과제 중심 학습을 효과적으로 실현할 수 있도록 구조와 기능이 설계 및 개발되었으며, 학생의 개념 표현과 개념 변화, 그리고 교사의 학생 관찰과 안내에 효과적이었다.

주요어: 웹 기반 학습 환경, 과제 중심 학습, 상대 운동, 개발 연구

학번: 98717-804

감사의 글

What is man, that thou art mindful of him? and the son of man, that thou visitest him? (Ps. viii. 4)

과제 해결을 위해 열심히 활동했던 경민, 관영, 명준, 민건, 민정, 장혁, 현지, 혜림, 혜민 등의 친구들에게 감사합니다. 이 친구들을 지도하는 데 수고해 주신 김형석, 정형식 선생님께 감사합니다. 웹 기반 학습 환경 개발에 대해 의견을 제시해 주신 김현명 선생님, 개발된 웹 기반 학습 환경을 평가해 주신 지찬수, 윤혜경 선생님께 감사합니다. 논문을 읽고 조언해 주신 김은숙, 조광희 선생님께 감사합니다. 논문을 지도하고 심사해 주신 박승재, 소광섭, 김영민, 나일주, 유준희 선생님께 감사합니다.

웹 기반 학습 환경을 짊어지고 불시의 정전과 네트웍 이상을 이겨 낸 “케플러”, 온갖 프로그래밍과 논문 작업으로 혹사당해도 꿋꿋하게 버텨 낸 “아인슈타인”, 비디오 편집, 플래시 제작 등의 고난도 작업을 거뜬히 해 낸 “다빈치”, 이 친구들에게 이제는 편안히 지내라고 하고 싶습니다.

항상 격려해 주시고 도움을 주셨던 연구실 여러분들, 친지와 친척 분들, 그리고 믿고 기도해 주신 부모님께 감사드립니다.

사람이 무엇이관대 주께서 저를 생각하시며 인자가 무엇이관대 주께서 저를 권고하시나이까 (시편 8:4)