New Challenge of Information Science Education Based on PBL Using Squeak eToy: ISEC-SeT

Takeshi Fujioka Hideyuki Takada Hajime Kita
Graduate School of Informatics
Kyoto University
Japan

fujioka@db.soc.i.kyoto-u.ac.jp htakada@db.soc.i.kyoto-u.ac.jp kita@media.kyoto-u.ac.jp

Abstract: In this research, we have designed a problem-based leaning (PBL) curriculum called ISEC-SeT (Information Science Education Curriculum with Squeak eToy). This curriculum is designed for education of information science in high school using computer programming as a tool of problem solving. We adopt Squeak eToy as programming environment for the PBL, which has GUI programming environment, so that even a beginner can make programs easily. The results of our questionnaires show that the students were much interested in Squeak eToy. About 70% of the students who experienced the IDEAL cycle, which is known as a process of problem solving, could understand what problem solving was and acquire problem solving skills with Squeak eToy. The students have agreed to finding and solving problem by themselves. While they had much trouble over the process of problem finding and solving, all the students finally achieved their own problem solving. The teachers who participated this course observed that students could maintain their motivation all the time by finding a problem and solving it by themselves.

Introduction

In Japan, Ministry of Education, Culture, Sports, Science and Technology (MEXT) establishes Courses of Study as the curriculum standards for educational courses in all elementary schools, lower and upper secondary schools, and kindergartens. In order to respond to the rapid advances in the revolution of information technologies and to foster information literacy among children, MEXT of Japan revised the Courses of Study in April 2003 and introduced a new subject "Information" as a mandatory subject in general high school education.

MEXT define the aim of the subject "Information" as follows.

- To acquire practical ability of utilizing information
- To understand information scientifically
- To have desirable attitude toward information society

One of the most important objects of "Information" is to educate children with sufficient balance among these aims in order to raise students' capabilities and attitudes to respond to progress of computerization actively.

MEXT requires that all high schools in Japan should choose at least one subject from "Information A," "Information B," and "Information C" and teach it for 2 hours per week through one year. The purpose of "Information A" is making students acquire the fundamental knowledge and skills for collecting, processing and sending information appropriately through practical use of a computer, information communication network, etc., and raising their attitude to utilize information actively. The purpose of "Information B" is making students learn how to express and process information in a computer and the roles and influences of the information technology supporting an information society, and making students acquire scientific view and method for utilizing a computer effectively in problem solving. The purpose of "Information C" is making students understand digitization of information and the characteristics of information communication network, supporting their capabilities utilizing a computer and so on effectively in expression or communication, making students understand how the progress of computerization affects a society, and raising their desirable attitude when participating in information society.

In 2003, the first year of the new subject "Information," high school information education faced various problems. Now, high schools are making efforts to solve the problems. In this paper, we report our challenge at Kyoto municipal Horikawa high school in Japan.

Background: New Subject "Information"

The state of "Information"

Figure 1 shows distribution of "Information" subjects chosen by Japanese senior high schools in FY2003 (Naigai, 2002). This figure shows that the high school students of great portion are learning the "Information A," which is a most general subject. The fewest is "Information B", which is for science and technology. This shows that science and technology, including computer programming etc., is hardly taught at the Japanese high schools in the 1st year of introduction of new subject "Information."

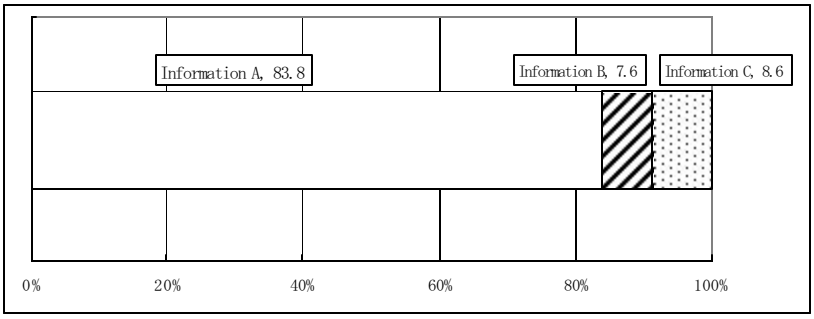

Figure 1: Ratio of students learning "Information A-C" in FY2003

Concerning the contents taught in the "Information" classes in FY2003, it is reported that the contents inclined toward "Computer Literacy" and "Investigation Study," as shown in Figure 2 (Nishino & Kawase, 2004). In "Investigation Study", various media, such as a computer and the Internet, are utilized as tools for activities of problem solving in international understanding, environment, welfare, health, and so on. Students perform a series of activities of collecting, editing, processing and sending information in its process. They access websites related to the theme and gathers information, exchange information with students of other schools or specialists with the electronic conference room, bulletin board about the theme, or e-mails, and present the results of their research to the class. Students utilize the Internet in each process. Thus, in many cases, students investigate about a specific theme and summarizes their idea using word-processing software, and present the results with presentation software.

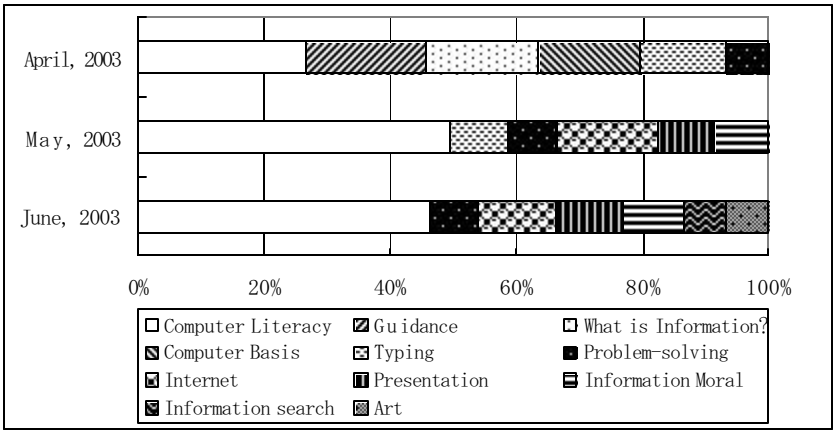

Figure 2: Contents of "Information" Classes (687 high schools, include plural answers)

Information Science Education

Information science, often called computer science, is a field of study about logical and mathematical structure and algorithm in information and its processing. Before 2003, information science was not taught at Japanese general high schools. But, for the students who learn information science at a university etc., it is indispensable to study the foundations of information science in high school.

There are also some countries where information science is taught in the stage of elementary and secondary education. For example, a systematic information educational curriculum has already established in UK (Tanaka, 1999). In the national curriculum of UK, information education is taught using various information technologies fundamentally in each subject, harnessing its characteristic. It is the so-called cross-curricular method. In the stage of upper secondary education called Key Stage 4, subject "information" is set as an elective subject. There are a completion examination of secondary education and GCSE (General Certificate Secondary Education) in the information education of UK.

It is a big issue how we should build Japanese information science curriculum to meet Japanese high school education.

Problem-Based Learning (PBL) for Information Science Education

Problem solving means process to solve problems that we do not know how to solve. John Bransford and others is introducing the process of problem solution as IDEAL (Bransford & Stein, 1984).

- Identifying problems (I)
- Defining problems (D)
- Exploring problems (E)
- Action on a plan (A)
- Looking at the effects and learn (L)

Problem solving approach aims at heightening students' problem solving capability practically by experiencing the IDEAL cycle using actual study materials and environments. Problem solving approach was historically seen as experiential learning in confrontation with systematic learning. However, it has come to treat modern subjects today. Generally, a method of learning through problem solving, often called problem-based learning (PBL), has the following features.

- PBL can raise a student's interest and concern.
- PBL needs pursuits and experiments.
- In PBL, students' attitudes and intellectual skills are more important than specific knowledge.
- In PBL, students learn in a group rather than individually.
- In PBL, a teacher is a promoter of study and has a role of a guide or counselor.
- In PBL, the result finishes with the form of a report, demonstration, presentation, or discussion.

One of the most popular projects of PBL is Jasper project (CTGV, 1997). This project is a practice in the comprehensive subject of science and arithmetic in an elementary school, and uses the video teaching materials like a drama. Students do not know which information in video is needed and when the information is needed until it forms the plan of a way in which a student solves (I, D). Students need to consider how to solve the problem using all their acquired knowledge from the video (E). While students are carrying out the plan, there is a trap, and they need to reexamine (A, L). They go into the complicated and interesting situation that they must move in the IDEAL cycle. The aim of Jasper project is to make students not only solve the given problem but experience problem solving by moving in the IDEAL cycle and look back to the process.

In the PBL, a teacher puts the problem solving process into learning and students can understand its domain and the problem solving itself. Since the problem is not "students' own problem", the difficulty may arise that they can not understand its meaning to solve.

Development of teaching materials for PBL is very difficult but definitely important. Like Jasper project, various teaching materials for PBL have been developed in education, such as science and mathematics, and it is reported that they had considerable study effect. However, PBL teaching materials for information science have hardly been developed yet, and we have little practice and knowledge about PBL for information science education in high schools.

Curriculum Development: ISEC-SeT

In this research, we have designed a PBL curriculum called ISEC-SeT: Information Science Education Curriculum with Squeak eToy. This curriculum is for information science in high school education. Information science education is hardly performed in Japan before 2003, the 1st year of subject "Information." In ISEC-SeT, we use computer programming as a tool of problem solving. We adopt Squeak eToy as programming environment for the PBL because it has GUI programming environment, and therefore even a beginner can make programs easily.

What is Squeak eToy?

Squeak (Squeakland 2004: available at http://www.squeakland.org.) is object-oriented programming environment based on Smalltalk-80. Squeak eToy is one application of Squeak. In Squeak eToy environment, we can operate visualized object "Morph" using GUI. One of the greatest features of Squeak eToy is offering "tile-scripting" function. By using "tile-scripting" function, beginners (for example, children) can program easily without remembering correct spellings of programming elements such as objects and methods and typing them. So, it does not take time for them to master basic Squeak eToy skills. The feature of Squeak eToy is as follows.

- Even a beginner can make programs easily and creatively.
- The objects are visualized as sketches on the screen.
- We can make programs by combining script tiles. (For example, "forward", "turn", etc.)
- The scripts of each object can be operated in parallel.
- We can treat various media such as a picture and a sound easily.
- We can install easily and freely.
- The Japanese version is supplied.

For these reasons, we introduce Squeak eToy environment to our ISEC-SeT.

Contents of the Curriculum with Squeak

This curriculum consists of two parts, the FIRST HALF and the SECOND HALF as below (Table 1).

Table 1 Curriculum for the FIRST HALF

	Students' Age (Grade)	Period	Class per a Week	Objects of Class
FIRST HALF	15-16 (10th)	Oct.-Mar. (6 months)	Two hours	To experience problem solving process To acquire basic skills of Squeak eToy
SECOND HALF	16-17 (11th)	Apr.-Sep. (6 months)	Two hours	To practice problem finding and solving by themselves

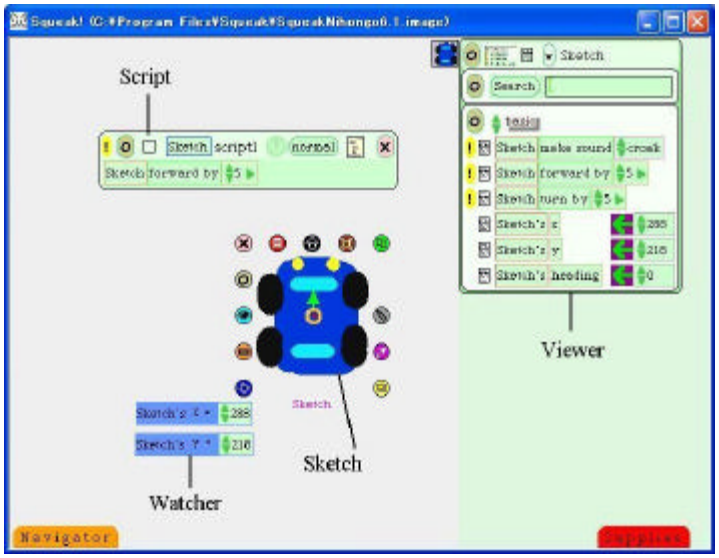

Figure 3: Squeak eToy

- Sketch:
  Any painted object, before it is named, is a sketch.
- Script:
  Objects can be sent messages and Instructions by combing tiles and running them inside of a "Scripter."
- Viewer:
  The viewer shows categories of properties and instructions for the object, represented by tiles. Values of properties such as "x", "y" and "heading" are also shown in the object's viewer. There are several categories in the viewer.
- Watcher:
  Watchers (simple and detailed) can be found in an object's viewer by clicking on the small menu to the left of its property.

- *FIRST HALF*

The objects of FIRST HALF classes are to experience problem solving process and to acquire basic skills of Squeak eToys (Table 2). Before the FIRST HALF, students have already learned how to make a document using word processor, how to present using presentation software, and so on. In the FIRST HALF, students learn how to operate Squeak eToy first and make simple programs on it (1st Term). Next, students learn problem solving process by experiencing its concrete process twice (2nd and 3rd Term). In this course students learn computer simulation and GUI design on Squeak eToy. At the end of each term, students make essays to report what they learn in the term. Teachers show the guidelines of the contents of each essay.

In next sections, we will show the details of curriculumfor experience of problem solving with Squeak eToy.

Table 2 Contents of the FIRST HALF classes (Each step consists of 2-3 hours lectures.)

1st Term: "Basics of Squeak eToy"	
The 1st Step	Squeak Programming Basics 1: How to Manipulate Objects
The 2nd Step	Squeak Programming Basics 2: How to Use "Test" function (Conditional branch) Computer Simulation Basics
The 3rd Step	Submission of an Essay: Computer Simulation Basics
2nd Term: Problem Solving 1 "Computer Simulation with Squeak eToy"	
The 4th Step	Squeak Programming Basics 3: Animation and Random Numbers
The 5th Step	Computer Simulation with Squeak eToy: Calculate the Circle Ratio by the Monte Carlo Method (*)
The 6th Step	Submission of an Essay: Calculation of the Circle Ratio with Squeak eToy

3rd Term: Problem Solving 2 "Design and Implementation of Simulation Applications"	
The 7th Step	GUI Design Basics on Squeak eToy: "Button", "Slider", "Joy Stick" and so on
The 8th Step	GUI Design of Simulator with Squeak eToy: Flying Objects Simulator (**)
The 9th Step	Implementation of GUI Submission of an Essay: Simulation of Flying Objects with Squeak eToy

- *Experience of Problem Solving 1: Computer Simulation with Squeak eToy* (*)

In the 5th Step of FIRST HALF, students practically learn problem solving using computer simulation, Calculation of the Circle Ratio with Squeak eToy, according to the IDEAL cycle as follows:

1. Lecture of identifying and defining problems: "Calculate the Circle Ratio." (I, D)
2. Lecture of exploring problems: "The area ratio of a square and its inscribed circle is 4:pi. Using this fact, we can compute pi by plotting huge amount of points at random in these figures and counting the total of the points in the square and the circle severally." (E)
3. Practical programming on Squeak eToy: "Students complete the program using their programming skills mastered in the 1st term." (A)
4. Verification of the result and submission of the essay: "Students verify the result of calculation and report the process of the problem solving." (L)

- *Experience of Problem Solving 2: GUI Design of Simulator with Squeak eToy (**)*

In the 8th Step of FIRST HALF, students practically learn problem solving through GUI design and implementation of Flying Objects Simulator, according to the IDEAL cycle as follows:

1. Lecture of identifying and defining problems: "Design and implement flying objects simulator with GUI." (I, D)
2. Lecture of exploring problems: "Movement of the x-axis direction of the object aslant thrown up within the x-y plane can be described by uniform and straight-line motion ($x = v_{x0} \cdot t$), and movement of the y-axis direction is motion with fixed acceleration. ($y = v_{y0} \cdot t - \frac{1}{2} g t^2$)" (E)
3. Practical design and implementation on Squeak eToy: "Students create a simulation program on Squeak eToy using the formulas which a teacher shows. They are required to add GUI to the program and complete the simulation application." (A)
4. Verification of the result and submission of the essay: "Students have tested the applications which they created and evaluate their ease of using." (L)

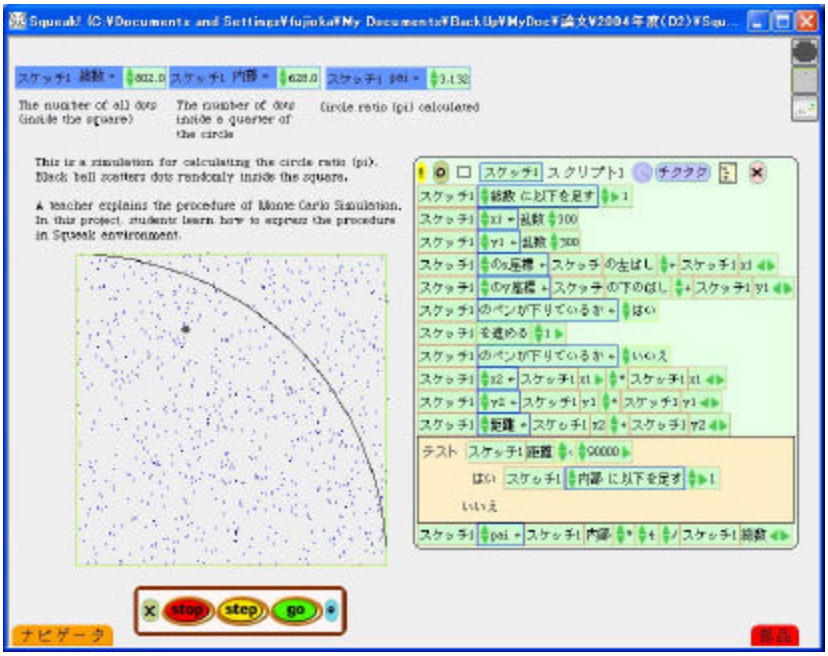

Figure 4: Calculation of the Circle Ratio with Squeak eToy

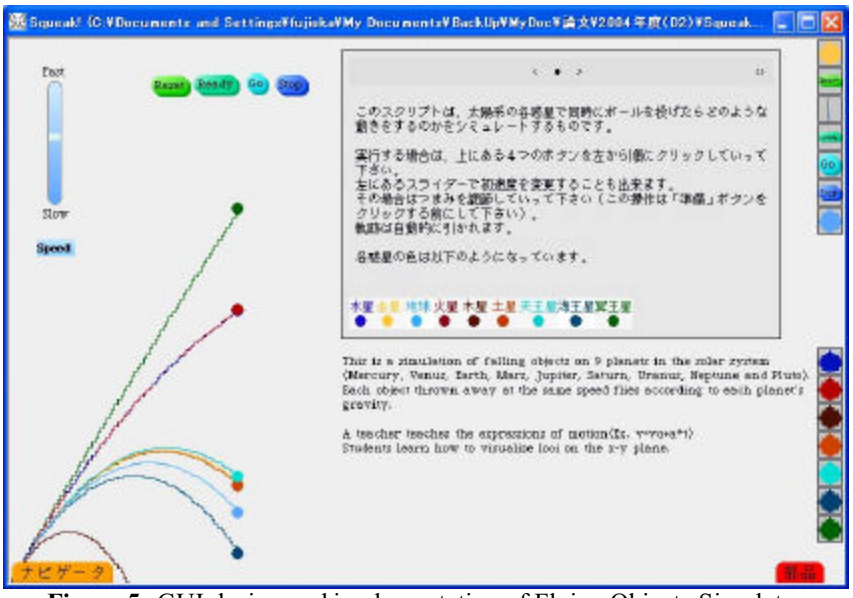

Figure 5: GUI design and implementation of Flying Objects Simulator

- *SECOND HALF*

The object of SECOND HALF classes is to practice finding and solving problem. In this course, students are required to find and solve a problem using a computer by themselves according to the IDEAL cycle, as below. Students present their research still in progress with a poster, and finally summarize all the results in a paper.

Table 3 Process of problem finding and solving in the SECOND HALF classes

Process of problem finding and solving by students	Period	Teacher's Support
1. Having clear awareness of issues in a certain field (I)	3-4 weeks	● To judge the possibility of achievement of students ' problems ● To help students find a problem which have moderate difficulty
2. Investigating the field (I)		
3. Analyzing the issue into solvable problems (D)		
4. Selecting the suitable method for solving the problem (E)		
5. Making a realizable research plan (E)	2 weeks	● To advice students to learn independently well
6. Researching according the plan (A)	7-8 weeks	
7. Summarizing the research results in a paper (L)	2 weeks	

Report of the Classes

We practice ISEC-SeT at Horikawa High School from October 2003 to September 2004 (Figure 6, 7). Horikawa high school, located in Kyoto, Japan, is a public high school for general education. There are six 40-person classes in one grade and the whole number of the students is about 720. In FY2003, 25 students chose the seminar of ISEC-SeT, and other students the seminar of physics, chemistry, and so on.

Figure 6: A scene of the seminar of ISEC-SeT in FIRST HALF in FY2003

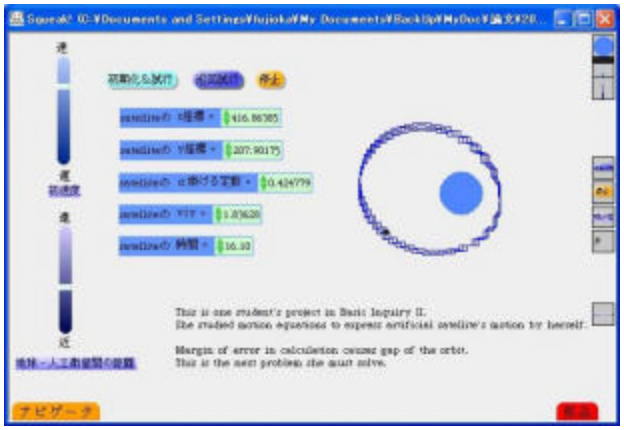

Figure 7: A Student's project in SECOND HALF : Simulation of artificial satellite flying around the earth

The Report of FIRST HALF

We had questionnaire surveys to examine what students think about Squeak eToy and whether they understand problem solving and acquire its skills.

The result of what students think about Squeak eToy (3rd, 6th and 9th STEP) is shown in Figure 8, and the result of how students think about problem solving is shown in Figure 9. These results show that their interest of Squeak eToy was very strong but their understanding was less than it. About 70% of the students who experienced the IDEAL cycle twice in half a year could understand what problem solving was and acquire problem solving skills. In the interview to the teachers, they also thought the students mostly understand it.

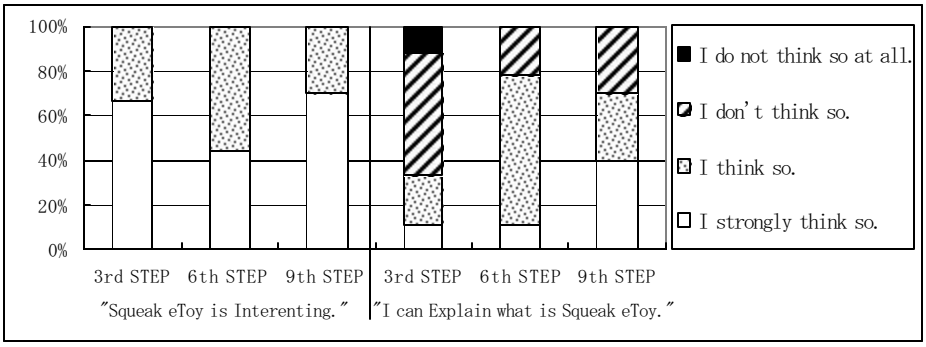

Figure 8: The result of questionnaire about Squeak eToy in FIRST HALF

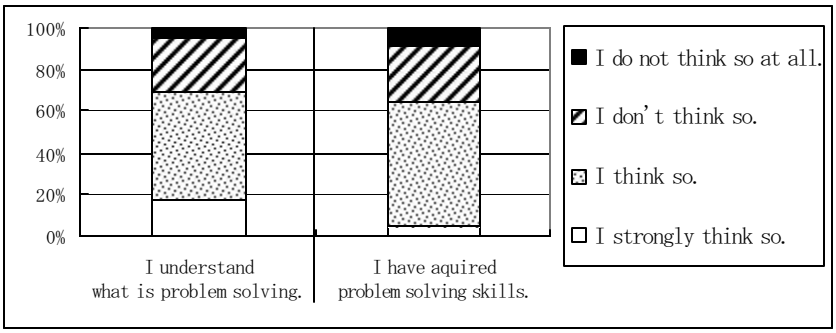

Figure 9: The result of questionnaire about experience in FIRST HALF

The Report of SECOND HALF

In SECOND HALF in FY2004, the students found various problems and solved them using information science. For example, a student found a problem about margin of error in numerical computation when she solved motion equations of artificial satellites around the earth (Figure 7). Finally, all the students achieved their own problem solving.

After SECOND HALF classes, we asked the students questionnaires below. The students answered one which is most fit out of five choices. [5: I strongly think so, 4: I think so, 3: Neutral, 2: I don't think so, 1: I don't think so at all.] ("Avg" means average and "Stdev" means standard deviation.)

- "I was able to find a problem without so much difficulties."[Avg=2.04, Stdev=1.24]
- "In problem finding, I was able to get sufficient advice from the teacher."[Avg=4.16, Stdev=0.94]
- "I did not understand what I should do first when beginning my research."[Avg=4.32, Stdev=0.80]
- "I had to change the research plan assumed first."[Avg=3.80, Stdev=1.32]
- "I felt frustration because my research activities did not work well."[Avg=3.84, Stdev=1.25]
- "If I have such a class in the future, I want to find and solve problem by myself again."[Avg=4.08, Stdev=1.04]
- "I think that the FIRST HALF lectures were helpful in the SECOND HALF."[Avg=3.28, Stdev=1.40]

The students agreed to finding and solving problem by themselves. However, they had much trouble over the process of problem finding and solving. The teachers had to play the roles much more than guides or counselors. They had to teach the students individually over the long time. This suggests that students have to acquire certain amount of knowledge and skills before SECOND HALF, their own practical problem finding and solving.

In the interview to the teachers, they said that a student could maintain her/his motivation all the time by finding a problem and solving it by her/himself.

At the middle of SECOND HALF, many students have noticed defects in their projects when they presented their research still in progress with posters. It is very important that we have some opportunities where a student checks her/his progress of research.

Related Work

LeTUS project (LeTUS, 2004 and Miyake & Shirouzu, 2003) supports students to find a problem and solves it by themselves. In this project, students observe familiar natural environment continuously and they find questions about the ecology of a living thing. Students solve the questions which they found by an experiment etc, and improve the quality of their questions gradually.

Our ISEC-SeT is for information science education in high schools and has the feature that we teach information science by PBL using Squeak eToy.

Conclusions

In this research, we have designed a problem-based leaning (PBL) curriculum called ISEC-SeT (Information Science Education Curriculum with Squeak eToy). This curriculum is designed for education of information science in high school using computer programming as a tool of problem solving. We adopt Squeak eToy as programming environment for the PBL, because it has GUI programming environment and even a beginner can make programs easily.

The results of our questionnaires show that the students were much interested in Squeak eToy. About 70% of the students who experienced the IDEAL cycle twice for half a year could understand what problem solving was and acquire problem solving skills with Squeak eToy. The students enthusiastically practiced problem finding and solving by themselves, while they had much trouble over the process of problem finding and solving. The teachers said that students could maintain their motivation all the time by finding a problem and solving it by themselves. At the middle of SECOND HALF of ISEC-SeT, many students have noticed defects in their projects when they presented their research with posters. It is important that we have some opportunities where a student checks her/his progress of research.

ISEC-Set teaching materials are not sufficient, and we need to support teachers to develop more interesting materials for students. We will also examine how teachers can support a student's activity well and lead to the goal in such PBL for information science.

References

Bransford, J. D., Francs, J. J., Vye, N. J. & Sherwood, R.D. (1989). New approaches to instruction: Because wisdom can't be told. In S. Vousniadou, & A. Ortony (Eds.), Similarity and Analogical Reasoning. Cambridge University Press.

Bransford, J. D. & Stein B. S. (1984). The Ideal Problem Solver. N. Y.:W. H. Freeman &Company.

CTGV (the Cognition & Technology Group at Vanderbilt) (1997), The Jasper Project: Lessons in curriculum, instruction, assessment, and professional development. Mahwah, N. J.: Laurence Erlbaum Associates, Inc.

Konomi, S. and Karuno, H. (2003). Initial Experiences of ALAN-K: An Advanced LeArning Network in Kyoto. Proceedings of the Conference on Creating, Connecting and Collaborating through Computing (C5), IEEE Computer Society. (pp.70-76).

LeTUS. (2004) http://www.letus.org/

MEXT: Ministry of Education, Culture, Sports, Science and Technology http://www.mext.go.jp/english/index.htm

Miyake N. & Shirouzu H.(2003), Learning Sciences and Technology, The society for the Promotion of the University of the Air. (In Japanese)

Nishino K. & Kawase N. (2004), The survey of the information education in a high school (total result).

Squeakland. (2004) http://www.squeakland.org/

Tanaka H. (1999) The trend of UK's comprehensive study and information education: ICT Education No1, Nihon Bunkyo Shuppan. http://www.nichibun-g.co.jp/joho/it-edu/001/i012326.htm (In Japanese)

Naigai Kyoiku. (2002) The number of adoption volumes of subject "Information" textbooks. http://www.comm.musashi-tech.ac.jp/~matuyama/hs_info/no_of_txt03.htm(In Japanese)