Development of an Education Model to Enhance Mathematics and Science Learning through Creation with Squeak eToy

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Abstract: The recent improvement of the Japanese standard curricula requires fostering children's ability to find and solve problems more actively. Although education with computers is thought to be able to play an important role to realize this requirement, there are little well-defined curricula and experience on how to conduct a class with computers for this purpose. In this paper, we will propose an education model that promotes elementary school children to learn math and science through creation process on computers. We will also show a curriculum example and experiences through conducting classes of the curriculum with results of questionnaires.

Introduction

One of important social changes happening in the 21st century is industrial re-structuring, and the number of people engaging in knowledge industry is expected to increase rapidly. This kind of society is often called "knowledge society." Even in the coming knowledge society, the subject that produces knowledge is none other than people. Therefore it is an important social issue to promote and cultivate each person's ability, especially for children who play an important role in the future. The Ministry of Education, Culture, Sports, Science and Technology in Japan (MEXT) has been trying to reform the education curricula for the purpose of developing "Zest for Living". As a part of this reform, a new subject, called "the period for integrated study," was established in elementary school in 2002. In this subject, each school is expected to create its own curricula. This may expand the possibility of education but in fact many teachers are confused because they have little idea about what they should teach.

Some schools are trying to foster the "Zest for Living" through creation that is considered to be a good way for children to learn various capabilities from the process. In addition, it is important to learn about computers because computers are getting to be utilized everywhere in our daily lives. Since it can be considered that programming is creation on computers, an education course with programming is a good way of supporting the promotion of "Zest for Living". However, an educational model through programming has not been established at elementary school in Japan.

We will propose an education model using Squeak eToy that has a GUI programming environment for elementary school children. We have been developing curricula that support the acquisition of logical thinking ability and the understanding of mathematical and scientific concepts. We have been performing practices of the curricula and evaluation of our curricula at public elementary schools in Kyoto under support of the Kyoto City Education Board.

In this paper, the present condition of the education in Japan and the advantage in educational use of Squeak eToy are described first. Next, an education model is examined from the practice result through one of our curricula. Finally, we discuss how our education model can be extended for the future.

Background

In this chapter, we first present the current situation and requirement of education in Japan

The Present Condition of the Education in Japan

In Japan, there are many discussions on improvement of education system. One of them includes reflection about the past curricula that consequently led to focusing on cramming much knowledge with students. To foster the abilities that truly enable students to perform important roles in the future, a slogan “Zest for Living” has been raised by the MEXT.

As a more concrete effort to this policy, a new subject was introduced to the Japanese standard curricula in 2002. It is called “the period of integrated study,” which aims at encouraging children to acquire active learning attitude, think and solve problems by themselves. Experience-based study and problem solving-based study can be the methods for realizing the aim of the new subject. The following two points are declared by MEXT as purposes of this new subject.

1. Letting children get the ability to find, learn and consider the subject by themselves
2. Studying learning subjects covering over the multiple traditional courses of study

A specific feature of the period of integrated study is that the MEXT has not prepared a well-defined curriculum like the traditional subjects such as mathematics and science. Every school is expected to define its own curriculum reflecting the school characteristics like localness and education policy.

Education with Computers

As an important curriculum for the period of integrated study, education with computers gathers much attention of not only teachers but also governors. “Information education” has been started in many educational institutes from elementary level to university level. In Japanese high school, a new subject “Information” has been also introduced to the standard curriculum.

Typical examples about what is taught in the information education for elementary school children include starting with keyboard typing, sending messages by e-mail and information search by the web search engines. There are a lot of experiences on these activities and its know-how is getting clearer in these days.

However, we think that computers can perform more effectively in education. The previous examples of computer usage are only to learn how to use the pre-defined functions of the typical and widely used applications. In this way, the process of children’s thinking tends to be restricted by what can be done in these applications.

On the contrary, we claim that creation on computers should be much focused on. We think that creation on computers can support children to learn various capabilities such as problem solving skills through the process in which their ideas are actually made visible to others. The learning process through creation is shown Figure 1.

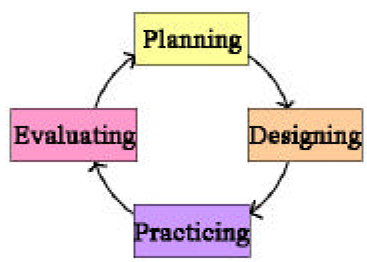

Figure 1: The Learning Process through Creation.

The most important issue to introduce the creation on computers is that there is no well-defined curriculum, because schoolteachers or governors don’t have enough experiences on creation on computers. According to the survey conducted by the MEXT in 2003, 72.7% of teachers answered that they can use a computer in their classes. However, a lot of teachers teach only how to use the typical applications or how to search information through the Internet. These experiences are not enough to define a curriculum for the creation on computers well.

We think that programming on computers fits the process shown in Figure 1 well. To introduce the creation to education with computers, there are many candidates for tools to be used. We decided to choose “Squeak eToy” from these candidates. The major reason to use Squeak eToy is that it provides a visual programming interface under which even elementary school children can create their own program.

Squeak eToy

“Squeak” is an object-oriented programming language that inherits most of the features of Smalltalk-80 and is extended to have modern multimedia processing capabilities. Squeak has some features, such as compatibility on major operating systems like Windows, Macintosh, and Linux, development as an open source project, and capability to handle various types of media. Squeak is a common environment enough to realize variegated functionalities such as a web browser, a web server and a 3-D manipulation. Moreover, Squeak is based on a simple but powerful architecture, called the "Morphic Framework," inherited from Smalltalk. The Morphic Framework enables every visual object, called "Morph", to be operated as an object through the visual interface that Squeak provides.

In Squeak eToy, the tile scripting function and user interface like generation and operation of objects on Squeak are implemented using the Morphic Framework. Figure 2 is an example of the tile script function for describing an action of a drawing object. It is possible to make a program with drug & drops by combining the tiles that perform operations such as "forward by" or "turn by" or check the conditions such as "isUnderMouse."

Squeak eToy is designed so that 8 to 12 years old children can quickly create projects and express their ideas in easy-to-understand environment.

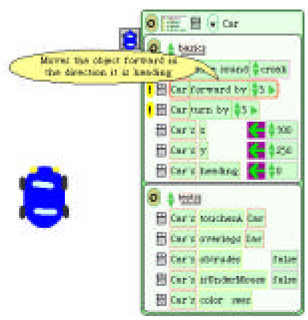

Figure 2: Squeak eToy

Squeak eToy is getting its popularity at various places in the world, including at the Open Charter School in Los Angeles. Ohshima and Abe have written a multilingual version of Squeak and Squeak eToy (Ohshima & Abe, 2003). That enabled us to bring Squeak eToy in Japanese classrooms.

There have been many experiences on education using programming language, such as Basic and Logo (D. Pea & Sheingold, 1987) in elementary school. Next, we describe the advantages of Squeak eToy.

Two kinds of scripts shown in Figure 3 and Figure 4 represent the same function. The graphical program in Figure 3 is made by the tile scripting environment while the program in Figure 4 is consisted by text. When trying to make a script by text, it cannot be written without the knowledge about programming language. Since the amount of knowledge about the programming language itself becomes very large, it is necessary to spend much time to study the language itself for elementary school children. On the other hand, children can make scripts by the tile scripting environment even if they have no knowledge about the language running behind the tile script. In other words, the tile-scripting environment is less dependent on the knowledge about the programming language than the text one. Therefore children focus their attention on creation.

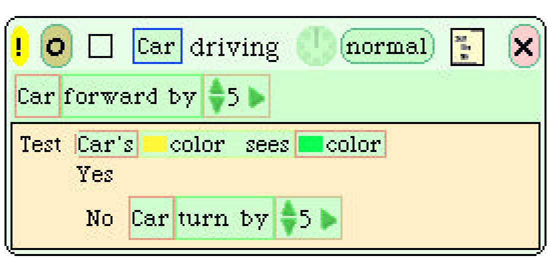

Figure 3: Tile Script

```
driving
    self forward: 5.
    (self
        color: (Color
            r: 1.0
            g: 0.968
            b: 0.226)
        sees: (Color
            r: 0.032
            g: 1.0
            b: 0.323))
        ~~ false
    ifFalse: [self turn: 5]
```

Figure 4: Text Script

In addition, it is important for children to work with their interest in the environment where children learn by themselves. Children can work keeping their interest in Squeak eToy because of the following reasons.

- Children themselves can draw a figure that becomes an object.

- Children can show their programming result immediately and visually.
- Children can move objects through the GUI.

These features can be applied to other GUI programming languages, but most of GUI languages are specialized in a certain specific function such as creating games. This is suitable when subjects for creation are restricted to games, but it lacks expandability. In this point, the expandability of Squeak eToy is high since all objects are commonly handled as visual objects (Morphs) and it has a possibility that various curricula can be developed.

An Education Model with Squeak eToy

The aim of our education model is to cultivate children's "Zest for Living" along with acquiring the mathematics and science concepts in addition to the logical thinking ability by programming with Squeak eToy.

Learning Objective Hierarchy

Learning with Squeak eToy requires children to acquire various kinds of skills and competence. Figure 5 shows a hierarchy of learning objectives where Squeak-based classes are conducted.

At the bottom level, basic computer competence like mouse operation and keyboard typing is required to operate a computer itself. Japanese children also have to master Kanji conversion to input Japanese and Chinese characters. The next level is basic Squeak competence that corresponds to application specific operations such as file loading/saving and operating script tiles with mouse and keyboard. Together with this, Squeak skills to make use of tile scripting and control program execution are required to make a program.

These skills and competence are only the basics of learning with Squeak eToy. Our main objectives reside in cultivating children's abilities to express human recognition as procedures with logical completeness. For example, only a few years old children can let a toy car follow a picture road with their hands. However, it requires a huge break-through to represent it on a computer program. To fill this gap, acquisition of mathematical and scientific concepts is apparently required. Development of an education model to make children acquire the ability to fill this gap is the most important purpose of our work.

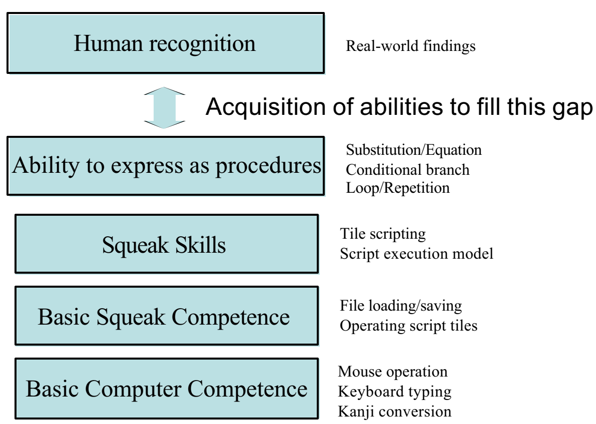

Figure 5: Learning Objective Hierarchy

Initial Experiment

We practice and evaluate our curricula with cooperation of the Kyoto City Education Board at two public elementary schools in the ALAN-K (Advanced LeArning Network in Kyoto) project since 2002 (Konomi & Karuno, 2003). Practice with Squeak eToy had already been performed in the United States (Allen-Conn & Rose, 2003), before we decided to start our project. First, we had a series of classes using the curricula which had been already conducted in the United States as a prior experiment in 2002 and 2003. A questionnaire survey was conducted for fifth and sixth graders taking Squeak eToy classes. Table 1 shows their statistical data and Figure 6 shows some results. 78% children answered that they liked Squeak eToy.

Table 1: Statistical Data

	Male	Female	Total
5th grade	57	61	118
6th grade	53	60	113
Total	110	121	231

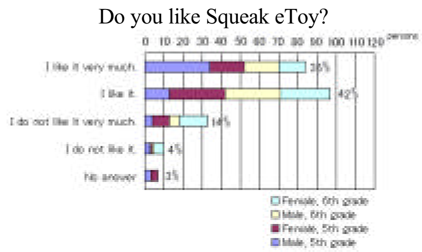

Figure 6: Result of Questionnaire

We interviewed teachers who looked at our classes. They thought children had a good time in the Squeak eToy classes. However, they could not image the following two points.

- What do children learn?
- How do teachers teach?

The situation under which children can program freely is not good for children to understand what they are studying. On the other hand, when the learning target is clarified, it can have risk that it is not different from the old cramming type study. Furthermore, teachers have anxiety since children sometimes try to make great projects which are difficult for the teachers to help the children. The reason why they have no confidence is that children can make what they like by programming, in addition to their lack of knowledge about computer.

These opinions are the same as the issues in the period for the integrated study. It will be very critical issues to implement the Squeak eToy curricula for real class usage.

The Definition of Curricula

In the previous section, the issues to conduct classes using Squeak eToy have been described. We propose that the curricula consist of the learning goals and the teaching materials. The learning goals show what children learn and the teaching materials help teachers.

- Learning Goals

  The learning goals consist of two parts.

  - Goals of Scripts to be made

    They show concrete targets of a program.

  - Goals of Concepts to be learned

    They show mathematical or scientific concepts.

- Teaching Materials

  Teaching materials include not only tools such as Squeak eToy projects, textbooks and tutorials but also the management solutions like class plans.

Teachers conduct classes with the following way reflecting the idea in Figure 1.

- Planning: Teachers show children what to make. (Children consider the goal of concepts.)
- Designing: Children consider how to make their project. (Children consider the goal of scripts.)
- Practicing: Children make their project.
- Evaluating: Children evaluate whether they achieve the learning goal.

Practice

We are developing Squeak-based curricula in various ways (Yoshimasa, Ohshima & Rose, 2004). The Squeak eToy workshops are held after school at two elementary schools every two weeks through a year in order to verify our education model. In these workshops, we took charge of a role of instructors.

In this chapter, we will consider our model, taking the tadpole curriculum adopted at one of the schools for example.

"Tadpole Curriculum"

First the outline about the tadpole curriculum is explained. The aims of this curriculum are described below.

As teaching materials, class planning, tutorial, and some sample programs are prepared. Figure 7 shows a screenshot of the teaching material in Squeak eToy.

- Learning Goals

  Simulating the movement of tadpole on Squeak eToy

  1. Shaking the tail
     - ✓ the observation of life and the mechanismof animation
  2. Moving randomly
     - ✓ the concepts of random number and range
  3. Moving slowly when hungry
     - ✓ conditional branching

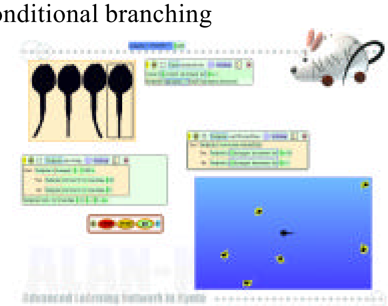

Figure 7: Screenshot of the Tadpole Curriculum

The text for children is prepared on Web. This text describes the goal of scripts and hints of the way and if children attain the goal of scripts, they are requested to answer some questions related with the goal of concepts and the questionnaire about this curriculum.

Environment

The workshops were carried out as an after-school activity at one of public elementary schools in Kyoto. Eleven fifth graders and twelve sixth graders who wanted to study with Squeak eToy attended. They knew how to use Squeak eToy basically before taking the tadpole curriculum. Three workshops were held and each of workshops took one hour and half. However, since a questionnaire was also performed within this time, substantial class hours were about an hour. In addition, the class has been achieved only to the goal of scripts, "Moving randomly" because of the lack of time. One of us taught as a teacher and one personal computer was given to each child. Figure 8 shows the seating arrangement of children.

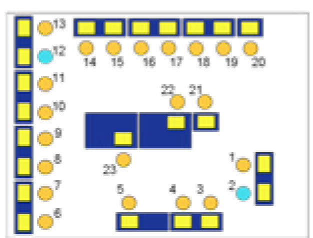

Figure 8: Seating Arrangement

Figure 9: Class Scene

Proceeding of the Workshops

Workshops proceeded according to the following process.

- Planning Part

  We let children consider how tadpoles move and write their ideas on a piece of paper. Next, children discussed their ideas. Figure 9 shows a class scene in which one of the children was explaining a feature of a tadpole shaking its tail by his body. Then, we let children make a tadpole shaking its tail.
- Designing Part

  Children considered how to realize a tadpole in Squeak eToy referring to the text on Web or discussing with friends. We gave some hints to children especially who had little idea.

- Practicing Part

  After children understood how to make a project, they tried to implement it. Most of the children addressed the challenge by themselves.

- Evaluating Part

  Children can judge whether they could achieve a project through the result of execution. In the workshops, we made children submit their projects when they completed each goal of scripts to be made. After submission, we showed the next goal.

The time of submission in the first class is shown in Figure 10. The vertical axis shows children numbers which correspond to the seat numbers in Figure 8 and the horizontal axis shows the time of submission. The goal of the first step is to draw three appropriate tadpoles each of which has a different direction of tails and the goal of the second step is to make a script of shaking the tail with the basic functions for animation.

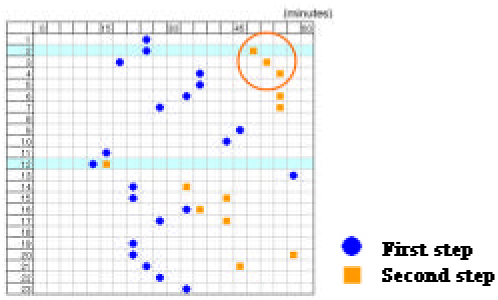

Figure 10: Time of Submission

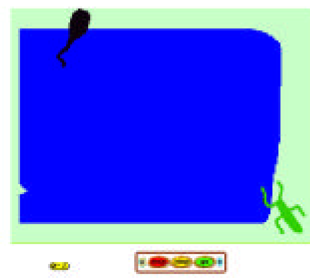

Figure 11: Project Made by No. 12

We pay attention to two children, No. 2 and No. 12. They made interesting projects we had never considered in these workshops. We call them “high creators”. The project shown in Figure 11 is made by No. 12. The flog jumps in random time interval and the tadpole escapes if the mouse is got close to it. He set this goal by himself and realized his ideas.

Some features of the high creators are found in Figure 10. The child No. 12 achieved the goals very early, so he made his own task and tried it in the rest time. On the other hand, the child No. 2 taught other children around him when he achieved his task. It reveals that the high creators played an important role in the classes.

Discussions

In this section, we discuss whether children have acquired the concept of the random number which is the goal of concepts of the tadpole curriculum.

The following questionnaire survey was conducted before and after the class.

- Before the class
  1. Do you know the random number? (Selection)
  2. If you know it, please explain it. (Free description)
- After the class
  1. Do you understand the random number? (Selection)
  2. Please explain it. (Free description)

Figure 12: Question No.1 (Before)

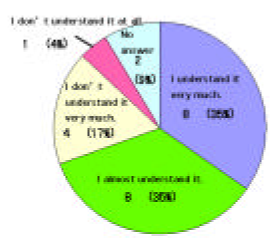

Figure 13: Question No.1 (After)

Figure 12 shows the result of the question No.1 for the questionnaire before the class was conducted. About 30 percent of the children knew about the random number. However, only four children could explain it in the next question. The result of the questionnaire which asked whether children understood it after the class is shown in Figure 13. Since we explained the random number, it was taken for granted that children could answer that they understand it. However, how they understand the random number is more important.

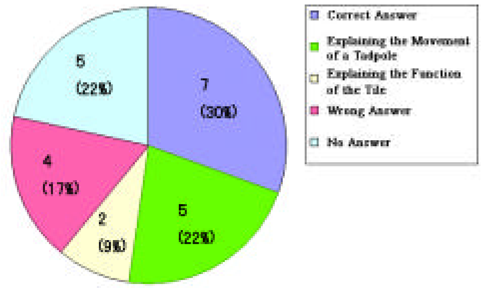

Figure 14: Question No.2 (After)

Figure 14 shows the result summarizing the free descriptions about the random number. Some answers are peculiar to the Squeak-based curricula. Five children explained it by the movement of a tadpole like that a tadpole moves by changing its speed. Two children explained the function of Squeak eToy tile itself of the random number.

This result says that about 30% children's answers were influenced by this curriculum. It is hard to say they could get the concept of the random number correctly. However, we consider that they can learn one of cases using the random number. They are expected to get the correct concept when they learn it in different ways.

Conclusion and Future Works

In this paper, we have described our practice with Squeak eToy in Japanese elementary schools. Through the practice, it is clear that our education model with Squeak eToy is effective for children to get some mathematical or scientific concepts. It will be very important to prepare various good curricula because children will learn in taking various curricula.

It is necessary to clarify how to improve and evaluate curricula. We consider it will be useful to analyze the process and projects of high creators. One of the goals of scripts in the tadpole curriculum, "Moving randomly" is taken for example. Figure 15 shows a script we prepared and one of the high creators made the script in Figure 16. A tadpole moves randomly in both scripts, while children can get the different mathematicalconcepts. They will get the concept of range in Figure 15 and the concept of probability in Figure 16. It will be very worth for children to take in the ideas of the high creators. A systematic way to utilize high creator's feedbacks to improve curricula is a major future work.

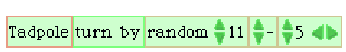

Figure 15: Prepared Script

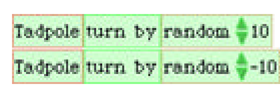

Figure 16: High Creator's Script

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