Using Instructional Activities Game to promote mathematics teachers' innovative instruction

Toshiki Matsuda

(Graduate School of Decision Science and Technology, Tokyo Institute of Technology, Tokyo 152-8552, Japan)

Abstract: NIER (National Institute of Educational Research, 2004) survey revealed that the most common attitude of Japanese high school students to mathematics is that "it is not useful in daily life but must be learnt for entrance examinations". It was also clarified that only 3.2 percent of mathematics teachers use computers in their classes. Therefore, a training system to improve teachers' professional competence through the design of lessons which will improve students' ability to solve problems in daily life was developed using ICT (Information and Communication Technology) in conjunction with mathematical thinking processes. The IAG (Instructional Activities Game) system developed by Matsuda (2004) was used to provide a platform for the execution of several game boards, which were designed to achieve different objectives for different conditions of teaching. Herein, the design of the STG (Simulate Teaching Game) game board and data sets of teaching materials and menu items for lesson plans are described, together with the means of elaborating the IAG system if new functions are required.

Key words: mathematics education; Instructional Activities Game; teachers' professional development; ICT education

1. Introduction

1.1 Issues of mathematics education in Japan and proposal of its solution

This project is concerned with the improvement of mathematics education in Japanese secondary schools. According to the NIER (2004) survey, the most common attitude of high school students to mathematics is that "it is not useful in daily life but must be learnt purely for entrance examinations". There are aspects of both the curriculum and methods of teaching that invite this attitude. In the curriculum, the issue concerns the content of the National Course of Studies. For example, the NIER survey asked students whether the contents "quadratic function", "trigonometric ratio", "numbers of cases" and "probability" in the compulsory subject "Mathematics I" for 10th grade were useful. The results showed that 30 percent of students replied "useful" for "numbers of cases" and "probability", and less than 10 percent replied "useful" for "quadratic function" and "trigonometric ratio". However, in the latest revision of the National Course of Studies in 2004, the latter two contents remained as the main contents of "Mathematics I" and the former two contents were moved to another subject, although the class for this subject would remain in a few schools because "Mathematics I" is the main subject of high school math. In addition, textbooks used in Japanese schools are authorized by the Ministry of Education, after confirmation that they satisfy the guidelines of the National Course of Studies. However, textbooks are never rejected for the

Toshiki Matsuda, associate professor, Ph.D. and M. Eng in System Science, Graduate School and Decision Science and Technology, Tokyo Institute of Technology; research fields: educational technology, science and technology education.

reason that they do not cultivate students' ability to adopt learning output to daily life, even though the contents of textbooks usually consist of explanations and exercise problems for mathematical terms, theorems and procedures, with few examples of their application in daily life. Because teachers must use a textbook in their classes, their lesson's plans are naturally designed based on such textbooks. Therefore, their lesson style becomes so-called "teaching mathematics for understanding higher mathematics"; e.g., explaining the definition of a new concept, presenting the relevant theorems and proofs, and then assigning exercises to familiarize students with using these concepts and procedures in mathematics problems. While this instructional method may be suitable for training mathematicians, less than 10 percent of students said that they want to be enrolled in jobs that require mathematical capabilities.

To resolve the above problems, either the curriculum or the instructional method should be changed. However, it is difficult to change the curriculum because mathematicians have the strongest influence on curriculum change and they are interested only in cultivation of mathematicians. Therefore, in this paper I concentrate on the instructional aspect.

In this section, I will present my perspective on how teachers' instructional method should change based on the three types of scientific resources for solving problems in daily life, as shown in Figure 1. The first approach uses experiments and observations, the second approach uses mathematical concepts and procedures, and the third approach, referred to as the "computer-based approach", uses computer simulations and calculations. The computer-based approach is, in many cases, easier to understand and utilize than the other approaches; in addition, it provides clues to solve problems using a mathematical approach. The NIER survey, however, found that only 3.2 percent of high school mathematics teachers use computers in their classes. This suggests the direction in which teachers' instructional methods may be open to change, and this project is intended to assist in making a computer-based approach ubiquitous in mathematics education in Japanese secondary schools.

When we address problems in daily life scientifically, we are likely to use a number of tactics that have parallels in mathematical thinking (see Figure 2, Matsuda, 1992), as a number of studies of mathematical thinking have shown (Polya, 1945; Katagiri, 1988). However, these studies, which gave examples of and instructions for mathematical thinking, did not define the frameworks of the external conditions that promote mathematical thinking in learners. They therefore provide no guidelines for teachers who would like to develop these ways of thinking in their classes. The present project therefore formulates tactics for promoting mathematical thinking and for training teachers to use them in their classroom programs.

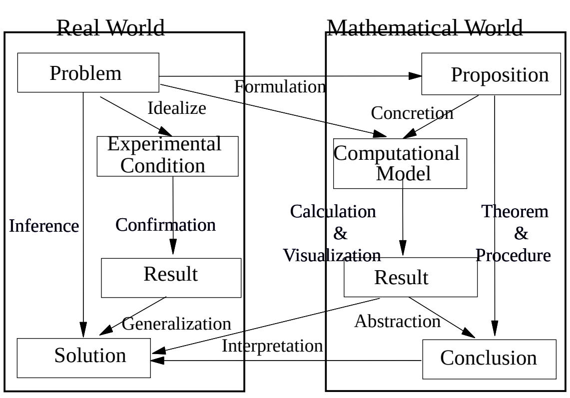

Figure 1 Three types of scientific approaches

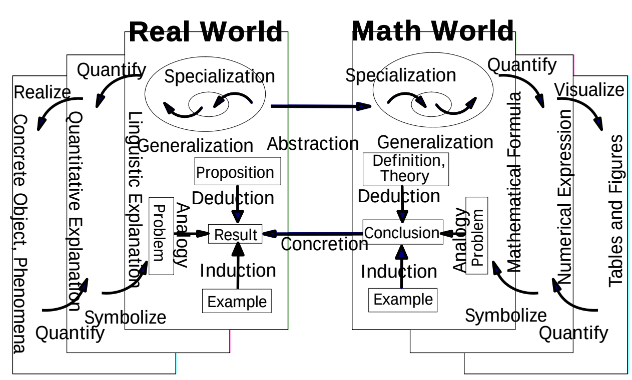

Figure 2 Mathematical way of thinking

1.2 Instructional Activities Game (IAG)

In order to train teachers effectively, this study uses the Instructional Activities Game (IAG) developed by Matsuda (2004). The IAG system has two game modes. One mode, referred to the Decision Making Game (DMG), was developed in order to execute game boards that are represented as a state transition diagram. The other mode, was the Simulated Teaching Game (STG), which was developed for evaluating lesson plans designed by users. When a user logs into the STG, the game first reads the user's lesson plan, which is designed on the DMG using the "objective analysis", "flow analysis" and "making a plan" processes (Matsuda & Ishii, 2006). A lesson plan comprises a sequence of sections chosen in the lesson flow analysis. Moreover, each section has its own learning objectives and is planned as a sequence of steps that consist of the following five elements defined in the Instructional Activities Model of Matsuda, et al. (1992): prediction of lesson situations, instructional intentions, method of communication, lesson content and changes in lesson situations. Once the lesson plan is read, the game flow is controlled by the step data of the lesson plan. At each step, the system saves in its working memory the information regarding the five elements with inner variables, which are used to represent the lesson situation or retain the user's responses. These are then compared with the "conditions for rule activation" in the game board. On activation of a rule, its corresponding action aspect will then display messages as a lesson event, ask for a response, update the inner variables, and/or provide feedback as advice or as a result of his/her decision. If, at any step, two or more rules match the information in the working memory, a meta-rule defined in the system determines the order of activation. After processing all rules corresponding to the current step, the STG repeats the process.

It should be noted that the IAG provides a platform for the execution of several game boards which are designed to achieve different objectives for different teaching conditions. In addition, although the DMG is utilized in many contexts, not only for teacher training but also for information morals education, history education, informatics education, and so on, when the DMG is utilized for instructional design, the data for teaching materials and menu items for describing lesson plans are crucial in maximizing the effects of training.

2. Purpose

As described above, this project develops a training system to improve teachers' professional competence through the design of lessons which will develop students' ability to solve problems in daily life by using ICT in conjunction with mathematical thinking processes. The design of the STG game board and data sets of teaching materials and menu items for lesson plans are described, together with the means of elaborating the IAG system if new functions are required.

(1) In order to promote lesson improvement, daily use of the system is important. Therefore, the STG game board and the data sets for describing lesson plans should be suitable for wide range of content areas.

(2) In order to encourage teachers to change their lesson style, lesson plans described in both old style and new style should be accepted so that differences between these two styles become apparent.

(3) The effectiveness of lesson plans is varied, and each teacher will set different priorities. In order to promote teachers' competency to cope with changes in societal values and lesson conditions, advice generated from the STG game board should not be provided with the assumption that there is an ideal lesson for each content area, but may be useful for teachers to improve lessons.

3. Reconstructing items for describing lesson plans

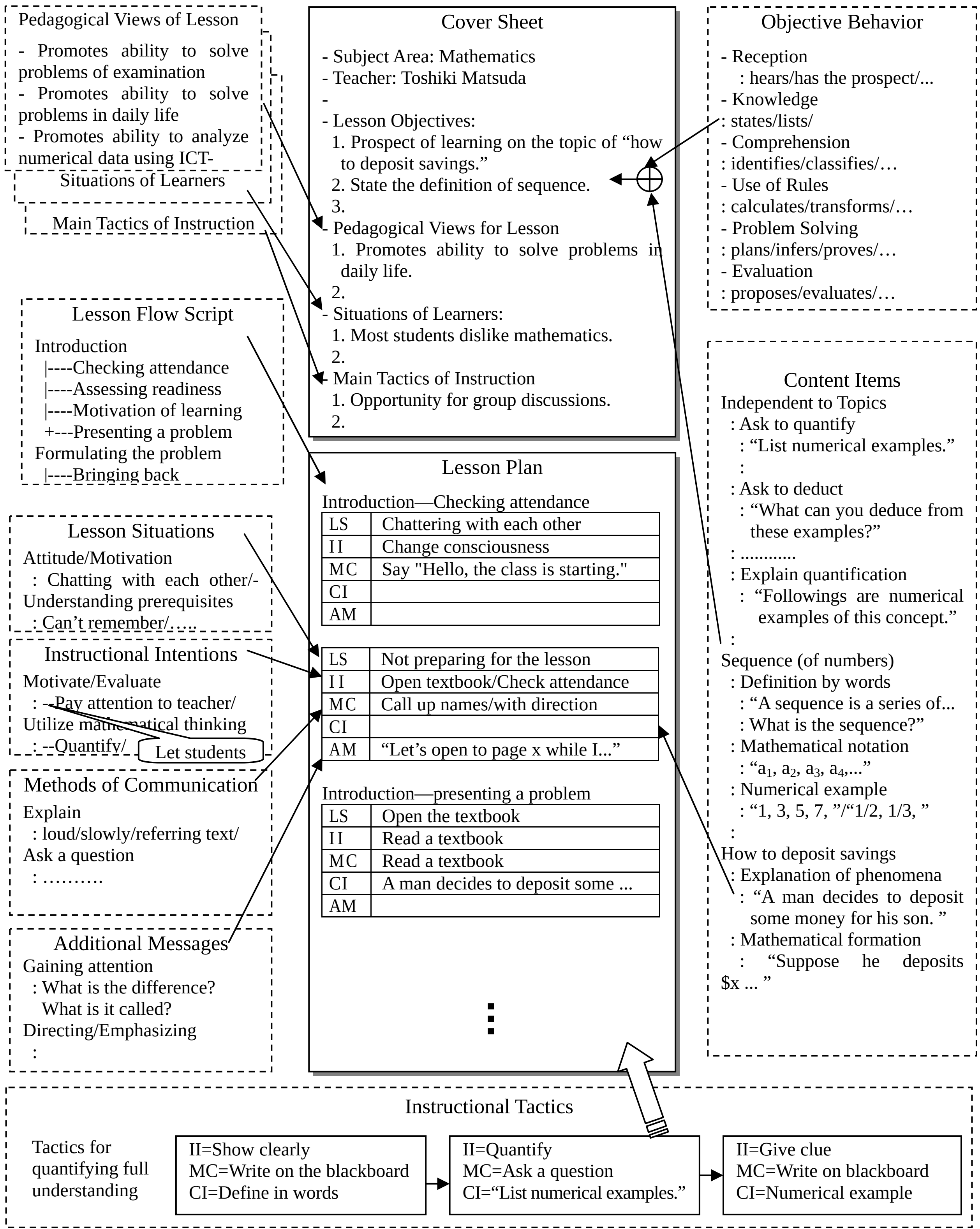

Figure 3 Relationship between lesson plan, data sets of items, and STG game board

Although the IAG system has been used to teach instructional design in pre-service teacher training, the elements employed to describe lesson plans were developed ad hoc, and its adequacy has not been tested. In the following sections, use of the IAG system will be discussed in relation to the Instructional Activities Model of Matsuda, et al. (1992) and its adaptation for new purposes. Figure 3 shows an overview of the results.

3.1 Objective analysis

When using the model for instructional design, users must define lesson objectives as combinations of a content topic and an action verb and create a diagram demonstrating the logical order of learning. Content topics are placed in a contents database. Definitions of objectives, therefore, depend on the content area. However, action verbs should be independent of contents. Based on this principle, common verbs had been used in both mathematics and science lesson designs for in-service teacher training. For the development of computer-based learning in mathematics, I decided to create a new specialized data set of action verbs, because the addition of the new action verbs required by the new instructional style would make the number of verbs in the database too large for easy selection.

Additionally, the current contents data makes insufficient provision for the formulation of the phenomena of daily life in mathematical terms. Although I intend to add this type of data, there are many different phenomena which correspond to mathematical ideas, and at most cases, one or two phenomena would be introduced per lesson. Of course, some phenomena will result in better lessons than others will. It will become difficult to find the appropriate item if the number of items in the list box is large. I therefore decided to create one topic for each phenomenon, and to require users to choose one or two topics for use in their lesson plan. In addition, the wording "to have the prospect of learning in the topic of…" has been added as an action verb for lesson objective (for example "to have the prospect of learning in the topic of how to deposit savings"), to enable users to choose content items for specific phenomena. Thus, the content items shown in the menu are contents directly corresponding to the topics of the section objectives and corresponding to their prerequisite. Furthermore, because the number of items in a category seemed to be large in spite of the above setting, the hierarchy of the contents menu was further extended from two levels to three by adding type of expression for each contents item. These types will serve to identify and clarify the tactics of instruction corresponding to the different types of mathematical thinking shown in Figure 2.

3.2 Lesson flow analysis

In this task, users determine the flow of a lesson by choosing one of the alternatives shown for each stage of the lesson flow script. The older script had similar sections at the first level of the hierarchy, but was designed to develop old style lessons. Therefore, the menu does not contain "individual learning using ICT" nor "group learning for problem solving". Moreover, because the older script had four levels in its hierarchy, the role of each section was more specific. Most of the sections in trainees' lesson plans had only a few steps, and more than half of them only one, although the IAG system assumed that each section consisted of a series of steps. This discrepancy between the model's assumptions and its outcomes is undesirable, and means that advice generated from the STG game board is inadequate.

In addition, because there are restrictions on connections among sections, the lesson flow cannot be changed in parts; the entire flow plan must be changed from the desired section until the end. Furthermore, if the lesson flow is changed, step data must also be re-assigned to each section in the new lesson flow. This might make users feel that the process is bothersome and thus avoid improving their lesson plans.

The hierarchy of the new lesson flow script has two levels which serve to discriminate between whether the lesson belongs to the old style or to the computer-based approach. Given this change, the choice of tactics for teaching a mathematical style of thinking could not be assigned to the sections. However, they can be registered as "instructional tactics" that can be chosen from a list box in order to add a series of steps consisting of specific intentions, method of communication, and types of contents in the next task.

3.3 Making a plan: Lesson situations, intentions, methods of communication and instructional tactics

In this task, in each section users must describe the process of communication in terms of a series of five elements, as defined in Matsuda et al's (1992) instructional activities model: prediction of lesson situations, instructional intentions, method of communication, lesson contents, and changes in lesson situations. The communication method is divided into "instructional action" + "values of its parameters". The former refers to "Instructional behavior" memorized as a script (Schank and Abelson, 1977), and the latter, together with the lesson contents of the particular step, is applied to the script to determine the characteristics of performance. When Matsuda and Ishii (2006) realized the hierarchical menu system, it could be realized as "action + parameters", as shown in Figure 3. However, method of communication is the key element for constructing the rules of the STG game board. Therefore, in order to minimize the changes of the STG game board at that time, the hierarchical menu system was used only to categorize each menu item by "action + a parameter" to each action category. The present project adopts Matsuda et al.'s model; and the first level of the hierarchy is used to present eight instructional behaviors and the second to present the values of parameters from which any number of items can be chosen.

Matsuda, et al. divided instructional intentions into the following four categories: controlling learner's cognitive activity, controlling class situations, controlling properties of information and controlling instructional behavior. In the present project, controlling instructional behavior is clarified either as "values of parameters", under method of communication, or is set automatically under "instructional behavior". Controlling properties of information is also set automatically when lesson contents are chosen. The items which need to be selected are therefore those classified as controlling learner's cognitive activity and controlling class situations. Because the menu items used for pre-service teacher training included the items of controlling properties of information and controlling instructional behavior, I removed these items and rearranged the controlling learner's cognitive activity and controlling class situations items in the instructional intention menu.

"Prediction of lesson situations" contains both the necessary conditions for an action to be taken in this step and the aspects that is desired to change. "Changes in lesson situation" consist of both desired improvements and problems. Because problems should be addressed in this step, they differ from the improvements to be introduced in the next step. Unfortunately, few teachers can discriminate between the two in the instructional design tasks. The reason why they can succeed in teaching without being able to distinguish between these tasks is thought to be that they have acquired the knowledge or heuristics for coping with these issues from their instructional behavior script or from the rules in the monitoring scheme, as defined in Yoshizaki (1988), which control the decision making process. Therefore, to decrease the load of this task, the items provided under "prediction of lesson situations" focus on aspects to be changed in this step, and it is left optional whether to describe the changes needed in the lesson situation if problems occur.

After preparing data sets of items, I constructed sets of instructional tactics as the templates for a series of steps described by the combination of these items. These tactics include methods frequently used in both traditional teaching methods and novel methods necessary for computer-based lessons. These tactics can be individually entered in suitable sections of a lesson flow script in order to decrease the number of items in a list box.

Trainees should be required to describe the reasons for their choices when making their lesson plans in terms of the conditions, goals, and subject area of a lesson. These descriptions will be referred to as a cover-sheet.

3.4 Micro-teaching: STG game board

The STG game board should then be re-designed so as to correspond to this reconstruction of items. In addition, the new STG game board should suggest the influence teaching style has on students, as the purpose of this study is to encourage teachers to change their teaching styles, and thus produce more positive attitudes towards mathematics in their students. The following rules should be applied to game board set-up: (1) Confirm intentions, types of lesson content, and methods of communication to promote a mathematical way of thinking in students; (2) Change the values of inner-variables which represent situations of each student modeled in the game board; (3) Show their situations as feedback.

4. Completing the project

In this article, both the data set of items for describing lesson plans and the STG game board were reconstructed. However, it is not apparent whether they are adequate for the purpose of this study. To test the model, 18 students who are taking the "Method of Mathematics Education 3" unit in my pre-service teacher training course will create lesson plans four times between October 2007 and January 2008. Based on the analysis of their lesson plans, the items and the STG game board will be progressively improved.

References:

Bransford, J.D., Brown, A.L. & Cocking, R.R. (Eds.). (1999). *How people learn: Brain, mind, experience, and school*. Retrieved from http://www.nap.edu/html/howpeople1/.

Gagne, R.M., Wager, W.W., Golas, K.C. & Keller, J.M. (2005). *Principles of instructional design*. Wadsworth, Belmont, CA.

Katagiri, S. (1988). *Concretization of mathematical ways of thinking*. Meiji-Tosho, Tokyo.

Matsuda, T. (2004). Instructional activities game: A tool for teacher training and research into teaching. In: R. Shiratori, K. Arai, F. Kato. (Eds.). *Gaming simulations, and society: Research scope and perspective*. Springer-Verlag, Tokyo, 91-100.

Matsuda, T. & Ishii, N. (2006). "Instructional Activities Game" for supporting practice teaching. *E-Learn 2006*, 2922-2928.

Matsuda, T. (1992). Development of an Instructional Activity Model—Based computer simulation system. *Japan Journal of Educational Technology, 16*(1), 41-53.

Matsuda, T., Tago, K. & Sakamoto, T. (1992). An Instructional Activity Model for developing a computer simulation system. *Japan Journal of Educational Technology, 15*(4), 183-195.

National Institute of Educational Research. (2004). *Investigations of academic ability and an attitude survey on the feelings of children with regard to their studies*. Retrieved from http://www.nier.go.jp/kaihatsu/katei_h14/H14_h/result.pdf.

Polya, G.. (1945). *How to solve it: A new aspect of mathematical method*. Princeton University Press, Princeton, NJ.

Schank, R.C. & Abelson, R.P. (1977). *Scripts, plans, goals, and understanding*. Lawrence Erlbaum Associates, Hillsdale, NJ.

Yoshizaki, S. (1988). Development of a model for teachers' decision making. *Japan Journal of Educational Technology, 10*(2), 51-60.

(Edited by Victoria and Lee)