Multi-Entry System for Supporting Teachers in Designing Instruction

Toshinobu Kasai[a], Kazuo Nagano[b], Riichiro Mizoguchi[c]
[a]*Graduate School of Education Master's Program, Okayama University, Japan*
[b]*Faculty of Liberal Arts, University of the Sacred Heart, Japan*
[c]*Institute of Scientific and Industrial Research, Osaka University, Japan*
kasai@cc.okayama-u.ac.jp

Abstract: As a result of the computerization of school education, teachers are faced with the design of new instruction problems which are different from usual instruction in the various points. The purpose of this study is to develop a system which can support teachers in the instructional design process flexibly and dynamically for their various requests. Main characteristics of this system are: 1) making use of ontology as a base, 2) facilitating teachers' instructional design process flexibly and 3) providing teachers with multiple entries to be supported by the system from various needs. For realization of these functions, this paper proposes FIMA (Flexible Instructional design support Multi-Agent system), which complies with the FIPA specifications. In this paper, we describe a structure of FIMA with its design rationale and its effectiveness.

Keywords: Instructional Design, IT Education, Teacher Education, Ontology, Multi-Agent

Introduction

Recently, the computerization of school education has attracted much attention. There are various goals in the computerization of school education. The establishment of ICT (Information and Communication Technology) equipment in every school [1] and the development and publication of digital materials [2][3] which are parts of these goals have been attained already. However, an enhancement of teachers' ability to use ICT in instruction and the enrichment of information technology (IT) education have not been done satisfactorily, though these goals are especially taken seriously. One of the causes of this problem is that teachers cannot fully understand the goals of IT education, because the instruction from the Ministry of Education is abstract, though these goals are expected to be attained by every teacher. This description does not clearly specify or demonstrate how teachers should make use of ICT in the instruction, what kind of benefits teachers can get from the use of ICT and what kind of competencies teachers should teach in IT education; hence, teachers must arrive at such practical understandings on their own.

For this reason, many organizations have held teacher training meetings and provided various useful resources for them [4][5]. However, most of them are not essential supports such as systematizing and expressing the goals of IT education and the purposes of ICT use in instruction, but superficial supports such as training of computer operation and providing digital materials and lesson plans. As a result, teachers still have difficulties in understanding the contents of the teacher training and support information in-depth. To solve this problem, it is useful to clearly express concepts such as educational goals, which have previously been expressed only tacitly, in a form that can be shared among teachers. The various support information which has already been provided can bring about higher effect by giving meaningful information in terms of these shared concepts. However, such static support cannot help teachers design instruction effectively, since teachers still need to know what information is necessary to improve his/her instruction and to identify where to improve and how to make use of the information appropriately. This is why we intend to

develop a system which dynamically supports teachers in the instructional design process (in this paper, we call this support "dynamic support"). That is, we need both static and dynamic support. We thus aim at the realization of a teacher support system with paying attention to the following two issues.

1. To systematize essential-concepts for making metadata to annotate various support information for sharing it among teachers.
2. To make the design process easier and more effective from the viewpoint of the computerization of school education.

Concerning the former point, we think that the ontology engineering approach works well. So, we built an ontology of the goal of IT education with high quality [6], and authored metadata of various support information resources based on Semantic Web technology [7]. The authors have conducted the research on the static support and obtained sufficient results [7] which provide teachers with various support information with sharing the concepts of the goals of IT education. This paper is concerned with the second issue, that is, dynamic support. Further investigation of the second issue reveals the following questions:

- Are educational goals set suitable to students' learning state?
- Is the planned ICT use in instruction effective?
- Is the instruction executable by the teacher of the IT skill with the ICT equipment in the school?

Because these questions are answered dynamically during the instructional design process, it is necessary to support teachers dynamically in designing instruction. We think that an ontological approach is suitable for such dynamic support as well as for the static support. We can make use of the static support more effectively, since it is possible to dynamically provide teachers who are designing instruction with necessary and appropriate supports using the same ontology.

Here, we describe an instructional design process which is suitable for designing instruction of IT education. We examined the features of IT education and proposed an instructional design process model which is suitable for these features [8]. An instructional design process model by Gagne [9] is typical among the models presented so far. This instructional design process is a waterfall type process in which the teacher first decides the educational goals of instruction and then designs detailed instruction to achieve these goals. However, in the process of designing instruction of IT education, it is often necessary to add the goal of the instruction which relates to its situations and the teaching materials during the design process, since required abilities for students might change according to the detail situation given to them. Therefore, our proposed instructional design process model has to allow a more flexible process. Furthermore, for dynamic support, we aim to control the teacher's instructional design process flexibly based on this model.

And, the viewpoints which teachers should consider in the instructional design process are presumed to change. For example, because the necessity and importance of information ethics education is likely to increase in the near future, teachers might have to begin to design instruction from the viewpoints of information ethics education. So, the dynamic support system has to be able to cope with change flexibly. To meet these requirements, it is not easy for the usual system architecture to control and manage the system. Therefore, we propose a Flexible Instructional design support Multi-Agent system, called FIMA, which complies with FIPA (Foundation for Intelligent Physical Agents) specifications.

In FIMA, each agent has a function that can support teachers from each viewpoint that teachers should consider in the instructional design process. Any agent could be the first functional module fired by the first action taken by the user. For example, when a teacher asks FIMA for support for instructional design in which he/she makes use of ICT and it can execute on a premise of his/her ability of ICT use, FIMA's TM Agent becomes the entrance of the system and supports him/her. It has the function of supporting teachers from the

viewpoint of the teacher's ability of ICT use. The agent which becomes the entrance of the system requests information from the other agents' viewpoints if necessary, and provides teachers with support information through the integration of the gathered information. FIMA can realize dynamic support which allows teachers to go into the system from multiple entries with various viewpoints thanks to the FIPA-compliant multi-agent architecture.

The remainder of this paper is structured as follows: in section 1, we specify the requirement of dynamic instructional design support. In section 2, we explain the structure of FIMA. In section 3, we show an example of dynamic support by FIMA. And, in section 4, we report the results of qualitative evaluation of FIMA by two incumbent teachers. Then, in section 5, we discuss the work related to our approach. Finally, in section 6, we present a summary and plans for future work.

1. Requirement Specification of Dynamic Instructional Design Support

We have discussed the computerization of school education with nine incumbent teachers in these three years to investigate actual conditions for it. The concrete materials for this discussion are lesson plans provided by Okayama Prefectural Information Center [5]. These lesson plans aim at enhancement of students' problem-solving ability by making use of digital materials that are open to the public on the Internet. In this section, we summarize the results of the discussion identifying necessary functions for the dynamic support from the following two viewpoints:

- Problems with instruction that was designed from the viewpoint of the computerization of school education.
- Problems that incumbent teachers encounter in the computerization of school education.

Concerning the former aspect, we investigated the instruction plans and found two major problems: there is no clear description about what competency the instruction tries to train and the other is there is no clear purpose of presenting digital contents. Because of the space limitation, we discuss only the first one in the following. It is that we cannot understand what kind of competency a teacher aimed to enhance in an instruction. For example, consider an instruction in which students did extracurricular activities such as a sweet-potato-digging experience and opened its process to the public on an Internet web page. In this lesson plan, the teacher set educational goals which were related to understanding the potato plant and the skill of creating the web page. However, the competency that the teacher should prepare as a goal for each detailed learning activity in the instruction was not indicated clearly. Even for the same learning activity, suitable instructional activities change according to the competency which the teacher selects as the educational goal. Concerning the example of the creation of a web page, a teacher must perform different instruction according to the cases where the educational goal is the enhancement of ability to make use of computer or where the educational goal is the enhancement of ability to make a good report. Since these detailed goals are not indicated in the lesson plan, it may produce the misunderstanding that teachers are allowed to let students do learning activities without any instructional intention.

Concerning the latter aspect, we can summarize the problems into two major problems. The first is that most teachers do not adequately understand the essential goal of IT education. For example, most teachers who are not specialists in IT education mistakenly believe that the use of the technology itself is the main goal of IT education, though the ability to use information systems is an indispensable aspect of IT education. This misunderstanding often causes such an instruction that makes students practice touch typing as IT education.

The second is the inflexibility in setting instructional goals. Most of the teachers are inculcated by the usual instructional design process model such as Gagne's model in which they begin instructional design with setting educational goals. Because of this, when teachers design the details of the instruction to attain educational goals, they do not usually revise or add the educational goals once they started the design process. In the reality, however, they have only rough educational goals in the beginning which should be refined as the process proceeds.

Next, we consider the conventional support for the above problems. Many organizations provide teachers with various support information from the viewpoint of the computerization of school education. However, we thought that there are the following problems in the support.

- It is not enough for removing the misunderstanding which many teachers believe that the use of the technology itself is the main goal of IT education, since the support explains the goal of IT education from the viewpoint of learning activity rather than from the viewpoint of the competency that teachers should instruct.
- The static support cannot support teachers in setting detailed educational goals and deciding detailed instructional and learning activities to attain the goals according to their situation at each step in the instructional design process.
- Concerning support that provides digital materials, for each material, objective information was added but the instructional context (scene and purpose) in which teachers can make use of it were not indicated. So, it is difficult for teachers to search necessary materials according to their situation in the instructional design process.

To solve these problems, in this study, we identified the requirement specification of instructional design support as follows:

- To build ontologies which define the concepts of the goal of IT education and the purpose of ICT use and to use these ontologies as a conceptual basis of instructional design support.
- To support teachers according to their situation dynamically in instructional design process. For this dynamic support, we take more seriously the following requirements.
  - ✓ To facilitate a flexible instructional design process so that teachers can revise educational goals during the design process.
  - ✓ To allow teachers' instructional design to begin not only with the setting of educational goals but also with various other factors according to teachers' needs.
  - ✓ To facilitate suitable use of ICT in instruction by making teachers understand its purpose in-depth.
  - ✓ To provide teachers with support information according to their situation by the static support system [7].

To meet these requirements and to cope with the change in the needs for the computerization of school education, we propose a dynamic support system called FIMA which is based on multi-agent architecture.

2. Structure of FIMA and Its Design Rationale

We defined and created six agents for FIMA as shown in Fig. 1. In all data that the system uses, only data that user inputs during the design of instruction can be referred to by all agents. Other data can be referred to only from the agent that has the role of processing the data. We explain the functions of each agent below.

The UI Agent has a GUI and its role is to connect FIMA with users (teachers). A user sends various data and requirements through the GUI, and messages from FIMA to the user are sent to the UI Agent and displayed on the GUI. Because the UI Agent knows the functions of the other agents, the UI agent can select the agents that can deal with the user's input and requirements. Then, the UI Agent sends those agents messages requesting the

necessary information. When a user does not request any supports, because FIMA only controls the instructional design process, FIMA sends the input lesson plan data to the ID Agent.

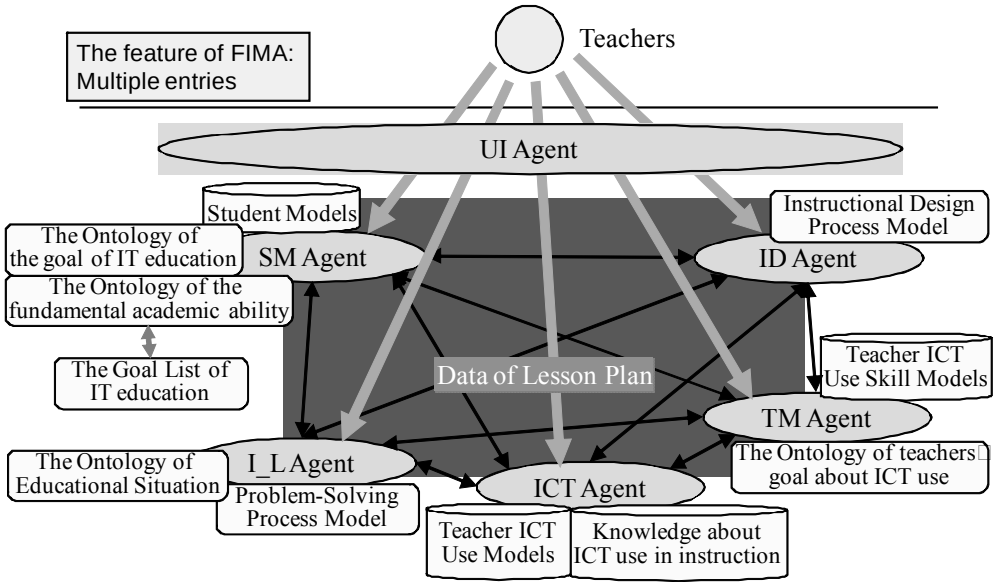

Fig. 1. The functional agent structure of FIMA

The ID Agent has the instructional process model proposed in [8] and its role is to control the user's instructional design process in FIMA. Although the ID Agent tries to lead a user to design instruction in the flow of the instructional design process model, the user can anytime jump into another flow and request FIMA's support. When the user changes the flow, the ID Agent tries to control his/her instructional design process according to the parts that he/she has already designed.

The I_L Agent has an ontology which defines a structure to describe educational situations and the process model of problem-solving which is important for teaching practical abilities. And, the I_L Agent has the role of supporting users in designing instruction from the viewpoint of the instructional or learning activity. According to the requests of other agents (including the user), the I_L Agent can show examples of instructional or learning activities and evaluate whether relations between the activities and educational goals or learning environment are appropriate.

The SM Agent has the ontologies of educational goals and Student Models that record the learning histories of students. And, the SM Agent has the role of supporting users in designing instruction from the viewpoint of educational goals. According to the requests of other agents (including the user), the SM Agent can show the structure of the concepts of educational goals and evaluate whether the educational goals a user selects for a particular instructional unit are appropriate or not.

The ICT Agent has Teacher ICT Use Models which record the ICT use history in the past instruction. And, the ICT Agent has the role of supporting users in designing instruction from the viewpoint of their ICT use in instruction. According to the requests of other agents (including the user), the ICT Agent can show examples of ways users can make use of ICT in instruction and evaluate whether the way a user make use of ICT in the instruction is appropriate or not.

The TM Agent has an ontology of teachers' goal for ICT use and Teacher ICT Use Skill Models. And, the TM Agent has the role of supporting users in designing instruction from the viewpoint of their skill to make use of ICT. According to the requests of other agents (including the user), the TM Agent can show the structure of the concepts of teachers' goals for ICT use and evaluate whether a user can execute his/her plan in instruction from the viewpoint of the skill to make use of ICT.

3. An Example of Dynamic Support by FIMA

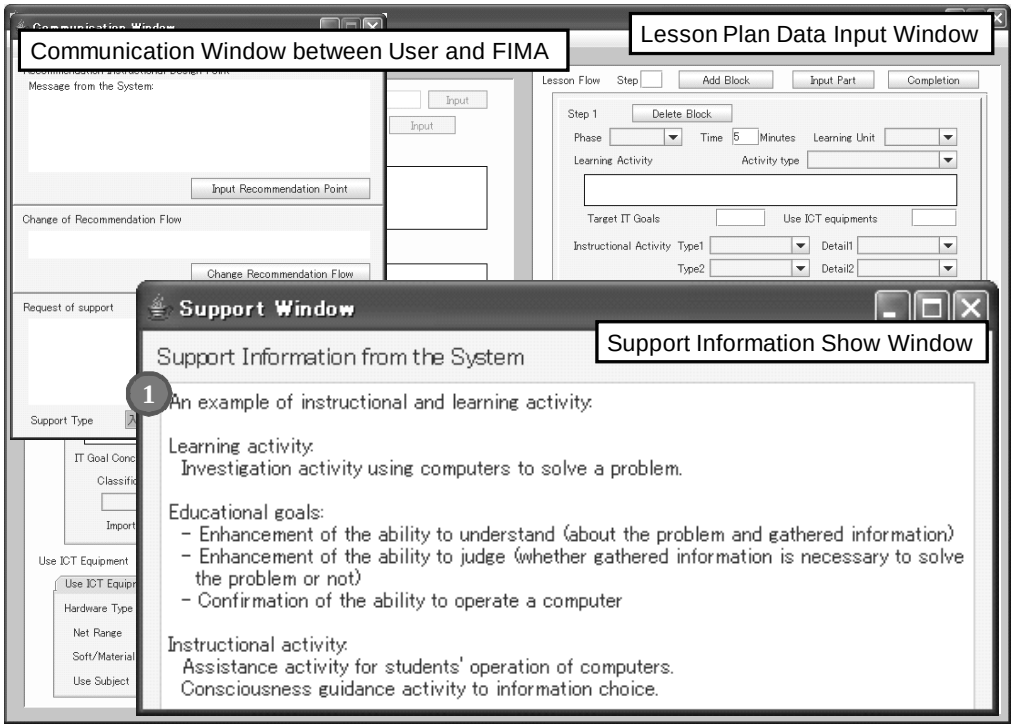

Fig. 2. A screen shot of FIMA

In this section, we show an example of the dynamic support by FIMA and the communication among the agents for realization of this support. Fig. 2 shows a screen shot of FIMA. In the example, a teacher initiated instructional design from the viewpoint of ICT equipment and asked FIMA to provide him/her with an example of an instructional and learning activity in this environment. We show the dialog between the teacher and FIMA and the communications among the agents.

1. The teacher decided to have students utilize computers.
2. The UI Agent sent the input data to the ID Agent and required control of his/her instructional design process.
3. The ID Agent guided the teacher in deciding an instructional and learning activity.
4. The teacher requested FIMA to provide an example of learning activities with a computer and instructional activities.
5. The UI Agent selected the ICT Agent that can support users from the viewpoint of ICT use in instruction and entrusted the ICT Agent with his/her requirement.
6. The ICT Agent decided a way (knowledge) of ICT use which was similar to the way of teacher's ICT use in the past instruction based on the Teacher ICT Use Models. In this example, the ICT Agent decided a way that students make use of computers with a purpose of facilitating their investigation activities based on the past ICT use in which the teacher aimed at enhancing students' ability to operate computers (Actually, the agent decides more than one example to use here).
7. The ICT Agent asked other agents (in this example, the I_L Agent, the SM Agent and the TM Agent) to provide information from each agent's viewpoint related to the contents which the ICT Agent decided. For example, the ICT Agent requested the I_L Agent to provide an example of instructional and learning activities based on the selected way of ICT use.
8. The ICT Agent provided the teacher with support information into which the agent integrated information received from these agents. In this example, support information was provided to the teachers as shown at part "1" in Fig. 2.

4. Results of the Qualitative Evaluation of FIMA

We conducted an experiment to investigate qualitatively the usability and functionality of FIMA. Two incumbent teachers who are students of the graduate school to which one of the authors belongs were test subjects for this experiment. They had been instructed about the computerization of school education and the ICT use in instruction in detail in classes of the graduate school. So, they knew suitable instruction for IT education and a suitable way of making use of ICT in instruction. And, they had experienced the creation of lesson plans for IT education using ICT in the usual way in the class without the support of FIMA.

For the experiment, we asked them to design a lesson plan for IT education using FIMA. Then, we asked their opinions of FIMA's usability and functionality. We found the following major positive opinions from the viewpoint of usability.

- It was easy to design a lesson plan, because a teacher could describe all data on only one window.
- It was convenient that a teacher could select the concepts of the Goal List of IT education and the ontology of the goal of IT education.

On the other hand, a problem that it would take quite some time before they get to used to the complicated operation of FIMA was identified.

And, we found the following major positive opinions from the viewpoint of the functionality.

- It was useful to be able to get suitable support information dynamically according to his/her situation.
- It was effective to facilitate annotation of educational goals and purposes of ICT use for each concrete learning activity, because a teacher could think deeply and naturally the intention of each concrete instructional activity.
- It was easy to understand the contents of support information and evaluation from FIMA, because the contents were classified into parts from various viewpoints.

Although there was not negative opinion, a request of an addition of new function that can provide teachers with suitable instructional and learning activities to attain an educational goal was shown. In the near future, we intend to meet this request by alignment with other research which takes an ontological engineering approach to organize instructional/learning theories [10].

This experiment does not sufficiently demonstrate that FIMA can facilitate teachers to design better instruction from the viewpoint of the computerization of school education. However, we believe we succeeded to show a potential of FIMA from the viewpoints of the usability and the functionality.

5. Related Work

We would like to briefly introduce some of the other projects related to our approach.

[11] developed a novel use of agent technology using autonomous agents to address the key functions of intelligent tutoring systems, which uses learning style schemes to adapts to students individual needs, and which supports the use of learning objects. The incorporation of agents and learning objects is based on learning style a pedagogic foundation for adaptivity. [12] proposed a new ITS architecture that involves sophisticated planning agent at four different levels (course planning, lesson planning, tutorial actions planning and generation of multimedia presentations) of the ITS processing. This architecture takes advantages of previous ITS architecture and provides a uniform view of ITS components that can facilitate collaboration between them.

Many multi-agent systems have been developed for various purposes, because consideration from the various viewpoints is important in the field of Education. However,

to the best of our knowledge, there is no system which can support teachers in designing instruction dynamically regardless of if it is based on multi-agent architecture or not. We believe that one of the causes of this is that most of typical instructional design process models were expressed inflexibly. So, the characteristic of our study is to propose FIMA which can support teachers dynamically in more flexible instructional design process based on multi-agent architecture.

6. Summary

In this paper, we proposed FIMA (Flexible Instructional design support Multi-Agent system) that supports teachers in designing instruction dynamically and flexibly from various viewpoints. We decided necessary functions for the dynamic support through discussion of the computerization of school education with incumbent teachers. As the result, main characteristics of this system were: 1) making use of ontology as a base, 2) facilitating teachers' instructional design process flexibly and 3) providing teachers with multiple entries to be supported by the system from various needs. To meet these requirements, we applied multi-agent architecture that complies with FIPA specifications to FIMA. Each agent of FIMA has functions that support instructional design from one of the several viewpoints. In this paper, we showed an example of the dynamic support by FIMA and communications among the agents. And, we explained results of the qualitative evaluation of FIMA from the viewpoints of the usability and the functionality.

In future work, we intend to develop a new version of FIMA with an alignment with other research which takes an ontological engineering approach to organize instructional/learning theories.

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