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Building an Ontology-Based System Which Supports the Instructional Design Process

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Abstract: In this study, we have developed a system called FIMA (Flexible Instructional Design Support Multi-Agent System) which supports teachers dynamically in designing instruction by facilitating their thinking in ways characteristic of expert teachers' thought processes: 1) multiple viewpoints thinking, 2) contextualized thinking and 3) the problem framing and reframing strategy. We especially focus on instructional design that integrates the use of information and communication technology (ICT). In this paper, we show examples of concrete supports which the FIMA prototype system we have built provides.

Keywords: Ontology, Instructional Design, Multi-Agent, ICT Use in Instruction

Introduction

The educational gaps caused by differences in teachers' professional abilities are a perennial problem, especially for complex tasks like instructional design. Among several approaches to this problem, providing teachers with an efficient and usable support system is promising, since most teachers want to participate in the process of designing high quality instruction. In order to investigate strategies to support less-skilled teachers in designing instruction, it is best to analyze skilled teacher's thinking processes in approaching this task. Sato et al. investigated differences in thinking processes between expert and novice teachers when they analyzed existing instructional plans [1]. This investigation came to the conclusion that the thinking of expert teachers is characterized by the following three features: 1) multiple viewpoints thinking, 2) contextualized thinking, and 3) the problem framing and reframing strategy. Because it is also important for teachers to analyze instruction objectively when they themselves design instruction, this study aims to support teachers in designing high quality instruction by directly facilitating these three types of thinking.

By "multiple viewpoints thinking", Sato means that expert teachers conceptualize instructional propositions and learning propositions in a mutually dependent way. To facilitate teachers' multiple viewpoints thinking, it is important to make them conscious of the relations between various concepts concerning both instruction and learning when they design instruction as well as effective to provide support information together with related concepts according to the teacher's needs. By "contextualized thinking", he means that expert teachers think of a lesson part not independently but in the context of other lesson parts which occur before and after it during an instruction. To facilitate such contextualized thinking, it is important to make the teacher conscious of the flow of instructional and learning activities for the achievement of educational goals; indeed, many teachers want such support to help them confirm whether or not the flow of instructional and learning activities they have designed will achieve a given educational goal. By the "problem framing and reframing strategy", he means that expert teachers are so flexible that they can easily adapt to a situation without persisting in the pre-set plan and their thoughts. By

contrast, the instructional design process conducted by most teachers, including some expert teachers, is a waterfall type process like the instructional design process model described by Gagne [4] which is still typical among the models presented to date. So, it is important to facilitate teachers' "problem framing and reframing strategy" when they design instruction. To facilitate this thinking, it would be effective to control teacher's instructional design process flexibly; for example, to stimulate teacher to reconsider educational goals according to the progress of the instructional design process.

Supporting teachers by facilitating the above three thinking skills simultaneously in the design process rather than independently must be done dynamically, because modification of part of an instruction requires reconsideration of the whole instruction by "multiple viewpoints thinking" and "contextualized thinking". In order to realize such support, we have proposed a Flexible Instructional design support Multi-Agent system, called FIMA. The characteristic goals of FIMA are as follows:

- Not to design instruction automatically, but to support teachers dynamically in designing instruction by themselves
- Not to enhance teachers' skill, but to facilitate teachers' multiple viewpoints and contextualized thinking
- To facilitate a flexible instructional design process
- To provide teachers with support information adaptively to their situation [2][3]
- To evaluate the flow of instructional and learning activities based on instructional/ learning theories described in the OMNIBUS ontology [6] and to support teachers according to the results [5]

The remainder of this paper is structured as follows: in section 1, we describe the structure and support functions of FIMA, which we have designed based on the support principles of this study. In section 2, we show an example of concrete supports by a prototype FIMA system. Finally, in section 3, we present a summary and plans for future work.

1. Structure and Support Functions of FIMA

We defined and created five agents for FIMA. Each agent has a function that can support teachers from each viewpoint that teachers should consider in the instructional design process. All agents can be the first functional module fired by the first action taken by a teacher as the user. First, an agent that supports teachers from the viewpoint of the ability and states of students is the SM (Student Model) Agent. Second, an agent which supports teachers from a viewpoint of their own ability is the TM (Teacher Model) Agent. Third, an agent that supports teachers from the viewpoint of the relationships between the learning activity and instructional activity is the I_L (Instruction and Learning) Agent. Next, in this study, because we regard support for the computerization of school education as important, support from the viewpoint of suitable use of ICT as a tool by teachers and students is important. So, we introduce an ICT (Information and Communication technology) Agent, which supports teachers from the viewpoint of the relationship between the use of ICT as a tool and the learning/instructional activities. The functions of these four Agents are designed to support teachers after instructional design as well. We prepare an ID (Instructional Design) Agent which provides support teachers in designing instruction dynamically. The ID Agent facilitates teachers' multiple viewpoints and contextualized thinking dynamically during the process of instructional design. The ID Agent also controls the instructional design process flexibly to facilitate their problem framing and reframing strategies. Thanks to the agent-structure, in which different agents perform different functions that teachers should employ in the instructional design process, as well as the interaction between the agent functions, FIMA can support teachers dynamically in designing instruction by themselves.

FIMA has the following three kinds of support functions to support teachers dynamically in the instructional design process.

- To facilitate necessary thinking
- To offer suggestions
- To diagnose designed lesson plans

First, FIMA facilitates the three types of thinking by providing teachers with messages indicating what they should consider in designing instruction. For realization of this support function, the ID Agent serves as the first functional module and interacts with other agents if necessary.

Second, FIMA provides suggestions whenever a teacher asks for this type of support during the instructional design process. When teachers ask FIMA for suggestion, they specify the viewpoint and premise of the needed suggestion. Viewpoints which teachers can select are "learning/instructional activities", "students' ability", "instructor's ability" and "ICT use in instruction". Premises which teachers can specify are the "educational goal", "ICT" and "learning/instructional scene" which have been already described in the lesson plan. For example, a teacher can ask FIMA for a suggestion from the viewpoint of learning/instructional activities to attain a particular educational goal, by specifying the educational goal as the premise and selecting the viewpoint of learning/instructional activities.

Finally, diagnostic support is provided when teachers ask for diagnosis of the whole/parts of lesson plans which they have designed. When teachers ask FIMA for diagnosis, they select the viewpoint of diagnosis and can specify a particular focal point if necessary. Here, the viewpoints and the diagnostic points which teachers can select and specify are the same as in the suggestion function. For example, a teacher can ask FIMA for diagnosis from the viewpoint of the flow of the instruction which he/she has designed to attain an educational goal, by selecting the viewpoint of learning/instructional activities and specifying the educational goal as the diagnosis point. For realization of the suggestion and the diagnosis supports, the agent which has the specific role selected by the teacher becomes the first functional module and interacts with other agents if necessary.

For realization of these support functions, FIMA has various conceptual structures which are defined as ontologies and knowledge which is described based on the concepts. To put it concretely, the SM Agent has an ontology which defines the conceptual structures of the educational goals and contents, and the TM Agent has an ontology which defines the conceptual structure of the teacher's competency. And, the I_L Agent and the ICT Agent has knowledge about suitable relationships between the concepts which are defined in the ontologies and learning/instructional activities and use of ICT. To describe the relationships, we have prepared concepts which represent the essence of learning and instructional activities and concepts which represent the expression way of digital materials and reasons for making use of ICT. FIMA asks teachers to select these concepts in the instructional design process. The concepts which teachers can select as the essence of instructional and learning activities have been extracted based on the OMNIBUS ontology. We have prepared the concepts of activities with which teachers are familiar and that have concrete relationships with the concepts defined in the OMNIBUS ontology. Thanks to this description of the relationships, FIMA can align with the OMNIBUS ontology.

So, FIMA can realize three kinds of supports invoking various ontologies which contain the OMNIBUS ontology and knowledge described in relation to those ontologies.

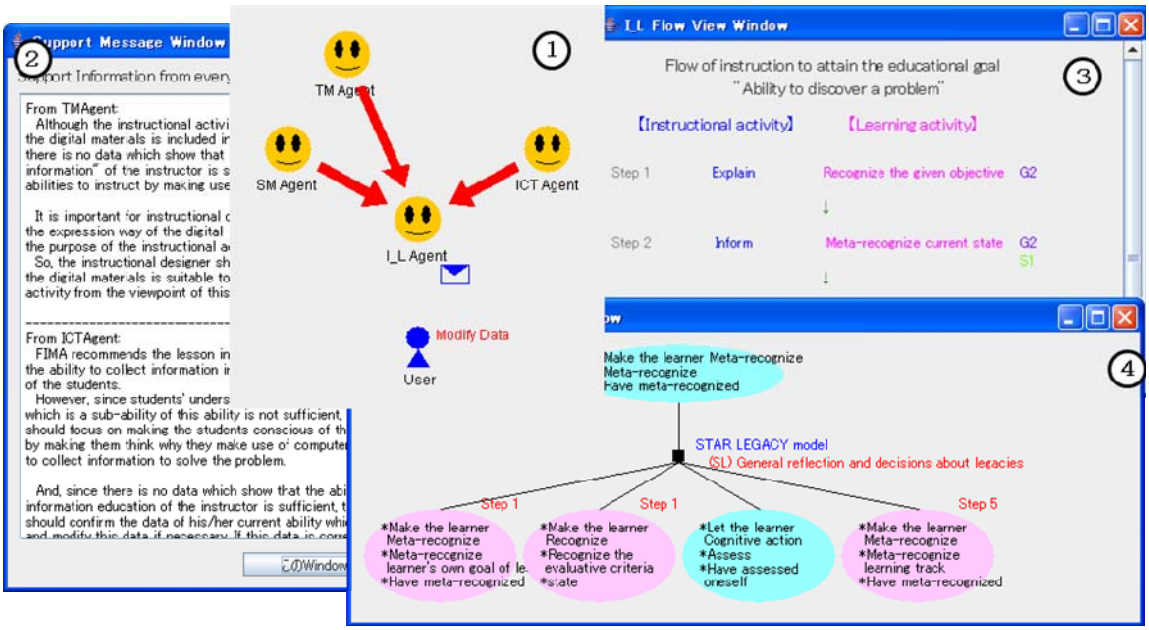

Figure 1. The Example of the Screen Shots for the Diagnostic Support

2. An Example of Using the Support to Diagnose by FIMA

In this section, we show an example of FIMA's diagnostic supports that were provided when the first author of this paper designed an instruction using FIMA. And, we explain interaction between the agents to realize the supports. In this case, we assumed that students were novices at making use of ICT and the teacher was novice at IT education, because one purpose of this study is to support teachers who are not specialists of IT education for the computerization of school education. And we set data of students' learning history and teacher's current ability based on this assumption.

Figure 1 shows an example of screen shots which were presented when the teacher asked FIMA to diagnose from the viewpoint of the flow of the instruction which he had designed to attain the educational goal which is to enhance the "ability to discover a problem". In this example, the I_L Agent serves as the first functional module and provided the teacher with various results of diagnosis and support information by interacting with the ICT Agent, the SM Agent and the TM Agent, shown at ① in Figure 1. The messages from these four agents were shown in the window at ② in Figure 1. For example, the message actually provided by the TM Agent is that "*Although the instructional activity which the instructor makes use of the digital materials is included in the flow of the instruction, there is no data which show that understanding of "knowledge to express information" of the instructor is sufficient which is one of the necessary abilities to instruct by making use of the digital materials suitably. It is important for instructional designers to judge whether the expression way of the digital materials is more suitable to achieve the purpose of the instructional activity. So, the instructional designer should confirm whether or not this use of the digital materials is suitable to achieve the purpose of the instructional activity from the viewpoint of this knowledge*". And, to facilitate "contextualized thinking" of the instructional designer, the I_L Agent presented the flow of the learning and instructional activities designed to achieve the educational goal, shown at ③ in Figure 1. Furthermore, to support to confirm suitability of "contextualized thinking", the I_L Agent translated every instructional and learning activity into concepts defined in the OMNIBUS ontology, and extracted and presented the instructional/learning theories related to this flow of the learning and instructional activities, shown at ④ in Figure 1. Although we cannot describe in detail how to extract the relevant theories due to space limitation, the I_L Agent extracts a set of theories reasoned that it is most related to the flow based on the relationships between

learning and instructional activities in each step and the flow which is composed of the steps. Based on the explanation of these theories, the instructional designers themselves can confirm suitability of the instruction and try to improve it by their "contextualized thinking".

3. Summary

Through the consideration of the thinking of expert teachers, this study aims to support teachers in designing high quality instruction through facilitating the three types of thinking: 1) multiple viewpoints thinking, 2) contextualized thinking, and 3) the problem framing and reframing strategy. For the support, we proposed FIMA which is based on multi-agent architecture in consideration of these support's principles. In this paper, we showed the examples of concrete supports by the prototype FIMA system and the agent-structure to realize these supports.

The prototype system of FIMA has been implemented. The first author could design an instructional plan by getting various supports which included the support examples described in section 2 which were provided by this prototype of FIMA. We could confirm that these supports were suitable to achieve the purpose of this study. However, because various ontologies and knowledge description which are basis of FIMA are not yet sufficient in the current implementation, its functionality is limited. To put it concretely, the concepts of goals and contents of education cover only the field of subjects "science" and "technology" in elementary and secondary education, and the concepts of teacher's ability cover only the ability to instruct IT education and to instruct using ICT. And, because there are some forty knowledge descriptions as yet about suitable relationships between the concepts which the I_L Agent and the ICT Agent have, the supports realized based on these knowledge descriptions are limited. In future work, we intend to extend these description ranges and to deploy FIMA into the practice of designing instruction by teachers.

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