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Long-term Practice of Ontology Based Support System for Organizing Thoughts to Cultivate Intention Sharing Skills

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Abstract: The research objective is to propose a research activity support system for cultivating novice researchers' intention sharing skills. We develop a research activity support system in which researchers focus on organizing the structure of their own thinking processes as a pyramidal structure consists of chains of inquiries and answers. Then, we explain support functions and evaluation results about our system. Based on the practical use, we confirmed that the proposed system contributes to learners' positive changes in consciousness toward intention sharing.

Keywords: Intention sharing skills, structuring inquiries, thought organization support system

1. Introduction

A speaker's skill at accurately recognizing and explicitly sharing his or her own speech intentions (intention sharing skill) is particularly important not only for the simple communication of facts, but also for creative discussions about ideas and concepts (Enrici et al., 2011). Deficiency in this skill can lead to problems such as confusion due to the speaker's intentions being misunderstood, or inability to cover the items that should have been discussed, making it impossible to obtain consent or creative input from other participants in the discussion.

In this study, we focused our attention on the improvement of intention sharing skills at academic research meetings, which is expected to contribute to the development of creative discussions. Academic research meetings often involve discussions of ambiguous and unclear concepts, and the research process is confined within a small group of researchers. In a place aimed at creative discussions, the sharing of thought contexts is essential, and to achieve this, researchers must have not only a comprehensive understanding of their own thought processes but also high-level communication skills to communicate these ideas clearly. Because academic research meetings are continuous and cumulative, it is reasonable to consider them as places where the improvement of intention sharing skills requires the accumulation of long-term training.

To cultivate intention sharing skills in academic research meetings, it is important for learners to organize their thoughts and improve their readiness for meetings. In this study, we focus on internal self-dialogue as an activity that encourages organization of thoughts. Based on this idea, we prepared "inquiries" that stimulate the internal self-dialogue (Ash & Clayton, 2009), and we structured them based on thought processes that are considered to be necessary for learners to organize their thoughts.

2. Approach

2.1 Thought Organization Activities to Improve Intention Sharing Skills

We present an outline of a learning model of intention sharing skills, taking academic research meetings as an opportunity. In this study, we are targeting learners who have just started doing

research. Our proposed model aims to gradually improve their intention sharing skills with reference to the research activity cycle described by Tsuchida et al. (2007). Regarding the contents to be shared in discussions, we perform (1) preliminary thought organization activities to perform deep introspection before academic research meetings (*thought organization*), and then (2) prepare materials for these meetings based on these activities (*thought systematization*). Then, (3) display intention sharing skills in the academic meetings (*spoken intention sharing*) and (4) by performing a high-quality review of content of the discussion, we perform activities to prepare for the next discussion (*thought reconstruction*).

By repeating the above four phases in a series of cycles, this model aims to gradually cultivate intention sharing skills. The research beginners targeted in this study sometimes omit their reasons and objectives, and only reflect the facts and results in the creation of materials at step (2) and in the discussions of phase (3). In this learning model, the learner's own research activities are organized at step (1) before the discussion, and after the academic research meeting, the learner reviews the discussion contents and reorganizes his or her thoughts at step (4). This process is thought to lead to clarification of the learner's intentions, and an explanation of the gist of the research. In other words, as an activity to increase the learner's readiness for academic research meetings at step (1) and (4), we aim to encourage the verbalization of latent thought processes in the learner's research tasks. Inspecting the structure of expressed thoughts makes it easier to perform metacognitive monitoring and control compared with organizing thoughts inside one's head and should make it possible to achieve a logical organization of one's thought structures on the subject of research.

We use the Pyramid Principle (Minto, 2009) as an expression framework for thought organization. This is a structuring principle that is useful for hierarchically organizing thought structures and clarifying the intentions behind thoughts (such as the reasons for thinking this way, the thought processes from which they arose, and so on). Although there are guidelines and exercises for structuring one's thoughts, adapting this knowledge to one's own thought context (research content) is not easy for research beginners. Therefore, by providing "inquiries" as stimuli in line with the learner's thought context, we can implement a mechanism that encourages the verbalization of intentions in a thought organization activity.

2.2 Structuring Inquiries to Promote Verbalization of Intentions

In thought organization based on the Pyramid Principle, "inquiries" are prepared to encourage deep thought through repeated inquiries and answers. To draw out the learner's thought context and adaptively present the inquiries to be considered, the inquiries should preferably not be listed in an ad hoc way but systematically structured based on the generality or uniqueness of the research field. Since the system is able to grasp the correspondence between inquiries, it can dynamically select and present inquiries that are useful for encouraging deep exploration of intentions with regard to thoughts that are expressed linguistically by the learner.

In our study, this is achieved by structuring inquiries from the viewpoint of thought processes based on ontology engineering methods (Mizoguchi & Bourdeau, 2016). In the ontology, the concepts of inquiries are categorized from the viewpoint of thought activities into three main categories: *meta-cognitive activities*, *cognitive activities*, and *actions*. In meta-cognitive activities, concepts are defined with reference to the characteristics of critical thinking advocated by Tanaka & Kusumi (2007). In cognitive activities, concepts that cross over between research fields are defined with reference to the hypothetical thought methods of Uchida (2006), while concepts that are specialized to a particular research domain (the field of intelligent learning support system) are defined with reference to the constituent elements needed for intelligent educational systems presented by referring to Mizoguchi (1995). Concepts related to actions define activities represented as outside actions as a result of the abovementioned cognitive activities.

The concept of meta-cognitive activity is defined in terms such as "thinking about discovered problems as a result of thought process that are worth tackling", and "thinking about other selection criteria". The concept of cognitive activity is defined in terms such as "thinking about research objectives", "thinking about solution methods", and "thinking about practical designs", and the concept of action is defined in terms such as "writing", "reading", and "implement systems".

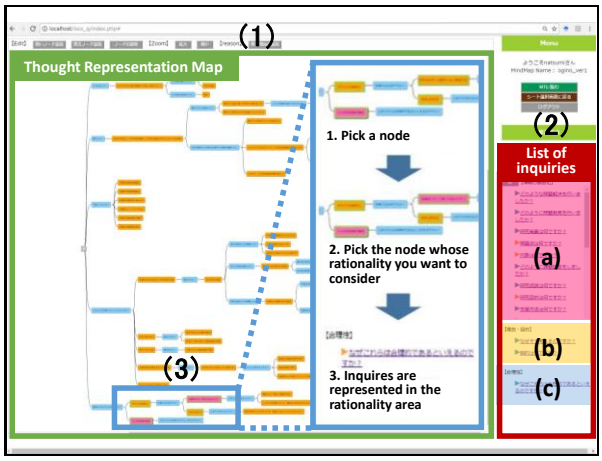

Figure 1. Thought Organization Support System

Each thought activity with inquiry concept specifies its *sub-activities*, *inputs* and *outputs*. A sub-activity is an activity that is necessary in order to achieve an activity. For example, when performing the thought process "thinking about educational practice designs", the sub-activities are defined as "thinking about a purpose of educational practice", "thinking about a hypothesis of educational practice", "thinking about practical procedures", and "thinking about ideal results of educational practice". In addition, the inputs prescribe the concepts necessary for considering a certain thought process, and the outputs prescribe the concepts of the results produced by this thought process. It also specifies concepts defined as objects (results) that are separate from the concept of thought processes (e.g., research objectives, learner models, educational practice designs, etc.). Taking the concept of "thinking about educational practice designs" as an example, the inputs are specified as "research objectives" and "learner models", while the outputs are specified as "educational practice designs".

By building an ontology in this way, it is possible to associate concepts based on sub-activities and input/output attributes. By using this relationship to present adaptive inquiries according to the learner's thought context, it should be possible to make learners aware of the activities that are necessary to clarify their own thoughts.

3. Thought Organization Support System

To increase the learner's readiness for discussions, we developed a thought organization support system that incorporates the structured inquiries (Fig. 1). For this system, assuming that it will be used in the actual context of research activities, we provided an interface (Fig. 1(1)) where inquiries (blue nodes) and their answers (orange nodes) can be represented in a pyramidal chain structure. By adopting this representation form, we aim to gradually change the learner's latent intentions into verbal expressions.

The inquiry-list area (Fig. 1(2)) shows a list of inquiries related to the thought processes that are considered to be necessary when engaged in research. This is implemented by reading a file that specifies the ontology of the inquiries mentioned in Section 2.2. From the displayed inquiries, the learner can freely select those that match his or her thought context and add them to the thought representation map. This is aimed at implementing support that incorporates the learner's thought context by providing the learner with thought organization "training wheels" in the form of inquiry stimuli from the system while respecting the learner's own thoughts. When the learner has selected an inquiry from the list, the system understands the concepts embedded in the thought representation map, so inquiries associated with this concept are presented. In this way, by adaptively presenting inquiries related to the learner's thoughts, we hope to stimulate the activity of the internal self-dialogue and encourage improvement of the quality of thought organization activities. The inquiry list is divided into the following three categories according to when inquiries are presented to learners on the system.

Information expression category (Fig. 1(a)): The inquiries at the base are displayed when building the structure of the entire target research field. For example, the concept "put into educational

practice" of a selected inquiry ("How is it put into educational practice?") is defined with "educational practice design" as the input. Here, inquiries relating to the concept "thinking about educational practice designs" that have "educational practice design" defined as the output (e.g., "What is educational practice design?") are presented to the learner. In this way, we encourage base level thought organization activities by adaptively presenting inquiries according to the learner's thought context.

Reason/purpose category (Fig. 1(b)): As an inquiry to promote the expression of reasons and purposes, two inquiries are displayed relating to reasons ("Why do you think so?") and purposes ("What is the purpose?"). These inquiries are essential for organizing one's thoughts and are set based on the idea that it is necessary to be constantly aware of one's reasons and purposes to clarify one's intention. Regardless of the thought states that appear in the thought representation map created by the learner, we expect meta-cognitive activities are promoted by always displaying these two inquiries.

Rationality category (Fig. 1(c)): Here, inquiries about rationality are displayed based on the ontology. Regarding the learner's thoughts that are turned into verbal expressions in a thought representation map, it is important to examine the links between an inquiry and its answers, and to consider their rationality, such as whether related thoughts give rise to contradictions. Based on these ideas, we implemented a mechanism to make learners think rationality. The procedure is shown in Fig. 1(3). Currently, when multiple sub-activities are defined for a particular concept, their relationships are defined heuristically by considering that it is important to examine rationality in this sub-activity.

4. System Evaluation Experiment

Twelve students (five 4th-year undergraduates, three 1st-year master's students and four 2nd-year master's students) have been using this system continuously from April 2017 to March 2018. In this paper, we investigate whether continuous use of the proposed system can contribute to the desired improvement of intention sharing skills.

4.1 Questionnaire Survey of Thought Organization Support System

It is difficult to establish common evaluation criteria because of the feature whereby intention sharing skills are implicit, and because the opportunities to demonstrate these skills depend on what is discussed at academic research meetings in a laboratory. We therefore conducted a questionnaire survey to measure what sort of change in learner awareness is encouraged as a result of introducing this system from the viewpoint of intention sharing. The questionnaire categories were as follows.

Usefulness of the system: This category checked the effects contributed by this system in each phase of the learning model discussed in Section 2. These effects were evaluated on a five-point scale (5: Very useful, 4: Somewhat useful, 3: Indifferent, 2: Not very useful, 1: Not at all useful), and the reasons for these choices were also solicited (free response).

System function: This category checked whether each function provided by this system is useful for thought organization. The evaluated functions were i) *clarity of inquiries and answers*, ii) *information expression category*, iii) *reason/purpose category*, and iv) *rationality category*.

Critical thinking attitude: Critical thinking is a skill that can be used to examine whether expressed thoughts have a logical structure. We confirmed whether this system's thought organization activities caused a noticeable increase in the awareness of critical thinking. We prepared a questionnaire based on the Japanese version of Critical Thinking Attitude Scale (Hirayama & Kusumi, 2004).

4.2 Evaluation Results and Discussion

Results of Evaluating the Usefulness of the System: Table 1 shows the average score of each phase in the learning model. The system received favorable evaluations in each phase.

Table 1

Evaluation Results Relating to the Usefulness of the System

Phase	Average score (Variance)
A. Thought organization	4.33 (0.24)
B. Systematization of toughts	4.08 (0.27)
C. Spoken intention sharing	3.91 (0.27)
D. Reconstruction of thoughts	4.17 (0.52)

Table 2

Evaluation Results Relating to System Functions

System function	Average score (Variance)
E. Clarity of inquiries and answers	4.50 (0.45)
F. Information expression category	4.08 (0.81)
G. Reason/purpose category	3.92 (0.63)
H. Rationality category	4.08 (0.81)

Thought organization phase (Table 1A): The reasons they gave for these responses included "It's important to express one's thoughts in order to organize the contents of one's research, and this system seems to be suitable for systematically summarizing a project at the level of bullet points", and "I was able to get a comprehensive grasp of the entire research project". These results confirmed that the system encourages learners' thought organization activities.
Thought systematization phase (Table 1B): This suggests that by organizing the contents of research on a thought representation map, the system contributes to the reflection of their research in media conveyed to other people (in materials for academic research meetings, slide shows, and so on).
Intention sharing phase (Table 1C): Their reasons included "It makes it easier to express my own ideas clearly, resulting in smoother communication of ideas", and "It makes it easier to share premises of my own thought process, resulting in deeper discussion of the content". When involved in actual creative arguments, many learners felt that the thought organization activities led to better quality discussions.
Reconstruction of thought phase (Table 1D): Although this system does not have inquiries or supporting functions dedicated to reflection activities, it was judged to be useful for organizing thoughts after discussions. This suggests that learners feel it contributes to their reflection activities by clarifying inquiries in the thought organization phase.

System Function Evaluation Results: Table 2 shows the results of evaluating whether each of this system's functions promotes thought organization activities. The evaluation results and considerations for each function are described below.
Expressing inquiries and answers (Table 2E): Based on a comment that said, "Since the inquires with no answers are expressed as points that have not been considered, it is possible to recognize parts that are not understood, and parts that need to be understood", we found that the clarification of inquiries helps learners to grasp their state of understanding. It can be said that this contributes to an understanding of research structures that is considered to be necessary for the organization of thoughts in this research.
Information expression category (Table 2F): Eight out of twelve learners responded that the inquiries presented in this category were useful for organizing their thoughts. The comments explaining these evaluations included one that said, "The inquiries presented in this category were important for clarifying my own ideas". This suggests that the structured inquiry set is useful for organizing thoughts about research.
Reason/purpose category (Table 2G): Eight out of twelve learners gave helpful responses to this item with comments such as "I felt that thinking was prompted simply by the explicit word 'why'," and "I tend to ignore reasons and purposes, so having to think about this inquiry constantly made me more aware". This suggests that the intended action of the system was function.
Rationality category (Table 2H): Eight out of twelve learners responded that the function for thinking about rationality was useful for organizing their thoughts. On the other hand, most of the learners who answered "3: Indifferent" remarked that the timing of this function made it difficult to use. Based on this response, it is necessary to consider improving the system.

Critical Thinking Attitude Evaluation Results: The learners were asked to evaluate their experiences on 33 items with a 5-point scale (–2: Totally disagree ⇔ 2: Strongly agree). The scores for each item were added together to obtain average scores. We found that all the learners gave

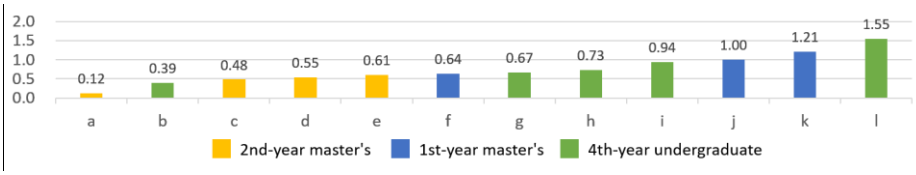

Figure 2. Critical Thinking Attitude Evaluation Results.

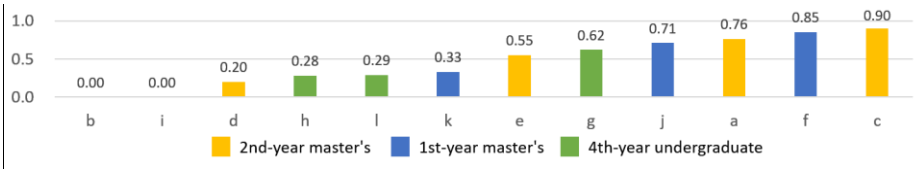

Figure 3. Proportion of Self-made Inquires in Thought Representation Map

positive responses. With regard to their critical thinking attitude, we observed a positive change against the background, so it can be said that this system achieves the intended effect.

Figure 2 shows the scores arranged in ascending order. From the overall viewpoint, it can be seen that the average scores were higher for the 1st-year master's and 4th-year undergraduate students than for the 2nd-year master's students. This suggests that the system achieved the intended effect as a set of training wheels especially for novice researchers.

Also, Fig. 3 shows the ratio of the number of inquiries created by learners themselves (not prepared by the system) to the total number of inquiries expressed on thought representation maps by each learner. From Fig. 3, it can be seen that the learners with more experience (the 1st-year and 2nd-year master's students) tended to use a larger proportion of inquiries prepared by themselves. This result also supports a usefulness of the system as a training wheels for relatively novice researchers derived from Fig. 2.

5. Concluding Remarks

The purpose of this research is to use academic research meetings as an opportunity to improve intention sharing skills. We structured inquiries from the viewpoint of thought activities in research, and we developed an ontology based thought organization support system incorporating these inquiries. We also conducted a long-term evaluation experiment for about one-year. As a result, we were able to confirm that the use of this system brings about a change in the awareness of intention sharing skills.

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