Ontology-based Thought Organization Support System to Prompt Readiness of Intention Sharing and Its Long-term Practice

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(Received 13 June 2018 and accepted in revised form 26 December 2018)

Abstract To achieve fruitful, creative discussions, it is important for speakers to verbalize and share the intentions behind their utterances with their listeners. Our research objective is to propose an activity support system for cultivating novice researchers’ intention sharing skills. We develop a research activity support system in which researchers can focus on organizing the structure of their thought processes in a pyramid made of chains of inquiries and answers. Then, we explain the support functions, evaluate the system, and explain the results. After learners used the system for about one year, we found that they experienced positive changes in their critical thinking and intention sharing skills. In addition, we found indications that the system was especially useful as a set of “training wheels” for relatively novice researchers.

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

1. Introduction

Interpersonal communication involves exchanging spoken words as well as silent information obtained through extrapolation and inference based on nonverbal cues and the listener’s existing knowledge. In this process, the listener’s comprehension of the speaker’s intentions is an essential requirement for supporting smooth communication, because it helps the listener interpret and assign meaning to what is being said(1).

A speaker’s ability to accurately recognize and explicitly share his or her own speech intentions (intention sharing skill) is particularly important not only for simple communications of facts but also for creative discussions about ideas and concepts(2). Deficiency in this skill can lead to problems, such as confusion, misunderstanding the speaker’s intentions, and inability to broach the subjects that should have been discussed, making it impossible to obtain consent or creative input from other participants in the discussion.

To our knowledge, there is no learning support system dedicated to specifically enhancing learners’ “intention sharing” skills by efficiently making usage of such verbal behaviors. On the other hand, in the communication science research field, several studies have stressed the important function played by nonverbal behaviors (e.g., gaze, gesture) in human communication in facilitating common grounding, sharing the speaker’s intention, and indicating the focus of attention(3,4). From this point of view, several learning support systems, which focus on training learners’ nonverbal behaviors while speaking in interpersonal communication, have been found successful in training intention sharing skills of information. For example, Hoque et al. proposed a speaker’s nonverbal communication training system called MACH (My Automated Conversation coach)(5,6). MACH provides feedback about a speaker’s nonverbal behaviors (e.g., head movement, smile intensity, speaking rate and pitch variation) during a simulated job interview with a conversational agent (interviewer). Learners can reflect on their behaviors in the videos and observe variation in their nonverbal behaviors over the course of the interview. Schneider et al. proposed a tool called Presentation Trainer that supports learners with the self-practice of basic nonverbal communication skills for public speaking(7). This tool presents immediate feedback on nonverbal information, such as body posture, gestures, and phonetic pauses, based on the learner’s body and voice information, using a Kinect device. The feedback function is achieved via a wristband type of haptic channel that suppresses the learner’s cognitive load.

In this study, we focused our attention on improving 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 or unclear concepts, and the research process is confined to a small group of researchers. In a situation aimed at creative discussions, the sharing of thought contexts is essential, and to achieve it researchers must have not only a comprehensive understanding of their own thought processes but also high-level communication skills so that they can communicate their ideas clearly. Of course, it is difficult to train intention sharing skills in a direct way because of the implicit nature of thinking. Because academic research meetings are continuous and cumulative, it is reasonable to consider them places where the improvement of intention sharing skills requires the accumulation that comes with long-term training.

In general, people make utterances for a particular purpose. In this study, we use the term “intention” to refer to the structure of the purpose behind a remark. If the speaker’s intentions are communicated to the listener and the content of the listener’s reply satisfies the purpose of the speaker’s remarks, some degree of “intention sharing” has been achieved. However, the evaluation of intention sharing involves the speaker’s intention sharing skills as well as the listener’s comprehension skills. This study is aimed at cultivating intention sharing skills. Specifically, by implementing support focused on improving the quality of the speaker’s intentions rather than the listener’s comprehension ability, we aim to make speakers more keenly aware of the importance of intention sharing to achieving creative discussions, and to be able to evaluate changes in their awareness of intention sharing, such as realizing the importance of clarifying the purpose and structure of what is said.

We feel it is important for researchers (speakers) to organize their thoughts and improve their readiness for academic research meetings. In this study, we focus on internal self-dialogue as an activity that encourages the organization of thoughts. Based on this idea, we prepared “inquiries” that would stimulate internal self-dialogue, and we structured them on the basis of thought processes that are necessary for researchers (hereafter, called “learners”) to organize their thoughts. This paper discusses the functions of the thought organization support system, which we developed based on these inquiries, and our evaluation of this system.

1 This paper is an extended version of the domestic and international conference papers[9–11].

2. Approach

Verbalizing intentions is necessary to enhancing intention sharing, but it is difficult when the intentions are unconscious. Therefore, awareness of one’s intentions is a prerequisite for verbalization. Even when a thought exists in one’s mind, it cannot be observed directly, which makes it difficult to recognize the intention behind it. This is one reason why verbalizing an intention is difficult. Based on the above understanding, we define the “intention sharing skill” as the ability to recognize and verbalize the intention behind a thought created in one’s mind. Then, we try to support the verbalization that enhances intention sharing by encouraging awareness of the intention behind a thought. The system supports learners in partially describing their intentions by providing a scaffolding environment that enhances their awareness of the intentions behind their own thoughts.

2.1 Thought Organization Activities to Improve Intention Sharing Skills

We present an outline for a learning model of intention sharing skills and use academic research meetings as opportunities to apply it (Figure 1). In this study, we target learners who are at the beginning of their research careers. Our proposed model aims to gradually improve their intention sharing skills in accordance with the research activity cycle described by Tsuchida et al.[12]. Regarding the contents to be shared in discussions, we perform (1) preliminary thought organization activities to catalyze deep introspection before academic
research meetings, and then (2) prepare materials for these meetings based on these activities. Then, we (3) display intention sharing skills in the academic meetings and (4) perform a high-quality review of the discussion content and practice for the next discussion. In the following section, we discuss the learning activities involved in each part of this four-phase cycle and provide guidelines for supporting them.

- Thought organization phase (Figure 1(1)): Clarify the learner’s latent thoughts before the discussion, including the selection criteria for decisions made in the course of research and the thought processes leading up to those decisions. Careful examination of one’s internal self-dialogue is essential to ensuring the learner is fully aware of his or her thoughts and can express them as intentions.

Inquiries and answers that emerge from the internal self-dialogue reflect the structure of the targeted research domains. By using the Pyramid Principle\(^{(13)}\) (a thought organization method that takes the listener’s comprehension process into consideration), we promote the expression of latent thoughts and understandings of connections within the structure of research.

- Thought systematization phase (Figure 1(2)): In this phase, discussion objectives, such as acquiring new opinions on unresolved issues and confirming policies, are set, and materials are created on the basis of the thought organization results of phase (1). On the basis of the organized content, the learner can clarify points to be shared with listeners at the next academic research meeting. Then, to ensure the learner can convey the purpose of the discussion to the listeners, he/she should select the content, organize it, and make sure the discussion materials reflect it.

The aim is to improve the learner’s readiness for discussion by examining whether the materials for the listeners reflect the purpose of the discussion and whether the listener can understand the learner’s logical structure.

- Spoken intention sharing phase (Figure 1(3)): In this phase, a discussion occurs at the academic research meeting. The learner works on clearly verbalizing the structure of his or her intentions.

It is desirable that the learner use creative arguments to achieve his or her discussion objectives. Increasing the learner’s discussion readiness should result in better correspondence between listeners’ inquiries and opinions and the learner’s thoughts and intentions.

- Thought reconstruction phase (Figure 1(4)): In this phase, the learner assesses and reviews the opinions and inquiries obtained in phase (3) and incorporates them in his or her internal self-dialogue.

Modifying the thought structure that was expressed before the discussion should lead to changes in the post-discussion thought structure, increasing the learner’s awareness of his or her latent thoughts. This review activity encourages a gradual development, helping the learner to organize the discussion content, based on how the listeners grasped it, so that it reflects those details in subsequent academic research meetings.

By repeating the above 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, only reflecting the facts and results when they create their materials in step (2) and discuss them in step (3). In this model, the learner’s own research activities are organized (Figure 1(1)) before the discussion phase (Figure 1(3)), and after the academic research meeting, the learner reviews the discussion content and reorganizes his or her thoughts (Figure 1(4)). This process should clarify the learner’s intentions and improve the explanation of the research. In other words, in increasing the learner’s readiness for academic research meetings (Figure 1(1) and (4)), we aim to encourage the learner’s verbalization of the latent thought processes behind the learner’s research tasks. Inspecting the structure of expressed thoughts makes it easier to perform metacognitive monitoring and control by comparison with the organization of thoughts inside one’s head. It should make it possible to achieve a logical organization of one’s thought structures on the subject of one’s research\(^{(14)}\)–\(^{(16)}\).

We use the Pyramid Principle\(^{(13)}\) as an expression framework for thought organization. This structuring principle is useful for hierarchically organizing thought structures and clarifying the intentions behind thoughts (such as the reasons for thinking a certain way and the thought processes from which an idea arose). 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 beginning researchers. Therefore, by providing “inquiries,” as stimuli in line with the learner’s thought context, we can implement a mechanism to encourage the verbalization of intention in a thought organization activity.

2.2 Structuring Inquiries to Promote the Verbalization of Intentions

In thought organization, based on the Pyramid Principle, “inquiries” are prepared to encourage deep thought via repeated questions and answers. In an initial experiment, conducted to verify the usefulness of inquiries, we confirmed that inquiries stimulated the learner’s internal self-dialogue activity and contributed to the displaying of intention sharing skills[17].

To draw out the learner’s thought context, inquiries should be adaptively presented. The inquiries to be considered should not be listed in an ad hoc way but systematically structured, based on the generality or uniqueness of the research field. Since the system can grasp the correspondence between inquiries, it can dynamically select and present the ones that best encourage a deep exploration of the intentions behind the thoughts expressed linguistically by the learner.

In our study, this process is achieved by structuring inquiries from the viewpoint of thought processes based on ontology engineering methods[18]. Figure 2 shows a part of a structured ontology. The yellow nodes represent thought activities that comprise the concepts of inquiries (e.g., “thinking about educational practice designs”). Each inquiry is defined as an instance of a
corresponding concept (e.g., “what is educational practice design?”).

In the ontology, the concepts of inquiries are categorized, from the viewpoint of thought activities, into three main groups: metacognitive activities, cognitive activities, and actions. In metacognitive activities, concepts are defined according to the characteristics of critical thinking.

In cognitive activities, concepts that cross over between different research fields are defined with reference to the hypothetical thought methods. Concepts related to actions define activities represented as the outside actions that result from the above-mentioned cognitive activities. For both cognitive activities and actions, concepts that are specialized to a particular research domain (the field of intelligent learning support systems) are defined by the constituent elements of research on intelligent learning support systems. For example, the concepts needed to examine an educational practice are defined as concepts, such as “thinking about educational practice designs,” “thinking about a purpose of educational practice,” “thinking about practical procedures,” and “thinking about ideal results of educational practice” (inside the blue line in Figure 2).

The concept of metacognitive activity is defined such as “thinking about discovered problems as a result of thought processes that are worth tackling,” “thinking about problems I found that can be dropped into a system,” and “thinking about other selection criteria.” The concept of cognitive activity includes such as “thinking about research objectives,” “thinking about solution methods,” and “thinking about practical designs.” The concept of action encompasses such as “writing,” “reading,” and “implementing systems.”

Each thought activity within an inquiry concept specifies its sub-activities, inputs, and outputs. Each sub-activity is necessary for achieving another activity. For example, when performing the thought process, “thinking about educational practice designs,” one must complete the sub-activities, “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 necessary concepts for a certain thought process, and the outputs prescribe the concepts that result from that thought process. Concepts specified as objects (results) are separate from 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” (inside the blue-dotted line in Figure 2).

For example, when an “issue” is defined as the input for “thinking about solving methods” (inside the purple-dotted line in Figure 2), it is possible to search for a concept that has “issue” in the output, and the system can present the learner with the inquiry, “What sorts of issues have been set?,” when he/she starts thinking about solving methods. By expanding the learner’s perspective beyond his or her current thoughts, the system aims to direct the learner’s attention to activities that should be performed beforehand.

Contrary to this time axis, a “solving method” can be defined as the output of, for example, “Thinking about solving methods.” In that case, it would be a mechanism for encouraging activities that look beyond one’s current thinking. It would result in a search for concepts that have “solving methods” as an input and present the learner with the inquiry, “What are the design principles for your system?” By introducing such inquiries, it is possible to encourage learners to coordinate their current efforts with subsequent activities to achieve consistency. By defining sub-activities, it is possible to encourage activities that deepen a learner’s current thinking.

By building an ontology in this way, concepts can be associated based on sub-activities and input/output relations. By using this relationship to present adaptive inquiries, according to the learner’s thought context, learners can be guided to increase their awareness of the activities they need to do to clarify their thoughts. We use inquiries as a form of stimulus, because we aim to encourage learners to extract their own intentions by digging into their thoughts. Applying the Pyramid Principle can give the learner a more comprehensive grasp of his or her thoughts. One can cycle through the system to gradually expand an ontology since the mechanism providing inquiries is generic. That is, the learner can continuously refine the provided inquiries so that they focus
3. Thought Organization Support System

To increase the learner’s readiness for sharing his/her intentions in discussions, we developed a thought organization support system that incorporates the structured inquiries of Section 2.2 (Figure 3). Assuming that the system will be used in the actual context of research activities, we provided an interface (Figure 3(A)) where inquiries (blue nodes) and their answers (orange nodes) can be represented in a chain structure. As a concept of the system usage, each learner tries to verbalize his/her own research project onto one map. This is based on the assumption that grasping the overall relationship of one’s own research project, in phases (1) and (4) in Figure 1, is essential to ensuring that one is fully aware of one’s thoughts and can logically express their relationships as intentions.

A pink node corresponds to the node on which the
learner is currently focused (or clicking). Under the focused node, the learner can add inquiry and answer nodes by clicking on an inquiry from the inquiries list (Figure 3(B)), the “Add self-made inquiry node” button, or the “Add answer node” button. The learner can make an original inquiry by clicking on “add-self-made inquiry node” if there are no inquiries matching his or her thought context among those displayed in the inquiries list.

By adopting this representational form, the system aims to support the gradual conversion of a learner’s latent intentions into verbal expressions.

The inquiries list area (Figure 3(B)) is related to the thought processes that are considered necessary to research. It is implemented by reading a file that describes 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. The aim is to implement a support system that can incorporate and respect a learner’s thought context while also providing him or her with thought organization, like “training wheels,” in the form of inquiry stimuli. After the learner selects an inquiry from the list, the system understands the concepts embedded in the thought representation map, and therefore the inquiries associated with that concept are presented. By adaptively presenting inquiries related to the learner’s thoughts, we hope to stimulate an internal self-dialogue that encourages improvements in the quality of the learner’s thought organization activities.

The inquiry list is divided into three categories (Figure 3(B)-(i), (ii), (iii)) which reflect when an inquiry is presented to the learner in the system. The inquiries classified into each category and the time at which they are presented are shown below.

• Information expression category (Figure 3(B)-(i)): The inquiries from a targeted research field are displayed as forming the base of the structure of an entire research field. For example, if the learner selects the inquiry, “What is educational practice design?” which is an instance of the concept “thinking about educational practice designs” (inside the blue-dotted line in Figure 2), the learner is presented with inquiries related to its sub-activities, inputs, and outputs, such as, “What is the research objective? (input)” and “What is a hypothesis of educational practice? (sub-activity).” We encourage a base level of thought organization activities by adaptively presenting inquiries according to the learner’s thought context.

• Reason/purpose category (Figure 3(B)-(ii)): To promote the expression of reasons and purposes, two inquiries are displayed that relate to reasons (“Why do you think so?”) and purposes (“What is the purpose?”). These inquiries are essential to organizing one’s thoughts and are based on the idea that constant awareness of one’s reasons and purposes is necessary for clarifying one’s intentions. Regardless of the thought states that appear in a learner’s thought representation map, we expect that displaying these two inquiries will promote metacognitive activities.

• Rationality category (Figure 3(B)-(iii)): Here, inquiries about rationality are displayed based on the ontology. After the learner’s thoughts have been turned into verbal expressions, via the thought representation map, it is important to examine the links between the inquiries and their answers and to consider their rationality, such as whether the related thoughts result in contradictions.

Based on these ideas, we implemented a mechanism to make learners think rationally. The detailed procedure is shown in Figure 3(C). For example, when the learner needs to select an answer node for a certain inquiry (e.g., “What is the hypothesis of educational practice?”), possible answer nodes (in this case, the children of the inquiry node, “What is the purpose of educational practice?”) are emphasized with a green outline as concepts for which rationality should be considered (Figure 3(C)-1). Here, the learner can select one of the green-outlined answer nodes by pressing the Shift key to select which rationality he/she wants to consider. Thereby, two pink nodes are selected in the interface (Figure 3(C)-2). Then, an inquiry about rationality (i.e., “Why do you think they are rational?”) appears on the inquiries list area (Figure 3(C)-3). By clicking on this inquiry, the rationality inquiry node is added to the thought representation map, and the user can verbalize the corresponding answer by adding an answer node (Figure 3(C)-4).

It is left up to the learner to decide whether to consider a rationality. The aforementioned function is realized by the systematized rational relationships among the concepts in the ontology. Currently, when multiple sub-activities are defined for a particular concept (e.g., “thinking about educational practice designs”), their relationships are defined by considering the importance
of examining the rationality of these sub-activities (e.g., “thinking about the purpose of educational practice,” “thinking about a hypothesis of educational practice,” and “thinking about procedures involved in educational practice”).

On the basis of this classification, we aim to encourage the clarification of intentions by presenting inquiries that are adapted to the learner’s thought context.

4. System Evaluation Experiment

In the practical experiment, students in the authors’ laboratory (Twelve students: five 4th-year undergraduates (B4), three 1st-year master’s students (M1), and four 2nd-year master’s students (M2)) continuously used this system from April 2017 to March 2018. All of them tackled research subjects related to the research field of intelligent learning support systems. The frequency of the academic research meetings was twice a month, in principle, for each learner.

To count students in our laboratory as fully-fledged experiment subjects and exclude arbitrary interference from us (the authors), detailed system specifications, such as what kind of concepts inquiries were defined as, and experimental conditions, such as analytical methods and their criteria, were discussed separately from students.

We explained how to use the system at the beginning of the practice. We asked the students to create one thought representation map that would represent their own research projects and to make self-made inquiries only when there were no inquiries that matched their thought contexts among those displayed in the inquiries list (Figure 3(B)). In addition, the students were advised only once, at the start of the study, to use the system for every research meeting; they did not receive any coercive instructions to do so.

The fact that this system was in continuous use confirms that it functions within the framework of research activity. In this paper, we investigate whether the continuous use of the proposed system can contribute to the desired improvement in intention sharing skills.

4.1 Questionnaire Survey of Thought Organization Support System

It is difficult to establish common evaluation criteria because intention sharing skills are implicit and opportunities to demonstrate them depend on the discussions at laboratory academic research meetings. Therefore, we conducted a questionnaire survey to measure changes in the learners’ awareness 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 system’s effects on 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). The reasons for the selected choices were also solicited (free response).

• **System function**: This category checked whether each of the system’s functions provided was useful for thought organization. The evaluated functions were as follows:
  - Clarity of inquiries and answers
  - Information expression category
  - Reason/purpose category
  - Rationality category

• **Awareness due to continuous use of the system**: This category asked about changes in awareness when preparing material for research presentations or academic research meetings. Based on free response items in the questionnaire, we confirmed that using this system increased recognition of the importance of intention sharing to creative argumentation and that it raised awareness of the value of clarifying the objective structure behind one’s remarks.

• **Critical thinking attitude**: Critical thinking means deliberating and reflecting on information in order to reach a logical, unbiased conclusion based on evidence; it helps make well-informed decisions about beliefs and actions(22). In the first place, “having awareness to inform listeners of one’s intention” means that one is aware of the need to eliminate discrepancies between oneself and one’s listeners to increase the sharing of intentions and factual contents. From this perspective, it is essential to anticipate and assume listeners’ possible criticisms or divergent opinions, including different standpoints and questions of consistency. Despite the lack of literature directly discussing the relation between intention sharing skills and critical thinking, it is expected that changes in critical thinking awareness could precede or coincide intention sharing awareness. Thus, in this practice, we investigated whether the system’s thought organiza-
tion activities caused a noticeable increase in the learners’ awareness of critical thinking. To measure their thinking skills, we prepared a questionnaire based on the Japanese version of the Critical Thinking Attitude Scale(23).

4.2 Evaluation Results and Discussion

4.2.1 Results of Evaluating the Usefulness of the System

Table 1 shows the average score for each phase in the learning model. The system received favorable evaluations in each phase.

**Thought organization phase (Table 1A):** All twelve learners responded with positive scores (4 or 5 points) for this system’s intended purpose of organizing thoughts in order to share intentions. The reasons given 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):** Out of the twelve learners, eleven responded positively. This suggests that by organizing research content on a thought representation map, the system contributes to reflections on research conveyed in other media to other people (in the materials for academic research meetings, slide shows, and so on).

**Intention sharing phase (Table 1C):** Ten out of twelve learners responded positively. Their reasons included “It makes it easier to express my own ideas clearly, resulting in a smoother communication of ideas,” and “It makes it easier to share the premises of my own thought process, resulting in a deeper discussion of the content.” When involved in actual creative arguments, many learners felt that the thought organization activities led to higher-quality discussions.

**Reconstruction of thought phase (Table 1D):** Ten out of twelve learners responded positively. Although it does not have inquiries or functions dedicated to reflection activities, the system was judged to be useful for organizing thoughts after discussions. The learners’ comments included statements such as “The system can be used to summarize whatever inquiries I received and my answers for them, resulting in increased awareness of which parts need reconstruction, in other words, enhancing metacognition,” which suggests that learners feel the system contributed to their reflection activities by clarifying inquiries in the thought organization phase.

4.2.2 System Function Evaluation Results

Table 2 shows the results of evaluating whether each of this system’s functions promoted thought organization activities. The evaluation results and considerations for each function are described below.

**Expressing inquiries and answers (Table 2E):** We found that clarifying the inquiries helped the learners to grasp their state of understanding. For instance, we received the comment, “Since the parts 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.” The system contributes to an understanding of research structures that can be considered necessary for organizing thoughts on research. The word “inquiry” also appeared in the evaluation of other functions and was associated with positive comments.

**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, “The inquiries presented in this category were important for clarifying my own ideas.” This suggests that the structured inquiry list is useful for organizing thoughts on research.
Reason/purpose category (Table 2G): Since learners always need to be aware of inquiries related to reasons and purposes, there is a mechanism that ensures they are constantly on display. Eight out of twelve learners gave helpful responses to this item with comments, such as “I felt that my thinking was prompted simply by the explicit presence of the word ‘why’” and “I tend to ignore reasons and purposes, so having to constantly think about this inquiry made me more aware.” This suggests that this aspect of the system achieved its intended 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 this part of the system.

4.2.3 Learners’ Description of Their Own Awareness

We administered a questionnaire survey about changes in feelings towards academic research meetings and research presentations before and after using the system. We received comments such as “I am now able to set clear inquiries about research activities, which I previously regarded as vague,” and “I now feel able to attend academic research meetings with a thorough grasp of my own ideas.” These comments show using our system promotes a sense of increased readiness for discussion.

4.2.4 Critical Thinking Attitude Evaluation Results

The learners were asked to evaluate their experiences with 33 items on a 5-point scale (−2: Totally disagree, −1: Somewhat disagree, 0: Neither agree nor disagree, 1, Somewhat agree, 2: Strongly agree). The scores for each item were added together to obtain average scores. We found that all the learners gave positive responses. We observed a positive change in the learners’ critical thinking attitudes, so it can be said that this system achieved the intended effect.

Figure 4 shows the scores, arranged in ascending order. Over all, 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 of providing a set of training wheels for novice researchers.

Also, Figure 5 shows the ratio of inquiries created by learners (not prepared by the system) to the total number of inquiries expressed on thought representation maps by each learner. It appears that the learners with more experience (the 1st-year and 2nd-year master’s students) tended to use a larger proportion of inquiries they had prepared themselves. To statistically examine differences between the three grades (i.e., B4, M1, and M2), we conducted a one-way ANOVA to analyze the ratio of the number of inquiries. The result showed that there were no significant differences among three groups ($F(2,9)=2.756, p=.116$). Then, we analyzed the difference between master’s students and undergraduates (i.e., M1+M2 vs. B4) to confirm the difference of experience with research activities. We conducted an independent $t$-test assuming equal variances since there were no significant differences between the two groups’ standard deviation ($F(4,6)=1.08, p=.49$). The test showed that the ratio of group M1+M2 was significantly higher than that of B4 ($t(10)=2.47, p=.033$). This result also suggests the usefulness of the system as training wheels for relatively novice researchers.

These findings suggest that learners with less research experience have a greater need for training.
wheels to help them organize their thoughts on research activities whereas more experienced students are more reliant on their own internal self-dialogue. Newer researchers, who have just joined a laboratory, can use this system to understand the structure of their research and stimulate their own internal self-dialogue, both of which are necessary for sharing their intentions in academic research meetings.

5. Concluding Remarks

The purpose of this practical research paper was to use academic research meetings as an opportunity to improve intention sharing skills. Based on the proposed learning model of intention sharing skills, we considered the importance of increasing learners’ discussion readiness, and we focused on inquiries that encouraged them to organize their thoughts. We structured inquiries based on the thought activities involved in research, and we developed an ontology-based thought organization support system to incorporate these inquiries. We also conducted a long-term evaluation experiment for about one-year to confirm whether the system helped improve awareness of intention sharing. Through a questionnaire survey, we were able to confirm that using the system increased most learners’ awareness of the importance of intention sharing.

In our evaluation, we did not analyze the behavioral transformation of each learner’s map construction process through the long-term practice. In the current version of the system, learners’ processing information, such as the time it took to add, edit, or delete an inquiry/answer node on the thought representation map, was not saved in the system’s logs. To strengthen the usefulness of our proposed learning model for the future, we need to evaluate the transformation of learners’ maps in detail. We may be able to understand the circumstances (timing and events) that lead to learners to produce self-made inquiries, as discussed in Section 4.2.4. To realize such an analysis, we are currently updating the system’s log saving policies. That way, we will be able to keep records of each learner’s map construction process at every step.

References

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