Kashihara, A. et al. (Eds.) (2024). Proceedings of the 32nd International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

Question Generation Support System Using Others' Research Frames

Daiki Maeda[a*], Kota Kunori[a] & Tomoko Kojiri[b]
[a]*Graduate School of Science and Engineering, Kansai University, Japan*
[b]*Faculty of Engineering Science, Kansai University, Japan*
*k554875@kansai-u.ac.jp

Abstract: Answering questions about our own research helps to clarify our arguments and advance our investigation. To generate questions about one's own research, we must view the research from different perspectives. In this study, we propose a method to view research from an outside perspective. The perspectives of others are reflected in the papers they have written; therefore, we constructed a system that supports researchers in extracting the research elements of other researchers' papers that are not considered in their own research and in capturing those elements in their own research.
Keywords: research activity support, question generation support, research frame

1. Introduction

In the furtherance of their research, researchers proactively pose problems and generate ideas to solve them. To generate ideas that are novel, valid, and reliable, it is important to generate questions about one's own research and consider the answers to those questions (Mori, Hayashi, & Seta, 2016). However, novice researchers, such as students who have just started their research activities, often have difficulty generating questions that lead to the formation of constructive ideas.

Several studies support research activities (Miyadera, Nakamura, Nanashima, & Yokoyama, 2008; Miyamoto, Kunimune, & Niimura, 2015; Ohira, Sugiura, & Nagao, 2016; Kitakoshi, Yanagisawa, & Suzuki, 2017). These studies support task management in research activities and the accumulation of know-how within a research group, but do not directly support the research activities, such as question generation. Instead of generating their own questions, researchers can use questions raised by others at research meetings or academic conferences. Nanjo & Kawahara's study supports the use of questions generated at research meetings or academic conferences (Nanjo & Kawahara, 2004). Their study records the questions asked at meetings and conferences but does not provide support for advancing research using these questions.

Question generation systems for inputted documents have also been developed. Nibras et al. developed a system that automatically generates questions from teaching materials for understanding concepts such as social studies. They proposed a system that applies natural language processing to sentences in teaching materials, extracts important entities such as the names of people, organizations, places, dates, and times, and automatically generates questions whose answers are the entities (Nibras, Mohamed, Arham, Mafaris, & Gamage, 2017). This approach can generate questions when answers exist to the input documents, but cannot generate questions for subjects that do not have answers.

Questions that delve into a claim are different from questions about a problem that has a solution, as long as they can guide the other person's thinking. Inoue et al. proposed a system that prepares in-depth questions in advance, extracts keywords representing claims from user input, and generates questions by fitting the keywords to the questions prepared in advance (Inoue, et al., 2021). Mori et al. proposed an ontology that structures questions from the viewpoint of thinking activities in research activities and proposed a question generation system that uses the ontology to encourage users to explore their verbalized thoughts in depth (Mori, Hayashi, & Seta, 2019). While these studies took the approach of preparing questions in advance, they could only generate prepared questions.

There are also Large Learning Model (LLM) that can generate a variety of questions (Vaswani, et al., 2017). The elements required for research vary according to the type of research (theoretical or practical) and the research domain. Therefore, the questions used to derive the necessary elements of research also vary from research to research. However, LLM do not understand the differences between types of research and research domains and are therefore unable to generate questions about the necessary elements of research. In this study, we aim to develop a system that enables researchers to generate a variety of questions about their own research. Questions arise from differences in perspectives. In other words, questions can be generated for research elements that the researchers did not take into account and such elements might be considered by other researchers. In this research, the elements of research that a researcher considers when he/she conducts research are called the research frame. The research frame is reflected in the researcher's research products, such as papers and presentation materials. Therefore, it is possible to extract the research frames of others by analyzing their research products. This study focuses on papers as research products and proposes a system for researchers that supports question generation about elements of research that have not been considered before by extracting research frames from other researchers' papers and mapping them to the researcher's own research frame.

2. Approach

2.1 Research Frames

A research frame is a framework within which a researcher perceives research. Figure 1 shows an example of a research frame.

Since research is a logical description of the elements that constitute research, there are two types of elements: research elements and logical elements. Research elements have an inclusive relation with other research elements and logical elements, whereby a higher-level element is composed of a lower-level element. In addition, a causal relation exists between elements, indicating that one element is the basis from which the other element is derived. In the example shown in Figure 1, the "Background" consists of the "Subject of research" derived and the "Current situation," and the "Subject of research" is derived from the "Current situation." "Current situation" is explained by "Common sense" and "Citation," where "Citation" is derived from "Common sense."

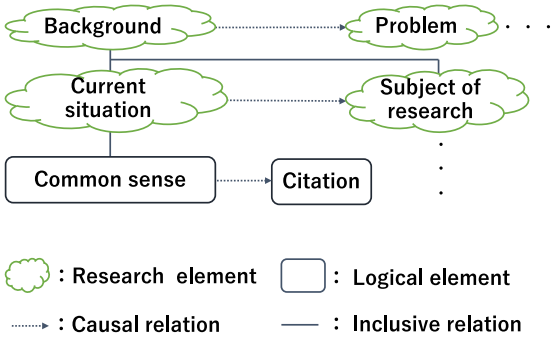

Figure 1. Example of Research Frame

2.2 Research Frames and Question Generation

Figure 2 shows the relation between the research frame and research products. Since the research frame is a framework within which a researcher perceives research, a researcher proceeds with research by deriving specific research elements that constitute the frame. On the other hand, the research products explain the research that has proceeded according to the research frame. The contents of

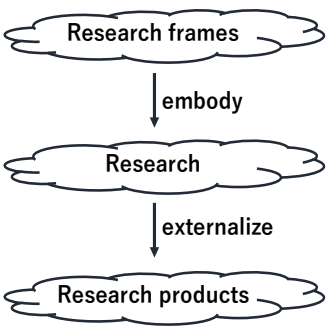

Figure 2. Research Frame and Research Products

research products are the logical elements that explain the research elements.

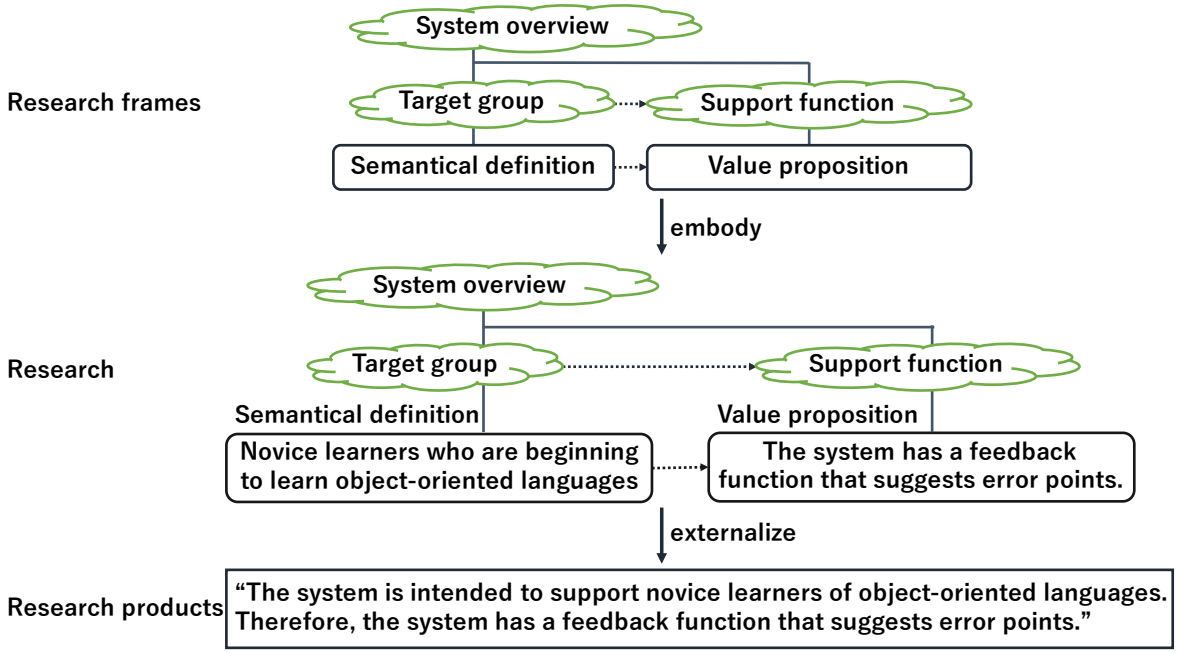

Figure 3. Specific Example of Research Frame and Research Product

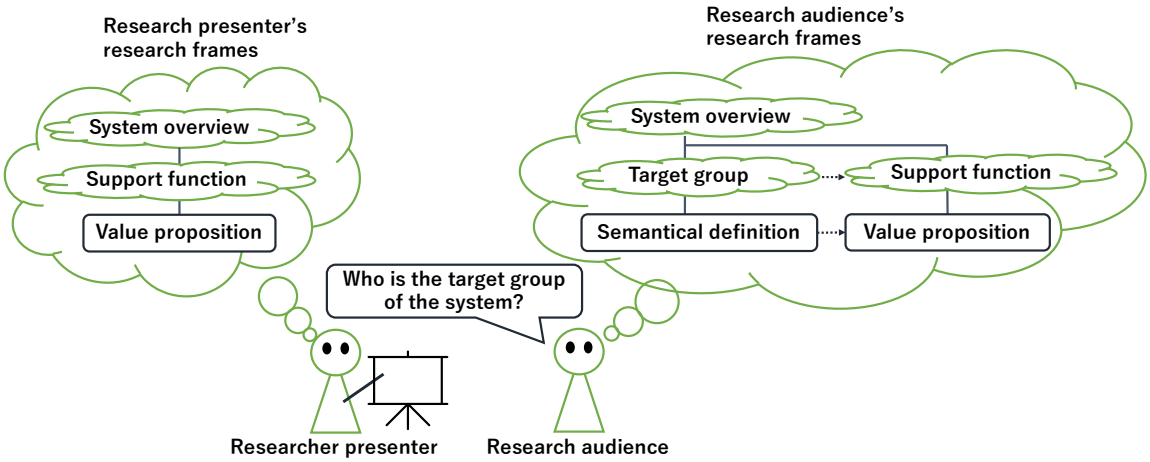

Figure 4. Example of Question Generation in Different Research Frames

Figure 3 shows an example. Suppose a researcher has the research elements “System overview,” “Target group,” and “Support function” in his research frame, and “Target group overview” has “Semantical definition” and “Support function” has “Value propositions” as their logical elements. In addition, there is a causal relation between “Semantic defined” and “Value propositions.” If a researcher tries to develop a system that has a feedback function suggesting error points for novice learners who are beginning to learn object-oriented languages, “Semantic defined” of the “Target group” is “Novice learners who are beginning to learn object-oriented languages” and the “Value proposition” of the “Support function” is “The system has a feedback function that suggests error points.” If the researcher writes his/her system by text, it can be expressed as “The system is intended for novice learners of object-oriented languages. Therefore, the system has a feedback function that suggests error points.”

Researchers’ research frames might differ because what is important in research varies depending on the fields of expertise and previous experience. Since researchers understand other research products based on their own research frames, questions arise from the differences of their research frames. Figure 4 shows an example of question generation between researchers in different research frames. Suppose that a researcher is presenting

his/her research to an audience. The audience has the “Semantic defined" of “Target group" as an inclusive relation of the “System overview” while the presenter does not. The audience will have questions about the “Target group” because it is not defined and might ask "Who is the target group?”

2.3 Approach to Question Generation for One’s Own Research

By extracting research frames from the research products of others and applying one's own research to the extracted research frames, it is possible to generate questions about one's own research. In this study, we target research papers as the research products of other researchers and develop a system that supports question generation about one's own research. The reason for applying the research papers is that they describe research logically and carefully and the research frames are easy to read.

In extracting research frames, if only the upper-level research elements are extracted, such as background and objectives, questions cannot be derived because they are common to almost all research. To be able to generate questions, we must be able to extract even detailed research elements. This study develops a system that extracts research elements that are detailed enough to discriminate the research frames of researchers. In addition, the system splits a research paper into units of topics to which these elements can be assigned so as to support extracting research elements at an appropriate granularity.

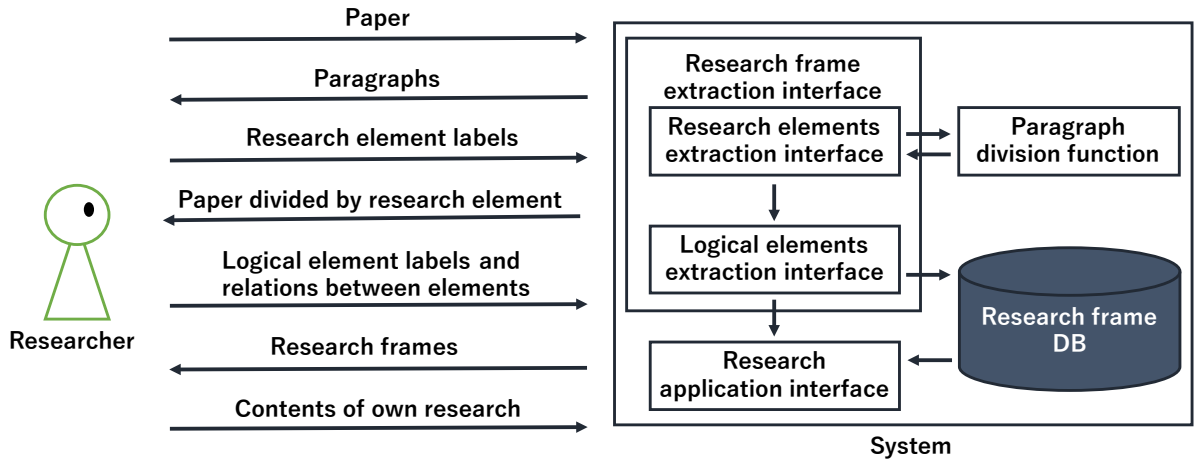

Figure 5. System Configuration

Figure 5 shows the system configuration. The system consists of two interfaces: a research frame extraction interface and a research application interface. The research frame extraction interface extracts the research frame from other papers. It consists of an interface for extracting research elements and an interface for extracting logical elements. The research application interface applies one's own research content to the extracted research frame. The split function splits an input paper into paragraphs that represent topics and sends them to the research elements extraction interface. The research frame database (DB) is used to store the research frames extracted by the researcher. It consists of paragraph sentences with labels of research elements and logical elements.

The system is invoked by the researcher by inputting a paper he/she wishes to analyze. The research elements extraction interface presents the paper split into paragraphs and candidate research elements as research element labels. The researcher assigns the research element labels to the presented paragraphs of the paper. If the paragraph contains several research elements, he/she is able to split the elements into smaller elements. When all research element labels are assigned to all research elements, they are stored in the research frame DB and the logical elements extraction interface is invoked.

The logical elements extraction interface displays sentences for each set of sentences to which research elements are assigned. It also displays their research element labels and

candidate logical element labels. The researcher is able to assign the logical element labels to the sentences. He/she is able to split the presented sentences that correspond to the logical elements, if necessary. The researcher also assigns causal relation links between the logical elements. If there is a causal relation between the lower-level elements, there is also a relation between the higher-level elements. Therefore, when a researcher assigns a causal relation link between logical elements, the system automatically assigns a causal relation link between the parent research elements. After the logical elements and their relations are assigned, they are stored in the research frame DB and the research application interface is invoked.

The research application interface loads the composed research elements and logical elements from the research frame DB and presents them as the research frame of other researchers. By inputting the contents of their own research into the presented research frame of others, researchers can identify research elements and logical elements that they have not thought of before. That is, researchers can fill in the content to the elements that they have considered but cannot fill in content that they have never considered. Considering the content of such elements means answering the questions. The system terminates when the researcher is able to fill in all elements in the research frame of the other researchers.

3. Research Frame Creation Support

3.1 Split Function

The split function divides the input paper into topics and presents them so that the granularity of the research frame extracted by the researcher does not become too large. Topics are often presented as paragraphs of sentences. Therefore, the function splits the paper into paragraphs.

Before splitting the paper, the split function removes the following elements from the paper that do not constitute a topic:

- Sentences written before the title of chapter 1 (such as paper title, author information, abstract, keywords)
- Sentences written after references (such as author introduction)
- Figures, tables, and formulas

Figures, tables, and formulas are research elements, but their contents are often explained in sentences. The function does not address figures, tables, and formulas and provides the sentences instead. After removing them, the function divides the paper by detecting line breaks.

3.2 Research Element Labels and Logical Element Labels

There is a study that analyzes types of objects in research presentation slides to support the creation of research presentation slides (Tanida, Hasegawa, & Kashihara, 2008). This study applies types of objects as research element labels. The defined research element labels are shown in Figure 6. They consist of two levels. There are seven elements in the first level research elements (Research background, Purpose of research, and so on). The second level research elements are included in one of the first level research elements.

The logical element label was defined with reference to the three elements of argumentation (Matsumoto & Kono, 2015). Matsumoto et al. stated, "An argument is an assertion with a basis. There are two types of bases: the reason for the assertion and the evidence as data to substantiate the reason." Since assertions and evidence (reasons and evidence) are necessary for research proposals, we consider that it is constituted by the same elements as an argument. The concrete logical element labels defined are shown in Figure 7. “Semantical definition" is an assertion that defines the meaning of something and a "Factual proposition" is an assertion about a fact that can be defined as true or false. “Value proposition" is an assertion of value that can be described by its validity and appropriateness. In evidence, "Empirical data" refers to data collected by scientific methods such as experiments, observations, surveys, and research, "Citation" refers to quotations from expert works and articles, and "Common sense" refers to common sense and socially accepted ideas.

- Research background
  - Current situation
  - Subject of research (People/Situation/Scope)
  - Problem to be solved
  - Related research
- Purpose of research
- Research approach
  - Key idea
  - How to solve the problem
  - Model to be researched
  - Definition of the concept
- Proposed method
  - Concrete problem
  - Technology/Algorithm
  - System overview
  - Concrete example
  - Development environment
  - System architecture
  - System interface
  - System usage flow
  - Expected effects
- Evaluation experiments Preliminary experiments/Case studies
  - Evaluation item
  - Evaluation target
  - Evaluation method/Conditions
  - Questionnaire item
  - Evaluation results
  - Consideration
- Summary
  - Future work

Figure 6. Research Element Labels

- Assertion
  - Semantical definition
  - Factual proposition
  - Value proposition
- Reason
- Evidence
  - Empirical data
  - Citation
  - Common sense

Figure 7. Logical Element Labels

4. Prototype System

4.1 Research Element Extraction Interface

When the researcher selects a paper to be analyzed on the screen for selecting papers, the research element extraction interface shown in Figure 8 appears. The researcher can select other interfaces in the interface selection area. The research element analysis area displays the papers in paragraphs split by the split function. The list of research element labels that can be assigned is displayed in the list of research element labels. Research element labels are assigned by right-clicking on the paragraph to display the context menu. When "Assigning label" is selected from the context menu, the research element label selection screen is displayed as shown in Figure 9. In this screen, the upper-level labels are displayed and lower-level labels are displayed by clicking the arrow on the right. By selecting the

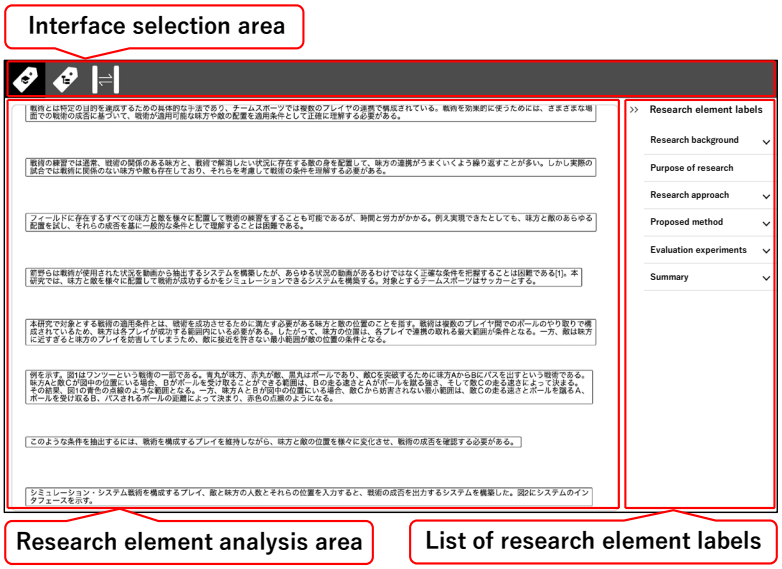

Figure 8. Research Element Extraction Interface

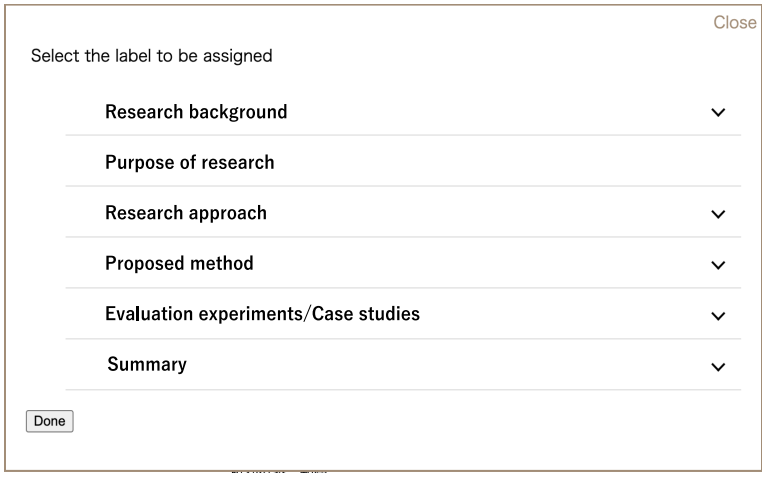

Figure 9. Research Element Label Selection Screen

research element label from the lower layers, the logical element label can be assigned to the element. Research element labels can be deleted by selecting "Delete label" from the context menu of the paragraph to be deleted. Paragraphs are split by selecting "Split Element" from the context menu of the paragraph to be split. The element splitting screen is then displayed and the researcher can split the text before or after the line break by breaking the line at the point where the researcher wants to split the text. The logical element extraction interface is invoked by assigning a research element label to all elements and selecting the logical element extraction interface in the interface selection area. If there is an element for which no research element label has been assigned, an error message will be displayed indicating that "There is an element for which no research element label has been assigned."

4.2 Logical Element Extraction Interface

Figure 10 shows the logical element extraction interface. The logical element analysis area displays sentences in the unit to which a research element label is assigned. The list of logical element labels that can be assigned is displayed in the logical element label list. The logical element labels can be attached and deleted in the same way as the research elements. The logical element labels are given as shown in Figure 11. The sentences can also be split using the same method as the research elements.

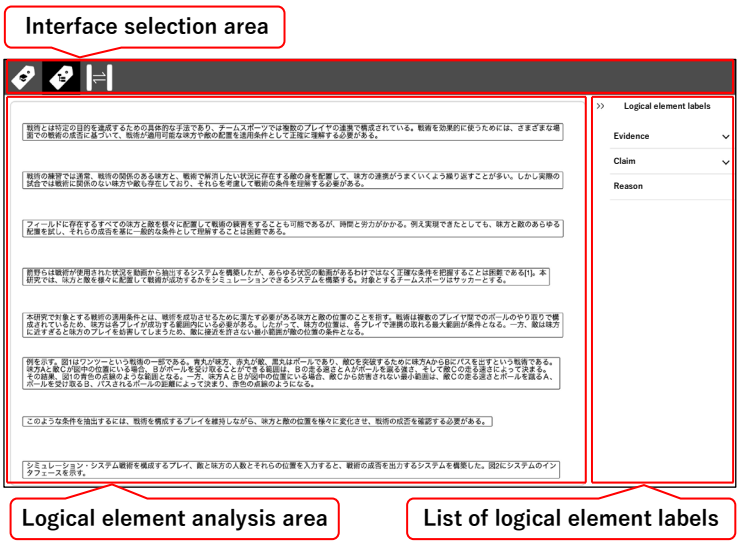

Figure 10. Logical Element Extraction Interface

A causal relation between logical elements can be added by selecting two logical elements to which the relation is added and selecting "Add link" from the context menu. To delete a relation between logical elements, the researcher can right-click on the link to be deleted and select "Delete link" from the context menu that is displayed. Selecting the research application interface in the interface selection area invokes the research application interface. If there is an element for which no logical element label is

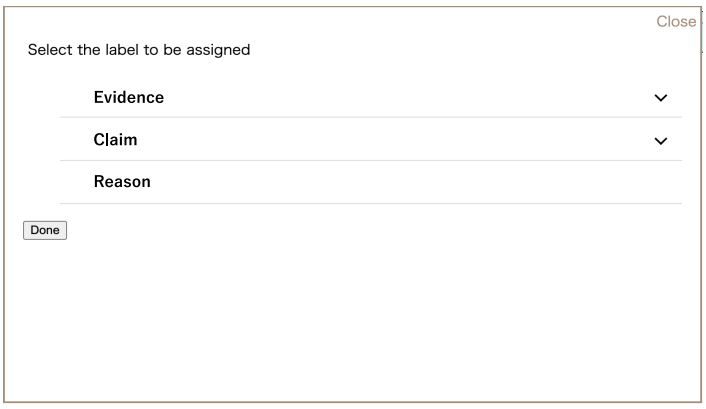

Figure 11. Logical Element Label Selection Screen

assigned, the system displays an error message stating, "There is an element for which no logical element label is assigned."

4.3 Research Application Interface

Figure 12 shows the research application interface. The research application area displays the research frames of other researchers created by the research element extraction interface and the logical element extraction interface. The research element input area is an area for inputting a researcher's own research. By clicking on the element to be input, the research element input area becomes available for input and the researcher inputs the contents of his/her own research to the corresponding research elements. At this time, inputting the elements that have not been considered by the researcher before is regarded as answering a question. The system ends when all the elements are filled in.

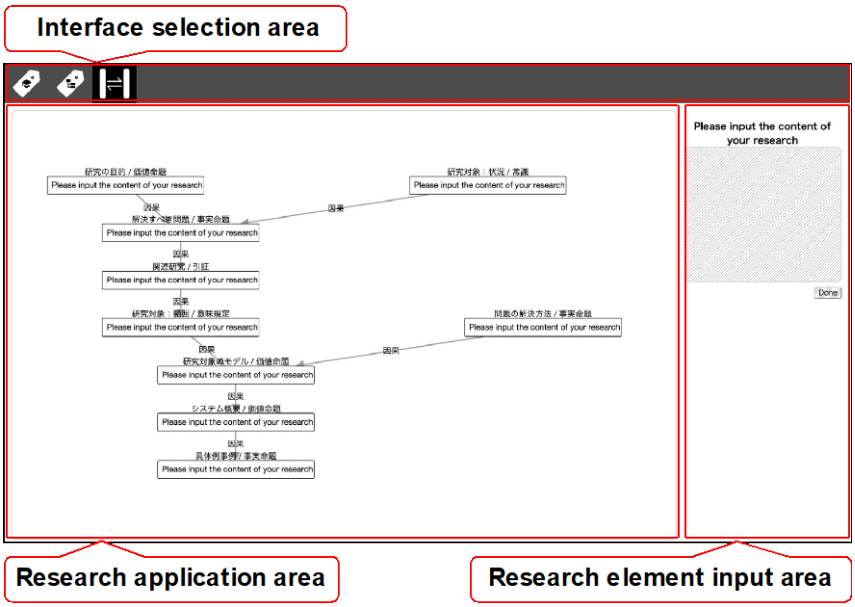

Figure 12. Research Application Interface

5. Case Study

5.1 Overview

We conducted a case study to evaluate whether researchers can advance their research using the prototype system. Collaborators in the case study were eight undergraduate and graduate students who belong to the same laboratory as the authors (who research learning/education support systems) and were novice researchers involved in the research group for one to three years. In our laboratory, the research contents are organized in a concept map, so this case study utilizes these content maps to understand the contents of their research.

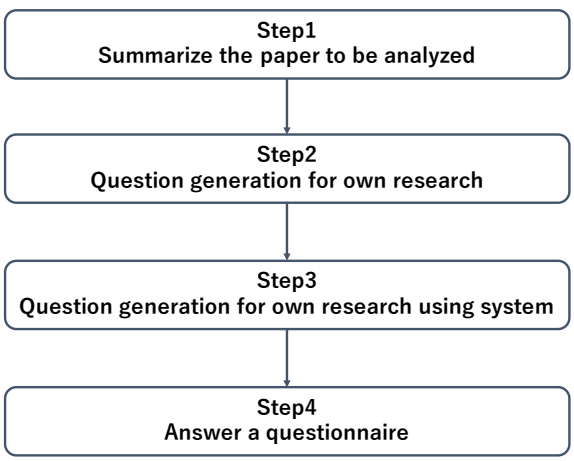

Figure 13. Case Study Procedures

The procedure is shown in Figure 13. To eliminate the step of finding other researchers' papers, we provided the collaborators with a paper to be analyzed and asked them to summarize it. The paper used in this case study was a six-page paper published for a research meeting in the learning/education support system field. This paper describes the learning support system for estimating

background knowledge of a communication target and its evaluation results (Step 1). Next, the collaborators were asked to generate questions about their research written as a concept map and to supply answers to those questions on the concept map (Step 2). They were then asked to generate questions using the prototype system and to answer the questions generated by the system (Step 3). At the end of the session, they were asked to answer a questionnaire (Step 4). The questionnaire asked, "Were you able to derive elements you should consider by using the system?"

5.2 Results

Table 1 shows the number of collaborators who were able to derive new elements by using the system. Table 2 shows the results of the questionnaire.

Table 1 shows that all the collaborators were able to derive new elements using the system. Table 2 shows that all collaborators thought they were able to derive the elements to be considered by using the system. Collaborator A responded, "(When using the system) I could not fill in some elements such as citations and related studies, so I realized that I need to increase the number of references to continue with my own research in the future." Collaborator D noted, "When I found elements that were in the research frames of others but not in my own research, I realized that, if they are important, they should not be missing." These results suggest that the system is effective in generating questions about one's own research and in supporting the furtherance of such research.

Table 1. Results of Using the System

	Yes	No
The number of collaborators who were able to derive new elements by using the system	8	0

Table 2. Questionnaire Results

Questionnaire	Yes	No
Were you able to derive elements you should consider by using the system?	8	0

6. Summary

In this paper, we developed a system to support the activities of novice researchers and advance their research by generating questions about their research. The system is based on the assumption that questions are derived from the differences in research frames between the researcher and other researchers. The system has an interface for extracting the research frames of others from their papers and an interface that enables the researcher to identify research elements that have not been considered before as questions by applying the researcher's own research contents to the research frames. To extract research frames with a granularity that enables the generation of questions, we defined the elements of a research frame in advance and developed a function that splits and displays sentences in units corresponding to these elements.

This study is based on the assumption that considering elements that are in the research frames of others but not in one's own research frame will support the progress of the research. However, focus points in research differ according to research expertise and background, and considering elements that researchers in other fields are focusing on may not necessarily deepen one's own research. For example, for researchers in the field of engineering who aim to devise new technologies for supporting activities, a detailed analysis of the cognitive situation of the people who are involved in the activities is not likely to lead to the development of the technology itself. To effectively further the research, it is desirable to select the research elements and logical elements of other researchers that are related to the individual researcher's research frame. To do so, the researcher must understand his/her own research frame and consider the meaning of the corresponding elements in that research

frame. In the future, we would like to support the selection of elements that should be considered and those that should not by introducing a phase in which researchers recognize their own research frames and consider the importance of other researcher's elements in their own research frame.

References

Inoue, K., Hara, K., Lala, D., Nakamura, S., Takanashi, K., & Kawahara, T. (2021). A Job Interview Dialogue System with Autonomous Android ERICA. *In Increasing Naturalness and Flexibility in Spoken Dialogue Interaction: 10th International Workshop on Spoken Dialogue Systems*, 291-297.

Kitakoshi, D., Yanagisawa, K., & Suzuki, M. (2017). Empirical Study of Student Evaluations of Research Activity Support System for Higher Education Students in Various Fields. *In 2017 Conference on Technologies and Applications of Artificial Intelligence (TAAI)*, 112-117. IEEE.

Matsumoto, S., & Kono, T. (2015). Daigakusei notameno 「Yomu・Kaku・Present・Debate」 no Houhou (How to Read, Write, Present, and Debate for College Students). Tamagawadaigaku Syuppanbu. (in Japanese)

Miyadera, Y., Nakamura, S., Nanashima, T., & Yokoyama, S. (2008). LabChart: A Support System for Collaborative Research Activities in University Laboratories and Its Practical Evaluations. *In 2008 12th International Conference Information Visualisation*, 169-178. IEEE.

Miyamoto, K., Kunimune, H., & Niimura, M. (2015). Proposal of a Supporting System for Planning, Executing and Reflecting Tasks in Research Activities. *Procedia Computer Science, 60*, 1414-1422.

Mori, N., Hayashi, Y., & Seta, K. (2016). Organizing Inquiries Prompting Learners' Readiness towards. *Institute of Electronics, Information and Communication Engineers(IEICE), 116*(314), 11-16. (in Japanese)

Mori, N., Hayashi, Y., & Seta, K. (2019). Ontology-based Thought Organization Support System to Prompt Readiness of Intention Sharing and Its Long-term Practice. *The Journal of Information and Systems in Education, 18*(1), 27-39.

Nanjo, H., & Kawahara, T. (2004). Language Model and Speaking Rate Adaptation for Spontaneous Presentation Speech Recognition. *IEEE Transactions on Speech and Audio Processing, 12*(4), 391-400.

Nibras, A., Mohamed, M., Arham, I., Mafaris, A., & Gamage, M. (2017). Automatic Question and Answer Generation from Course Materials. *International Journal of Scientific and Research Publications, 7*(11), 224-231.

Ohira, S., Sugiura, S., & Nagao, K. (2016). Gamifying Research Activity Support System. *Proceedings of the Fourth International Conference on Technological Ecosystems for Enhancing Multiculturality*, 739-745.

Tanida, A., Hasegawa, S., & Kashihara, A. (2008). Web 2.0 Services for Presentation Planning and Presentation Reflection. *Proc. of the 16th International Conference on Computers in Education(ICCE2008)*, 565-572.

Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., & Kaiser, Ł. (2017). *Attention Is All You Need. arXiv preprint arXiv:1706.03762.*, 1-11.