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Forest/CR: Critical Paper Reading Support System

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Abstract: This study presents the development and evaluation of a critical paper reading support system named “Forest/CR.” The system aims to enhance learners' critical reading skills by facilitating the formation of reading strategies. It achieves this by recognizing questions that learners were unable to generate independently and by allowing them to compare their interpretations with those of others. The system features functions such as paper content organization, comparison of reading content, and comprehensive evaluation support. An experimental study involving third-year undergraduate students demonstrated that the system effectively broadened students' reading activities, promoted the generation of critical questions, and supported the learning of new reading strategies.

Keywords: Critical Paper Reading, Research Activity Ontology, Reading Strategy

1. Introduction

The type of reading and writing that involves understanding advanced texts, critically examining them, and writing papers is referred to as “high-level literacy.” In recent years, the necessity of fostering this skill in secondary and higher education has been highlighted (Langer, J. A., 2001). Especially, critical reading skills, which involve examining text content from multiple perspectives without taking it at face value, play a crucial role in progressing through academic papers. To develop these skills, it is essential to understand the writer’s thoughts in a way that allows the reader to follow their own thoughts and form their own ideas after thoroughly examining them (Norris & Phillips, 2013). On the other hand, in reading academic articles that require a high level of specialized knowledge to understand, it is not easy for novice learners to critically refine the ideas of both the author and themselves from multiple perspectives while being aware of academic perspectives specific to the field, and an analytical framework to support such learning is not clear (Zheng et al., 2018).

When reading academic papers that require advanced specialized knowledge for understanding, such as those in the field of learning support systems, it is beneficial to adopt strategies for generating domain-specific questions that deepen understanding for critical reading. For example, to better understand a paper in this field, one should read with questions such as “What are the learning difficulties faced by learners in achieving their learning goals, and what is the rationale for the proposed learning support methods to alleviate these difficulties?” It is desirable to employ these reading strategies during reading, posing questions like “What methods are considered in this paper?” and “Are those methods valid?” while interpreting the author’s thoughts independently. Moreover, it is not enough to merely read sequentially; one should also review the strengths and weaknesses of the paper from a comprehensive and overarching perspective and provide an overall evaluation of the paper.

However, for novice researchers who do not have sufficient reading strategies, it is challenging to generate questions from multiple perspectives with an awareness of domain-specific academic viewpoints, and it is difficult to summarize their reading content from a comprehensive and overarching perspective to evaluate the paper as a whole. Therefore, this study proposes a critical paper reading support system that aims to reduce these difficulties.

2. Research Objectives

Okouchi (2003) identifies three aspects of critical reading activities. The first aspect is “monitoring one’s understanding,” which involves critically examining whether one correctly understands the author’s claims. The second aspect is “evaluating the author’s logic,” which involves critically assessing the logical consistency of the author’s arguments. The third aspect is a productive one that involves “deepening one’s thoughts” by considering new problems and alternative solutions based on the understood author’s logic. In academic papers focusing on learning support research, the second aspect of “evaluating the author’s logic” corresponds to activities such as assessing the validity and rationality of the support content embedded in the system described in the paper, based on the author’s views on the learning difficulties faced by learners in achieving their learning goals. The third aspect of “deepening one’s thoughts” involves critically examining the support methods proposed by the author for learning difficulties and considering alternative support methods, thereby engaging in a productive activity that deepens one’s own thoughts.

Several systems have been developed to support the improvement of critical reading skills, and all of them are general-purpose frameworks: To the authors’ knowledge there is no system that follows the learners’ thinking and the process of reading articles at the content level and provides feedback that captures the semantic connections specific to the domain. Therefore, based on the above three aspects, we have proposed a critical paper reading support system aimed at clarifying the content of self-dialogue where the reader confronts the claims of the author in an academic paper with their own thoughts (Nishida et al., 2023). The system utilizes a research activity ontology systematically defined based on the ontology engineering method (Mizoguchi, 2003) and includes a feature that prompts learners with adaptive questions during paper reading. The key feature of this system is that it supports the formation of the learner’s own thoughts in response to the author’s problem-setting and encourages the reader to confront the author’s ideas.

Considering the three aspects of critical reading mentioned earlier, asking questions while reading and critically assessing the logical consistency of the text are elements that influence the understanding process. For example, in learning support research, the understanding process differs between readers who recognize the importance of questioning learning difficulties and novelty when reading about support methods and those who do not. Therefore, our study defines the reading strategies aimed at in this research as “strategies for generating domain-specific questions to deepen the understanding of papers.”

While many studies focus on general and generic reading strategy instruction, there are few studies that focus on the generation strategies of domain-specific questions, as addressed in this research. The formation methods for such strategies are not well-established. Thus, attempting to form these strategies within the context of specific critical paper reading, as described earlier, is a novel aspect of this study.

3. Forest/CR: Critical Paper Reading Support System

3.1 Functional Requirements

In teaching reading strategies, it is effective to explicitly instruct the combination of strategies suitable for the reading purpose and context and to guide their appropriate use. It is also recommended that strategy instruction be implemented in meaningful reading contexts. Therefore, this study considers it effective to practically construct reading strategies while reading actual academic papers.

However, as mentioned in Section 1, it is challenging for novice researchers to critically read papers with an awareness of domain-specific academic perspectives, to generate questions from multiple viewpoints, and to form reading strategies from that process. Hence, this study aims to (1) provide stimuli to raise awareness of questions that learners could not generate on their own, thereby deepening their reading and promoting the formation of reading

strategies, and (2) promote learning of critical perspectives in papers through activities that involve providing overall evaluations of the read papers.

To achieve (1), we conceived that it is beneficial for learners to critically read papers and become aware of the questions they could not generate. Additionally, comparing their interpretations with those of others who have different interpretations of the same paper can help infer strategies for generating questions. To realize this, the following two requirements must be met. First, learners need a learning environment that enables them to critically read and understand the questions they could not generate (R1). Second, for learners to recognize the differences in reading activities between themselves and others and refine their reading by incorporating others' interpretations, it is necessary to compare these differences in a well-organized manner. Additionally, to infer the cognitive processes applicable when reading other texts, it is desirable for learners to analyze why they incorporated certain reading contents. Here, it is crucial that learners reflect not only on the specific content they could not generate but also on the entire paper (R2).

To achieve (2), it is desirable for learners to be in a state of sufficient understanding when providing overall evaluations. Additionally, for learners to evaluate from a comprehensive and overarching perspective, they need to consider various viewpoints and the academic value of the paper. Learners also need to be able to provide overall evaluations while cross-referencing their reading content and perspectives in an organized manner (R3).

3.2 Approach to Realizing Functional Requirements

The authors have proposed a system to promote critical paper reading by structuring and organizing the questions generated by the reader and their corresponding answers (interpretations) in relation to specific sections of the paper that serve as the basis for those interpretations (Nishida et al., 2023). Specifically, this system provides a tree-structured environment for organizing the intentions behind the thought processes related to the paper content (questions/interpretations/criticisms) using research activity ontology as a scaffold for domain-specific reading perspectives. The nodes on this tree are linked to the content (text) of the paper, making it possible to organize them systematically.

The research activity ontology used here includes concept definitions that are machine-readable, based on the specific and general characteristics of the research domain in the field of educational systems informatics. Based on this, the system can identify questions that learners should consider but may not have considered, indicating possible gaps in their thinking. Additionally, the research activity ontology defines the rationality between pairs of questions, enabling the system to dynamically question the rationality of connections between nodes that represent the author's claims as mapped by the learner. For instance, if the learner organizes the author's ideas around the questions "What are the support methods?" and "What are the learning objectives?", the system can highlight these and recommend examining the rationality between them with a question like "Is there a rational link between these?" This approach encourages activities that critically interpret the author's ideas from a domain-specific perspective (fulfilling R1).

By allowing learners to contrast their own "questions" and corresponding "interpretations" with those of others within the system as a chain structure of questions and answers, differences in understanding are made explicit (Nishibayashi, 1995). Therefore, this study aims to stimulate deeper comprehension from three perspectives:

(1) **Examination of un-asked questions:** The system visualizes questions posed by others that the learner did not consider. If learners believe these questions can deepen their understanding, they can incorporate them into their own reading map. This transition aims to move learners from a state of perceived sufficient comprehension to a more refined understanding.

(2) **Examination of own interpretations**: The system visualizes the interpretations of others who have asked the same questions as the learner. If the learner finds these alternative interpretations enriching, they can incorporate them into their own reading map. By

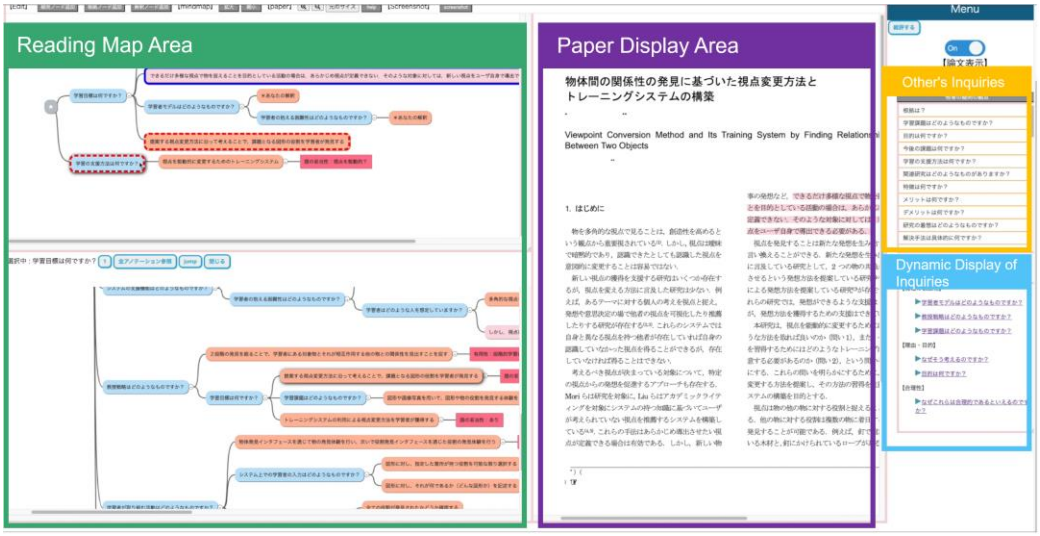

Figure 1. Screen shot of Forest/CR.

presenting different interpretations as stimuli, the system helps learners become aware of these differences, aiming for a more refined understanding. This process encourages learners to reflect on “why they did not arrive at such an interpretation” and “how they can think differently,” thereby fostering the learning of reading strategies (fulfilling R2).

(3) **Examination from a comprehensive and overarching perspective**: Drawing from the paper review perspectives specified by Japanese Society of Information and Systems in Education (JSiSE), the system provides viewpoints such as research questions, novelty, reliability, and usefulness. It allows for cross-referencing these perspectives with nodes on the learner’s reading map, encouraging a comprehensive evaluation that organizes the learner’s thoughts on the strengths and weaknesses from each perspective (fulfilling R3).

4. Development of Critical Paper Reading Support System

Figure 1 illustrates the system, named Forest/CR, developed based on the design principles. The system includes the following features:

(1) **Paper content organization support function:** This function helps users organize their thoughts, including their own questions, corresponding interpretations, and the evidence for these interpretations.

(2) **Comparison function:** This feature allows users to compare their organized reading content with others from two perspectives: questions and interpretations. This comparison aims to highlight differences in understanding and interpretation.

(3) **Comprehensive evaluation support function:** This function provides perspectives to consider when thinking about the overall evaluation of the paper, such as research questions, novelty, reliability, and usefulness. It also includes a cross-referencing feature between these perspectives and the nodes on the reading map, aiding in the organization of thoughts for a comprehensive evaluation.

Our system includes several features to assist in organizing and refining the comprehension of academic papers. As shown in Figure 1, it helps users organize their thoughts, such as their own questions, interpretations, and the supporting evidence, through a paper content organization support function. It also allows users to refine their organized comprehension by comparing it based on the two perspectives of questions and interpretations. Additionally, the system provides functions for reflecting on questions and interpretations adopted from others and offers perspectives for considering overall evaluations and inter-references between perspective nodes.

Learners can upload PDF-format papers They engage with the content displayed in the paper viewing area, referencing domain-specific questions listed to deepen their comprehension (e.g., “What are the difficulties in achieving learning goals?”). Learners create light blue question nodes representing what they wondered about and orange interpretation

nodes representing their understanding of the author's thoughts (e.g., "Learners should actively engage in learning"), organizing them in a tree format. They also mark the parts of the paper that support their questions and interpretations, creating pink evidence nodes linked to the interpretation nodes.

The system prompts learners to critically analyze their Interpretations. When learners add question nodes they deem important to the thought organization area, an orange "interpretation node" labeled "Your Interpretation" is automatically added. After responding to this interpretation node, a red "critique node" for recording criticisms of their interpretation is also automatically added. This critique node is tagged with pre-defined, hierarchical critique perspectives (e.g., value judgments, issues, opinions). This activity aims to deepen learners' understanding by systematically presenting nodes in the order of "question" → "interpretation" → "critique," and representing the reading process in a tree format.

The system also has a cross-referencing function between nodes and the paper text. Nodes and their referenced texts are highlighted in the same color. Because the system maps where different learners read and their thoughts, learners can review and organize their thoughts during reading, and compare their annotations and maps with those of others who read the same paper.

Learners can review questions listed in the "Others' Questions List," identify those they did not think of, and incorporate them into their maps if they find them useful for deepening their comprehension. They can also examine others' interpretations and add necessary insights to their maps. The system prompts learners to consider the strategies behind the questions posed by others, such as "Is there a clear reason for using the system?" This encourages the formation of critical reading strategies, such as understanding that the use of a system should be critically evaluated for its advantages and disadvantages.

Finally, learners input their overall evaluation of the paper in the Overall Evaluation Area (Table 1 will illustrate evaluation results input by a learner). The system guides them to consider the perspectives of novelty, usefulness, and reliability when writing their evaluations.

5. Initial Evaluation

We conducted an initial evaluation experiment using the system with five third-year undergraduate students who had only been assigned to the lab for four months. These students were inexperienced both in knowledge and research experience related to learning support research. They used the system to read a six-page paper published in an academic journal on learning support systems. The results of each phase are summarized below:

Phase 1 (Reading Map Organization): During the first phase, which spanned five days, the students used the system to read the paper and create comprehension maps. The average number of nodes created by the five students was 134.6, of which 47 were question nodes. Of these question nodes, 81% were provided by the system, and 19% were generated by the students themselves. According to the student survey, all five students reported that the system-provided questions expanded their reading activities. These results suggest that the system encourages students to ask more questions and promotes critical reading compared to when students read papers on their own.

Phase 2 (Comparison with Others' Reading): The average number of nodes increased to 168.8, approximately 30 more than in Phase 1, indicating that the system effectively broadened the students' comprehension. The average number of question nodes increased by 9.8, with nearly all being questions incorporated from others. This suggests that students were advancing their reading by answering these new questions. Excluding one student who encountered a system error that impeded the strategy learning mechanism, it was found that 69% of the 80 question and interpretation nodes adopted from others were answered by the students themselves.

Phase 3 (Overall Evaluation): In the third phase, students provided an overall evaluation and reflection on their practice. They wrote their evaluations based on the review criteria used in

Table 1. Critical Reading Results of a 3rd grade Bachelor Student (Overall Review)

	RQ	
What is the RQ of this research?	Viewing objects from multiple perspectives is valued from a creativity standpoint, but to recognize inherently ambiguous and implicit perspectives and intentionally change them, what methods should be learned, and how should opportunities for learning these methods be provided?	
	Strengths	**Weaknesses**
What are the strengths and weaknesses of this research from the perspective of novelty?	By focusing on support for acquiring methods to change perspectives rather than traditional support for acquiring fixed perspectives, we are designing a system that promotes the derivation of more diverse perspectives.	There are existing studies on support for acquiring individual perspectives, and applying these findings could make it sufficiently possible to construct multiple perspectives.
What are the strengths and weaknesses of this research from the perspective of usefulness?	The unique system interface that allows for the discovery of objects and their roles has been found to be effective in learning methods for changing perspectives through experimental application.	If the objects and the roles between objects presented as learning tasks in the system are not pre-set in a diverse and complex manner, the discovery experiences provided by the system will be insufficient, and it will not be able to significantly support learners in changing perspectives or learning methods for doing so.
What are the strengths and weaknesses of this research from the perspective of reliability?	This research presents a number of prior studies related to methods for acquiring perspectives, and the insights derived from these studies are logically consistent. The reliability of the proposed system is demonstrated through detailed data analysis in the practical results.	The theory is based on the premise that discovering perspectives involves generating new ideas and identifying the roles of objects in relation to other objects. However, this premise is defined with weak explanations and evidence, focusing narrowly on creativity and lacking general applicability, which undermines its reliability.
	Overall Review	
In addition to the RQ, please provide an overall review of this paper considering the strengths and weaknesses from the perspectives mentioned above.	To support the construction of multiple perspectives, the system aims to help learners acquire skills for changing perspectives rather than just providing opportunities to acquire them. The system has proven effective in achieving this goal. It also identifies challenges regarding the limitations of the support the system can provide, making it worthy of evaluation in terms of novelty and usefulness. However, it tends to overlook the possibility that repeated simple perspective derivation experiences can sufficiently foster the formation of multiple perspectives. Additionally, the theory was constructed with weak connections between important terms such as the discovery of perspectives, generation of ideas, and the discovery of objects and roles, treating them as equivalent without strong linkage. These remaining preconceptions about novelty and some insufficient explanations (or logical leaps) regarding reliability cannot be overlooked. Therefore, while the research is valuable and supported by ideal practical results, the paper itself lacks refinement.	

academic journals in Japan, as shown in Table 1. It is noteworthy that novice students with limited knowledge of educational systems and informatics could write such comprehensive evaluations. Additionally, when asked if they felt they had learned the strategies on a 5-point scale, the average score was 4.6, indicating a strong sense of having learned the strategies. This suggests that using the system helps novice researchers, who might otherwise focus solely on understanding paper content, to become aware of meta-level learning.

6. Concluding Remarks

In this study, we developed and evaluated the effectiveness of a system called Forest/CR to support the critical reading of academic papers. The system aims to promote the formation of reading strategies by recognizing questions that learners could not generate themselves during reading and comparing them with questions and interpretations from others.

The initial experimental results suggest that the system can contribute to improving learners' critical reading skills and serve as an effective tool for deepening their own thoughts. Future research should focus on enhancing the applicability and reliability of the system by strengthening its theoretical foundation and collecting empirical data. The outcomes of this study represent a significant step forward in the fields of educational technology and critical reading, and further development and application are anticipated.

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