Development of a Concept Map Evaluation Support System for Social Studies Learning

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Abstract: In social studies learning, it is crucial for students to develop a "structural awareness" that systematically organizes the connections between social phenomena. One approach to achieving this is concept mapping, and Tokutake et al. (2019) developed the S-R Score Table as a method for teachers to evaluate students' concept maps. However, the procedure for utilizing this method is complex, and interpreting the results requires specialized knowledge and insight. Therefore, in this study, we developed an evaluation support system that automates the creation of the S-R Score Table and displays the comparison results of the concept maps created by teachers and students in a comprehensive view. This system is designed to make it easier for teachers to evaluate the overall trends in students' structural awareness. The application of this system in actual classroom settings suggested that it could enhance teachers' ability to evaluate the structural awareness trends of the entire class.

1 INTRODUCTION

In social studies learning, it is crucial for students to grasp the meaning, significance, characteristics, and interrelationships of social phenomena. Brahami and Nada (2019) found that the process of extracting expert knowledge and mapping relationships improves creativity and innovation efficiency. Based on this, we believe that for students to form a structural awareness of social matters, it is first necessary for them to be able to grasp the "structural awareness" formed by the teacher, who uses a "structuring perspective" as an expert.

Methods to visualize students' structural awareness include the concept mapping method developed by Novak et al. (1984) and the hierarchical directed graphs by Sato (1987), both of which students can draw. In this study, Sato's hierarchical directed graphs are considered one method of drawing concept maps.

Research evaluating students' concept maps includes scoring comparisons between learners' and experts' concept maps (Aliya et al.,2021) and link comparisons (Kato et al., 1988, Jaruwat,2016). These studies compared individual learners' concept maps with those of experts, making it difficult to grasp the recognition trends of all learners. Therefore, Tokutake et al. (2019) developed the S-R Score Table to evaluate the structural awareness of individual students and the entire student body by comparing the connections in structural graphs drawn by teachers and students. In the S-R Score Table, each connection in the teacher's structural diagram is categorized based on the perspectives and ways of thinking required for the connection, giving meaning to the connections. This helps teachers evaluate individual students' structural perspectives and structural awareness based on the presence or absence of these connections in students' concept maps.

Next, by displaying the connection information of students' concept maps in a list, the S-R Score Table

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supports teachers in evaluating the structural perspectives and recognition trends of the entire student body. Also, in the S-R Score Table, attention coefficients are indicated as a metric to identify students with unique recognition patterns and links where the entire student body may have unique recognition patterns.

However, these methods are difficult to use directly in schools because of the complexity of the procedures for analysis and the specialized knowledge and insight required to read the indicators. In order to solve these problems, it is necessary to consider ways to facilitate their interpretation and reading.

Therefore, the purpose of this study is to develop an evaluation support system using the S-R Score Table to make it easier for teachers to understand the structural recognition trends of individual students and the entire student body.

2 OVERVIEWS OF THE S-R SCORE TABLE

The S-R Score Table, which lists the connection information from the concept maps of the entire student body, is developed with reference to the S-P table by Sato (1998), a method for graphically interpreting students' learning achievement. An overview of the S-R Score table is shown in Figure 1.

To create the S-R Score Table, each node in the teacher's concept map is assigned a sequential number. If the teacher connects node 1 to node 2, the link is labeled "1→2". Next, to explicitly show the structural perspectives required to draw the connections between nodes, the connections are categorized using the items in Table 1. These three item combinations define the structural perspectives in the S-R Score Table.

For instance, if the teacher connects nodes 1 and 2, which relate to "politics" and "culture"

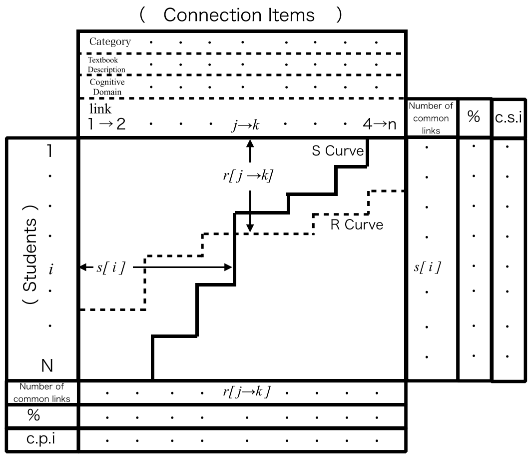

Figure 1: Basic structure of the S-R Score Table.

respectively, and this relationship is neither explicitly nor abstractly described in the textbook, requiring students to analyze and infer the causal relationship between the events, the connection between nodes 1 and 2 is categorized as "different fields, no description, analysis". The connections in the teacher's concept map, classified according to the items and elements in Table 1, are placed in the connection items of Figure 1.

When comparing the teacher's and students' concept maps, common links are marked as "1" and unique teacher links, which are not drawn by students, are marked as "0" in the table. Students are then ranked in descending order based on the number of common links, and each link item is similarly ranked.

Based on the number of common links for each student, an S (Student) curve (solid line in Figure 1) is drawn. In Figure 1, *i* represents the total number of common links for student *i*.

Next, for each link between nodes, an R (Recognition) curve (dotted line in Figure 1) is drawn according to the number of students who made the common link. In Figure 1, *r[j→k]* represents the total number of students who recognized the relationship and made the common link between nodes *j* and *k*.

Table 1: Classification items of links.

Item	Element	Content
Category	Same Category	Links drawn between events in the same category.
	Different Category	Links drawn between events in different category.
Relationship Description	Described	Links explicitly explained in the textbook.
	Undescribed	Links not explicitly explained in the textbook.
Cognitive Domain	Knowledge	Links inferred from relationships explicitly stated in the textbook.
	Interpretation	Links inferred from abstract descriptions or observations.
	Analysis	Links inferred from causal relationships arising from events.

In the S-R Score Table, the overall structural awareness of students is evaluated using the S curve and R curve. The S curve, drawn in descending order according to the total number of common links for each student, indicates that if the curve leans to the right side of the table, a higher number of common links are present, suggesting a well-formed structural awareness of social phenomena. Conversely, by examining the R curve and identifying links with high and low numbers of common links, teachers can discern which social phenomena were easily recognized by many students and which were challenging in terms of forming structural awareness.

3 METHOD OF SUPPORT FOR TEACHERS' EVALUATION

In the S-R Score Table, an attention coefficient is calculated to identify individual students and link items with unusual recognition patterns compared to the overall trend. These are denoted as C.S.i for individual students and C.P.i for link items. The calculation of the attention coefficient follows the method proposed by Sato (1998) for the S-P table. By examining the attention coefficient, interpretations can be made as shown in Figures 2 and 3.

As seen in Figure 2, C.S.i values exceeding 0.5 indicate unusual recognition patterns, while students with a correct response rate below 30% may be interpreted as having insufficient learning or unique response patterns. Similarly, Figure 3 shows that C.P.i values exceeding 0.5 indicate unusual recognition for specific link items.

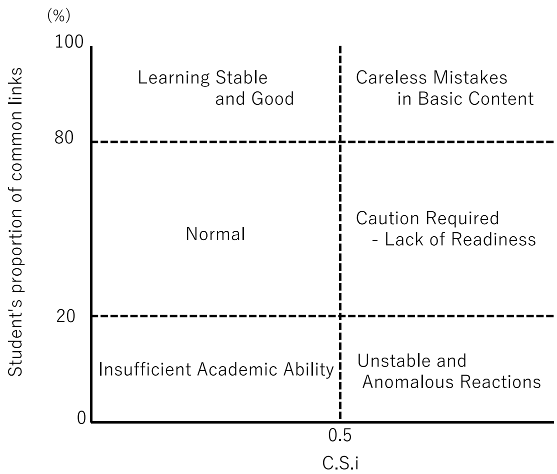

Figure 2: Interpretation of C.S.i in S-P Score Table.

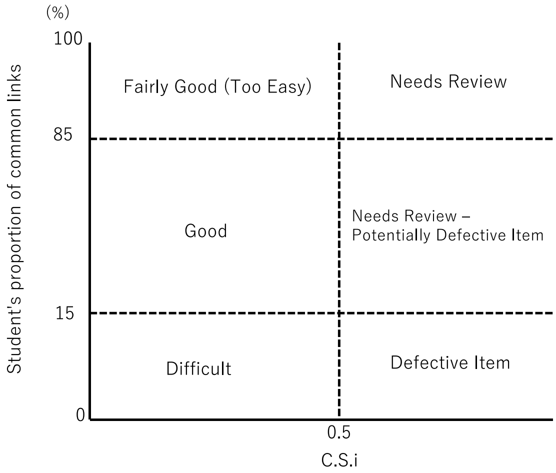

Figure 3: Interpretation of C.P.i in S-P Score Table.

Based on these findings, we established the following two requirements to support evaluation activities using the S-R Score Table:

1. By plotting the C.S.i values of each student in a scatter plot, teachers can understand the overall structural recognition trends of the students.
2. By plotting the C.P.i values of each link item in a scatter plot, teachers can understand the relationships between phenomena that students found difficult to understand.

Based on the above requirements, we developed the evaluation support system.

4 SYSTEM FOR CONCEPT MAP EVALUATION SUPPORT

The connection information of the students' concept maps is written into a CSV file in a predefined format and uploaded to the system, which then generates the S-R Score Table. Figure 4 shows the screen displaying the S-R Score Table generated by the system, where the S curve is shown in blue and the R curve is shown in red.

Category	Different	Same	Different	Different	Same	Different	Same			
text	Described	Undescribed	Undescribed	Described	Undescribed	Described	Undescribed			
cog	Knowledge	Interpretation	Analysis	Knowledge	Analysis	Knowledge	Knowledge			
student/item	6→10	5→7	8→11	1→2	7→8	3→4	9→10	S-SUM	%	C.S.i
StudentA	1	0	0	1	1	1	1	5	71.4	1.75
StudentB	1	1	1	1	0	0	0	4	57.1	0.0
StudentC	0	1	1	0	1	0	0	3	42.9	0.67
StudentE	1	1	1	0	0	0	0	3	42.9	0.0
StudentD	1	0	1	0	0	0	0	2	28.6	0.2
StudentF	1	1	0	0	0	0	0	2	28.6	0.0
StudentG	1	1	0	0	0	0	0	2	28.6	0.0
R-SUM	6	5	4	2	2	1	1	21		
%	86.0	71.0	57.0	29.0	29.0	14.0	14.0	42.9		
C.P.i	1.0	1.5	1.0	0.0	0.33	0.0	0.0			

Figure 4:S-R Score Table created by system.

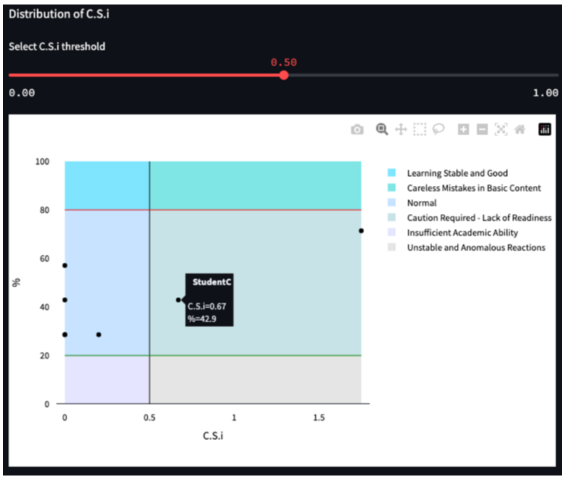

Figure 5: Scatter diagram of C.S.i created by system.

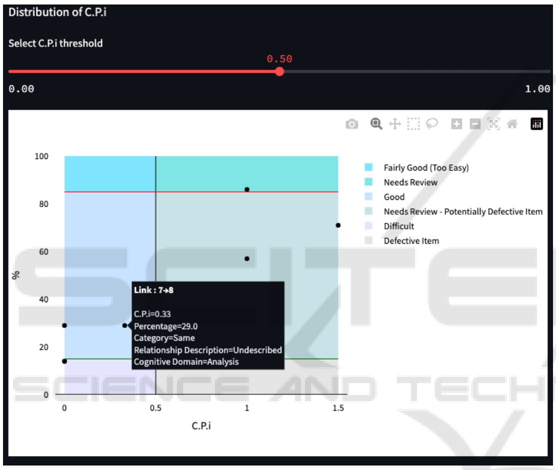

Figure 6: Scatter diagram of C.P.i created by system.

The interface displays not only the S-R Score Table but also scatter plots of C.S.i (Figure 5) and C.P.i (Figure 6).

A slider labeled "Select C.S.i threshold" is provided on the C.S.i scatter plot, allowing the threshold value for the attention coefficient to be adjusted. This feature supports teachers in reinterpreting the threshold value based on the scatter plot, making it easier to interpret students' structural awareness even if there are students with attention coefficients slightly below the standard threshold value, such as 0.45. Hovering over a point in the scatter plot displays the student's name, C.S.i, and the percentage of common links. By examining the scatter plot of students' C.S.i values, teachers can easily determine whether there are more students in a stable group with well-formed structural awareness or in a deficient group with insufficient learning. For students with a percentage of common links below 30% and an attention coefficient exceeding the threshold value, it can be interpreted that they may have made inappropriate connections or formed unique historical perspectives.

The same functionality is implemented for C.P.i. By examining the scatter plot of C.P.i values for the concept map links, teachers can visually interpret the proportion of links that were easy for students to understand and those that were difficult. Additionally, for links where 15% to 85% of the students have made the common links and the C.P.i value exceeds the threshold, it can be interpreted that the content of the nodes or links created by the teacher might not have been appropriate.

5 EXPERIMENTAL TRIAL

5.1 Experimental Setting

The developed system was applied to evaluate concept maps drawn by 21 second-year high school students enrolled in a history class. These students participated in lessons on drawing concept maps over a six-month period, ensuring they understood the method and were deemed suitable subjects for this study.

To avoid the influence of the teacher's instruction on the content of the students' concept maps, no direct instruction on the study material was provided. Instead, students were instructed to read the textbook and create their concept maps based on their understanding. Figure 7 shows the concept map created by the teacher.

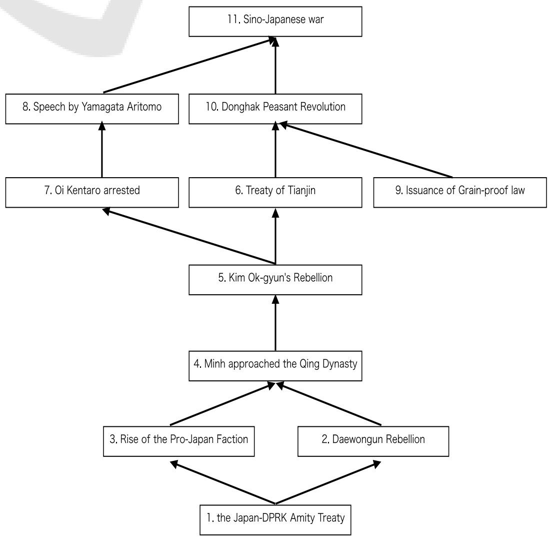

Figure 7: Concept map drawn by teacher.

Students were given the nodes from the teacher's concept map and instructed to independently arrange the nodes and draw the links.

5.2 Analysis and Result

5.2.1 Understanding Structural Perspectives and Trends in Structural Awareness

Based on the link information from the students' concept maps, the S-R Score Table generated by the developed system is shown in Figure 8.

Regarding Figure 8, focusing on the R curve, it can be observed that the number of common links decreases beyond "6→10." When examining the links from "2→4" to "6→10" in terms of structural perspectives, these links are classified as "textbook described, knowledge," regardless of whether they belong to the same field or different fields. Additionally, focusing on the S curve, it can be seen that the S curve to the right of "6→10" includes about half of the students, indicating that the percentage of common links exceeds 50%.

From these observations, it can be evaluated that approximately half of the students in the history course tend to develop structural awareness by utilizing structural perspectives to interpret the relationships between social phenomena described in the textbook, regardless of whether they are in the same or different fields. However, for the links classified as "described, knowledge" such as "1→2," "3→4," and "9→10," the percentage of common links falls below 30%. Therefore, it is necessary to further investigate the reasons for the decrease in the percentage of common links while reviewing the textbook and the structural diagrams drawn by the students.

On the other hand, for the links beyond "8→11" where the number of common links decreases, it can be seen that many of these links are classified under "analysis" or "interpretation" when focusing on the structural perspectives.

From these observations, it can be evaluated that students in the history course tend to find it difficult to develop structural awareness using structural perspectives for relationships between social

Category	Different	Different	Different	Different	Different	Different	Different	Different	Different	Different	Same	Different			
text	Described	Described	Described	Described	Described	Described	Undescribed	Undescribed	Described	Described	Undescribed	Undescribed			
cog	Knowledge	Knowledge	Knowledge	Knowledge	Knowledge	Knowledge	Analysis	Interpretation	Knowledge	Knowledge	Analysis	Knowledge			
student/item	2→4	4→5	5→6	1→3	10→11	6→10	8→11	5→7	1→2	3→4	7→8	9→10	S-SUM	%	C.S.i
StudentA	0	1	1	0	1	1	0	0	1	1	1	1	8	66.7	1.35
StudentB	1	1	1	1	0	1	1	1	1	0	0	0	8	66.7	0.29
StudentC	1	1	1	1	0	0	1	1	0	0	1	0	7	58.3	0.52
StudentD	1	1	1	1	1	1	1	0	0	0	0	0	7	58.3	0.0
StudentE	1	0	1	1	1	1	1	1	0	0	0	0	7	58.3	0.32
StudentF	1	1	1	1	1	1	0	1	0	0	0	0	7	58.3	0.06
StudentG	1	1	1	1	1	1	0	1	0	0	0	0	7	58.3	0.06
StudentH	1	1	1	1	1	0	0	0	0	1	0	0	6	50.0	0.28
StudentI	1	1	1	1	0	1	1	0	0	0	0	0	6	50.0	0.15
StudentJ	1	1	0	1	1	1	1	0	0	0	0	0	6	50.0	0.25
StudentN	1	0	1	1	1	1	0	0	0	0	0	0	5	41.7	0.16
StudentO	1	1	0	1	1	0	1	0	0	0	0	0	5	41.7	0.26
StudentK	1	1	0	1	1	0	0	0	1	0	0	0	5	41.7	0.35
StudentM	1	1	0	1	0	1	0	1	0	0	0	0	5	41.7	0.39
StudentL	1	1	1	0	0	0	1	0	0	0	0	1	5	41.7	0.58
StudentP	0	1	1	0	1	0	0	0	1	0	0	0	4	33.3	0.58
StudentQ	1	0	1	1	1	0	0	0	0	0	0	0	4	33.3	0.11
StudentR	1	1	1	0	0	0	0	0	1	0	0	0	4	33.3	0.36
StudentS	1	0	0	1	1	0	0	0	0	0	0	0	3	25.0	0.18
StudentT	1	0	1	0	0	1	0	0	0	0	0	0	3	25.0	0.22
StudentU	1	1	1	0	0	0	0	0	0	0	0	0	3	25.0	0.0
R-SUM	19	16	16	15	13	11	8	6	5	2	2	2	115		
%	90.0	76.0	76.0	71.0	62.0	52.0	38.0	29.0	24.0	10.0	10.0	10.0	45.7		
C.P.i	1.23	0.48	0.68	0.51	0.78	0.36	0.46	0.27	0.83	0.4	0.2	0.6			

Figure 8: S-P Score table created by the system

phenomena that require interpreting abstract descriptions in the textbook or inferring causal relationships arising from the phenomena.

5.2.2 Understanding Trends Using Scatter Plots of Attention Coefficients

The focus is on the students' C.S.i and the links' C.P.i. Based on the concept maps obtained from the experiment in this study, scatter plots of C.S.i and C.P.i created by the system are shown in Figures 9 and 10, respectively.

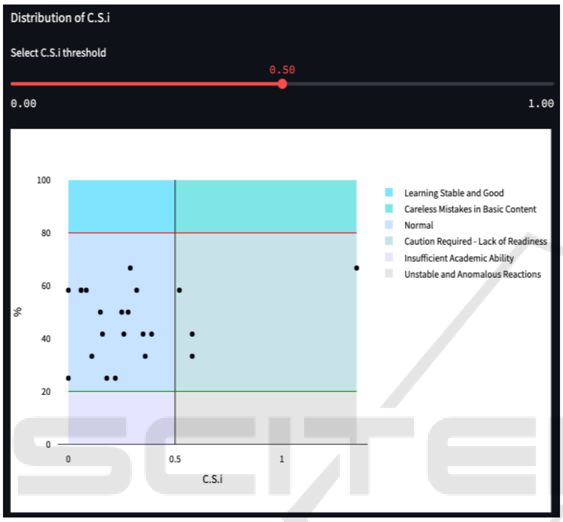

Figure 9: Scatter diagram of C.S.i in Experimental trial.

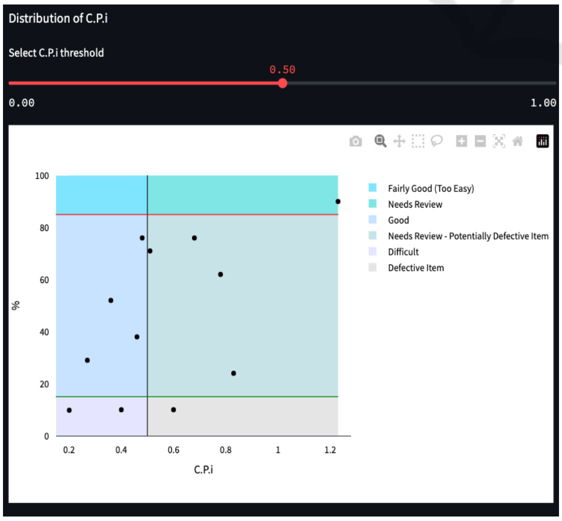

Figure 10: Scatter diagram of C.P.i in Experimental trial.

In Figure 9, it can be seen that 17 out of 21 students belong to the normal group. Therefore, it can be evaluated that the students in this class may have insufficient formation of structural awareness. Additionally, it is observed that four students have attention coefficients exceeding 0.5. These students are "studentA," "studentC," "studentL," and "studentP." According to the S-R Score Table, studentA and studentC have a common link percentage of about 60%. This suggests that while these two students have formed some degree of structural awareness, their structural awareness may be insufficient in certain areas.

On the other hand, studentL and studentP have a common link percentage of about 40% or lower. This suggests that these two students may be forming a unique historical understanding different from that of the teacher. In this study, the structural awareness held by the teacher is used as the correct model, but it cannot be said that the students' unique historical understanding is necessarily incorrect. Therefore, when evaluating these two students in a real classroom setting, it is necessary to review their concept maps to understand their structural awareness.

Regarding C.P.i, focusing on Figure 10, it can be seen that two links are classified as "Difficult." These links are "7→8 (Same fields, Undescribed, Analysis)" and "3→4 (Different fields, Described, Knowledge)." The link 7→8 is considered difficult for students to grasp the relationship between the phenomena as it is not described in the textbook, reflecting the teacher's professional perspective. On the other hand, the link 3→4, although described in the textbook, has the content on different pages, making it difficult for students to grasp the relationship.

For the link "9→10 (Different fields, Described, Knowledge)" classified as "Defective item" although the relationship is described in the textbook, it is on different pages similar to "3→4." Moreover, the content of node 6, which also influenced node 10, is described in detail, suggesting that the influence of node 9 on node 10 is minimal and thus not suitable to be included in the map.

On the other hand, the link "2→4 (Different field, Described, Knowledge)" classified as "Too Easy" with an attention coefficient exceeding 0.5 is explicitly described in the textbook, making it easy for students to recognize the relationship between the phenomena. However, the C.P.i is high because some students, despite the high common link percentage, missed this description and did not draw the link.

In the S-R table, C.S.i is calculated for each student and C.P.i is calculated for each link, but it is difficult to discern the tendencies of students and links from this data alone. However, by viewing the scatter plots of C.P.i and C.S.i implemented in this system, it has become easier for teachers to grasp these tendencies.

If teachers can grasp the overall tendencies of students and links, they can adjust the difficulty level of the lessons and design better instructional content. Additionally, using the scatter plots in this system makes it easier to identify students and links that deviate from these tendencies. If teachers can identify students who deviate from the norm, they can analyze those students' individual learning situations in more detail and consider optimal instructional strategies. Similarly, if teachers can identify links that deviate from the norm, they can determine which parts require more explicit teaching, thus aiding in the design of their lessons.

6 DISCUSSION

6.1 Practical and Managerial Implications of Plotting Results

In this study, we developed a system to assist teachers in evaluating students' structural awareness by comparing concept maps created by both teachers and students, and visualizing the differences. The S-R Score table proposed by Tokutake et al. (2019) is highly effective as a method for comparing concept maps between teachers and students. However, when teachers use this tool for lesson planning, it is necessary to focus not on the results of individual students, but on the overall trends among all students.

Therefore, the system developed in this study, which plots the results of each student and allows them to be viewed at a glance, is considered to be highly effective in helping teachers understand the overall trends in students' structural awareness and in considering the level and content of the lessons.

Additionally, plotting the correctness information and the attention coefficient (C.P.i) for each link is considered to be highly effective in helping teachers review the accuracy of their knowledge structure as experts and in understanding the relationships between phenomena that are difficult for students to grasp.

From these points, we believe that the system developed in this study sufficiently supports teachers in evaluating students' structural awareness.

6.2 Generalization of Methods and Feasibility in the Field

In this study, the developed system has been used in the context of history education and its effectiveness has been discussed. The use of concept maps to form structural awareness is also practiced in geography, politics and economics, which are different areas of social studies, and in science classes. In order to apply the S-R table and the system developed in this study to these subjects, we believe that it is necessary to change the classification items of the link. For example, in history education, historical events in the political field are sometimes related to historical events related to culture. To be able to capture the relationship between these events is very important in forming a structural awareness. For this reason, the classification of the “Same Category” and the “Different Category” are used to categorize the connections. However, in geography classes, not only causality and influence among events, but also inclusive relationships among events are sometimes considered important. Therefore, it may be necessary to reflect items such as “preconditions” and “inclusions” as elements of “Category”.

In the system developed in this study, the S-R Score table reflects the elements written by the teacher in the csv file. Therefore, the system is expected to be able to handle such changes adequately. In addition, the creation of the S-R Score table is automatic, so there is no need for teachers to follow complicated procedures.

Therefore, we believe that the system developed in this study is applicable to other fields and can be easily introduced to schools.

7 CONCLUSIONS

The purpose of this study is to develop an evaluation support system using the S-R Score Table to make it easier for teachers to understand the structural recognition trends of individual students and the entire student body.

As a result, using the S curve and R curve, it was possible to understand the students' perspectives on structurally capturing the relationships between social phenomena and the trends in their structural awareness.

The scatter plot of the attention coefficient C.S.i, which indicates the heterogeneity of students' structural awareness, revealed the proportion of students with unique recognition. Additionally, by examining the percentage of common links with the teacher's concept map, it became possible to make detailed interpretations of the students' recognition.

The scatter plot of the attention coefficient C.P.i, which indicates the heterogeneity of recognition for each link in the concept map, allowed for a visual understanding of the relationships between social phenomena that students likely have insufficient understanding of. Furthermore, it enabled the identification of nodes in the teacher's concept map that may be considered unnecessary for organizing the relationships between phenomena. From this, it was suggested that the function of the concept map evaluation support system developed in this study has the potential to assist teachers in easily understanding the structural recognition trends of individual students and the entire class.

Future task include the following:

1) The interpretation of C.S.i and C.P.i used in this study is based on the content of the S-P table, which measures students' attainment of test questions. Future tasks include improving the interpretation of C.P.i and C.S.i to be unique to concept map.
2) The developed system was introduced in a school setting and its effectiveness was verified, it was only done in one case. Hence, it is necessary to have multiple teachers use the system and evaluate its usefulness.
3) S-R Score Table evaluates students' structural awareness by comparing it with the concept map created by the teacher. However, in social studies learning, students' independently formed understandings cannot always be deemed incorrect. Therefore, a separate method needs to be considered to evaluate the validity of such unique structural awareness formed by students.

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