PREDICTIVE MODELING OF CLASS TARGET ACHIEVEMENT BASED ON STUDENTS' SPONTANEOUS INTERACTION DURING COLLABORATIVE LEARNING FOR CLASS MANAGEMENT TOOLS

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Abstract

Educators have difficulty in determining learning interactions in the classroom and in quantifying them, mainly due to lack of sufficient support needed for each student, as the instructor operates the class alone. The authors are developing a system to assist educators in making situational decisions about when to intervene and interact with students within the temporal and spatial constraints of the classroom. In this study, the authors investigated educators' intervention time in an environment where the understanding of the whole class was shared. The results indicate that the data provided by the system may be used to evaluate students by using the value of eigenvector centrality as a measure of instructural leadership. In addition, when learning objectives are achieved by about 20% of the students, the information that solves the question is widely diffused throughout the class.

Keywords: Collaborative learning, Learning analytics, Teacher support, Predictive models

JEL Classification: C61, C92, I21

1. Introduction

1.1. Burden for teacher during collaborative learning using the educational system

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It is difficult for educators to quantitatively determine learning interactions in the classroom. The main reason for that, in general, is the lack of sufficient support for each student, since the instructor operates the class alone. They can evaluate the quality of learning interactions among students by looking around the entire classroom, students' comments in class, and the submissions that students are required to provide. However, with these indicators, it is difficult for them to determine at what point throughout the entire class the interaction progressed and at what point the learners understood the topic during the class. In addition, it was impossible to manually record these data and reflect on the class management. This constitutes a loss of opportunity to receive advice from other teachers. Therefore, it is important for teachers to be able to check the status of learning exchanges in order to improve their classroom management. In order to carry out these goals, it is necessary to introduce an educational e-system, such as ICT equipment, into the classroom management.

A decade ago, the trend in educational electronic systems was ubiquitous learning, such as MOOCs (Massive Open Online Courses) and LMS (Learning Management Systems). These systems are educational services that use the Internet and are mainly utilized in higher education. Although ubiquitous learning systems have attracted a lot of attention, they have revealed issues such as lack of continuity in learning and lack of communication among students. In addition, it is difficult to use these systems face-to-face (F2F). The main cases of using these systems have been for out-of-class learning and unspecified educational services. For example, Mouri proposed a visualization system that integrates mutual learning visualization techniques and maps to connect real-world learners with the logs that the constructed ubiquitous learning system stores in cyberspace (Mouri et al, 2015). In addition, the jigsaw method (De Paz, 2001) can be considered as a learning exchange that takes place F2F, and collaborative learning is a major example.

Collaborative learning is a situation wherein two or more people learn together (Dillenburg, 1999). The use of collaborative learning allows for classes in which students take the initiative and interactively participate in activities with other students. One of the advantages of this class method is that it is possible to provide a class in which the entire classroom achieves the learning objectives. There are prior case studies that were introduced as examples for using collaborative learning. Phielix investigated the effectiveness of peer feedback and reflection tools and reported that students showed a positive attitude toward collaborative problem solving when using the reflection tools (Phielix et al, 2010). Peer feedback refers to the process in which students report on their learning activities to each other, providing feedback on areas for improvement and evaluation, and encouraging course correction. Through their peer feedback, they are able to self-evaluate their learning activities. It is also useful in that it allows students to learn about different approaches to the task. Peer feedback is a form of student feedback in which students critique each other's performance. The students critique each other according to predetermined evaluation guidelines. Peer evaluation differs in that the focus is on the dialogue between students instead of their grading of each other's performance (Liu N. F. et al, 2006). Setozaki adopted collaborative learning, in which children collaborate with each other to complete learning tasks with the aim of making it easier for students with weak spatial awareness to comprehend the material in astronomy education (Setozaki et al, 2017). One of the advantages of using an educational e-system is the ability to automate the analysis of the collected data. Some of the analyses described in the prior studies mentioned above were conducted primarily by manual labor. However, there are limitations to manual analysis. By using an educational e-system, it is possible to analyze large amounts of data.

However, if the system records and provides teachers with a huge amount of data during the class, it becomes a burden for them. Chatti reported that as the number of groups increases, the amount of available information becomes a burden, a state known as information overload. In general, teachers need to provide appropriate interventions to students with limited resources due to time and space constraints in the classroom (Chatti et. al, 2013). It is not desirable to develop information overload services under such constraints.

Therefore, educational e-systems need to provide services that effectively present an appropriate amount of information to teachers. The educational system presented in this study was developed on the premise that it effectively presents an appropriate amount of information to users (mainly teachers).

In addition, we analyzed the electronic data collected from the students' learning activities that occurred in physical space.

1.2. How the educational system can be used to support teachers

The teacher who manages the classroom operation during collaborative learning does not perform the general knowledge teaching type classroom movements, but rather performs a facilitating type of movement. For example, if students are having trouble solving a problem, they intervene. They may also provide interventions to help the class focus on the same goal. Thus, there are more interventions that are given to the students and are more important than in a typical classroom setting. Prior studies have identified students in need of assistance and support in implementing appropriate interventions. For example, Han have shown that a learning analytics dashboard they developed was effective in facilitating collaborative learning discussions (Han et. al, 2021). It has also shown to be effective in identifying students who need assistance in large classes. Van Leeuwen developed a support tool that provides information about students' cognitive activities to help teachers implement appropriate interventions for students (Van Leeuwen et al, 2015). They reported that their results did not improve teachers' ability to identify groups facing problems but allowed them to focus their interventions more specifically on groups that were experiencing problems.

These prior studies focused on identifying which students or groups of students the teacher should intervene with. However, there were no studies identified regarding situational judgments about when to intervene. It is also difficult for teachers to objectively and quantitatively determine whether or not a learning interaction in the classroom was successful. Therefore, in this study, we developed a system to record students' learning behavior by themselves. Using this system, we investigated whether it is possible to determine at what point the teacher should intervene while checking the progress of the entire class.

2. Hypothesis

The authors are developing a system to assist teachers in making situational decisions about when to intervene with students within the temporal and spatial constraints of the classroom. (Matsishita et. al, 2019) In this study, the authors investigated the teacher's intervention time in an environment where the understanding of the whole class was shared. Thus, the objectives of this study are as follows:

Purpose: To discover innovative indicators of facilitated learning that can be linked to teacher-managed collaborative learning aids by the developed system.

In addition, the hypothesis is as follows:

Hypothesis: Teachers with sufficient experience in classroom management during collaborative learning subconsciously possess indicators of whether the learning exchange was successful or not. They also use these indicators to conduct appropriate classroom management.

3. Experimental method

3.1. Outline

To validate the hypotheses of this study, an experimental study was conducted from February 1st to 4th, 2021. The experimental study used a developed system, described below, to record the students' own learning behavior. The subjects of this experiment were students in public elementary schools in Japan. These subjects were selected because they are more likely to belong to Japanese public schools and making them a suitable population.

3.2. Participants

A total of 31 students and one teacher participated in the experiment; the 31 students were between 11 and 12 years old and belonged to an elementary school (male: 14, female: 17). The teacher was a male in his 20s. This teacher was well experienced in managing collaborative learning. The tablet devices used were Chromebooks. These students were inexperienced in using Chromebooks in the classroom. Therefore, before the beginning of the experiment, we checked to be sure that the students were able to learn using the Chromebooks. In this experiment, we did not arbitrarily create groups in order to promote natural learning interactions within the class. This will allow us to see how information pertaining to learning behaviors was exchanged within the class. The experiment was conducted three times. Each class session lasted 45 minutes. Of the 45-minute class periods, all class subjects were mathematics. Problems were given in each class. The content of the exercise time problems was prepared by the teachers who participated in the experiment. The exercise expressed in the following refers to each problem that was conducted during class time. There were eight questions presented. One of these questions was excluded from the analysis due to insufficient time for the exercise.

3.3. Developed the system

The system developed for the experimental study is a web application. The system has two functions: the first is to share students' achievement of learning objectives with the entire class; the second is to record students' learning interactions. Both functions were developed to support teacher interventions. An overview of this system is shown in Figure 1.

3.3.1. Sharing student learning objectives with the entire class

The function of sharing the achievement of learning objectives of students throughout the system is described in Figure 2. In order to use this function, the teacher must give the requirements for the achievement of the learning objectives for the students. On the left side of Figure 2 is a part of the screen operated by the student. On this screen, there are four buttons ("Not yet", "Half", "Solved", and "Explainable") operated by the students. By selecting one of these buttons, the student can check and change the status of their learning objectives. The status of students' learning objectives is shared with the entire group in real time via the "Share Screen" on the right side of Figure 2. The purpose of using this screen is to support teacher intervention and to promote collaborative learning among students.

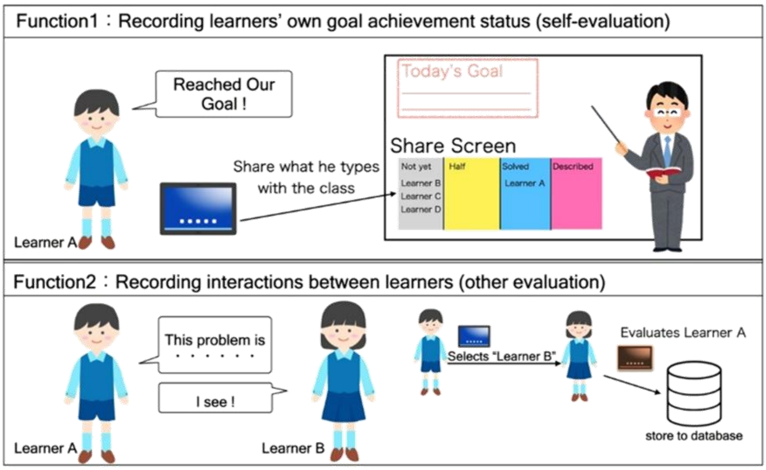

Figure 1. An overview of the system.

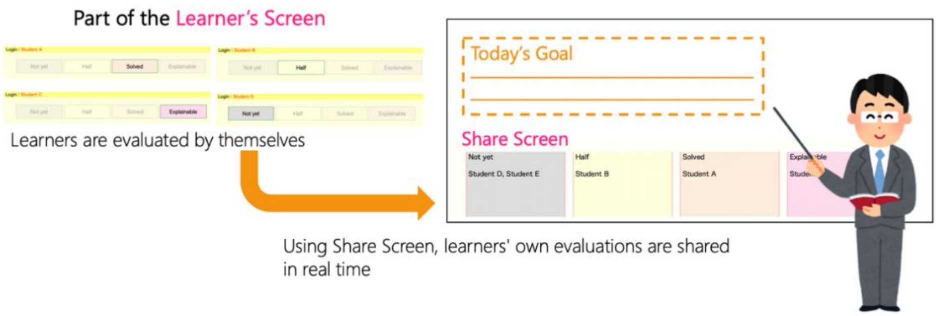

Figure 2. The function of sharing student learning objectives.

3.3.2. Recording students' interactions

The function for recording learning interactions is described in Figure 3. To use this function, the teacher must create a situation in which students are allowed to interact with each other. When students interact with each other, the learning interaction is recorded using a tablet device.

In this example, Student A is the student who gave the hint or explanation of the question, and Student B is the student who received the hint or explanation. Student A teaches Student B, and then Student A presses the button labeled "Student B" on his/her screen. When the button is pressed, a pop-up screen appears on student B's screen. This screen contains the sentence "Do you understand from Student A? and buttons labeled "Yes" and "No". When the "Yes" button is pressed, the "Student B" button on Student A's screen turns blue, and when the "No" button is pressed, the button turns red.

All of this interaction is stored as electronic data on a web server. The teacher can check this interaction on the teacher's private page. Figure 4 is a network diagram displayed on the private page for teachers. Every circle in the diagram represents a student. The arrows represent the interaction of information. The starting point of the arrow represents the student who taught, and the ending point represents the student who learned from the student. From this diagram, the teacher can read the information interaction among the students in the whole class. By looking at this diagram, the teacher can identify the central person in the class and the student with whom they should intervene.

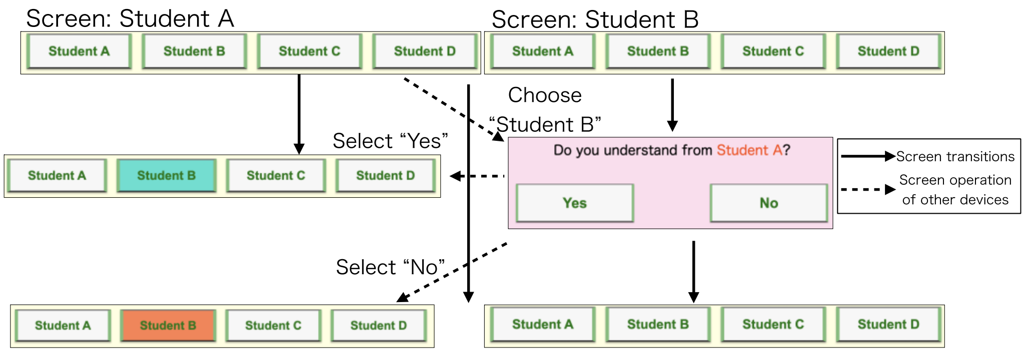

Figure 3. The function of recording interactions between students.

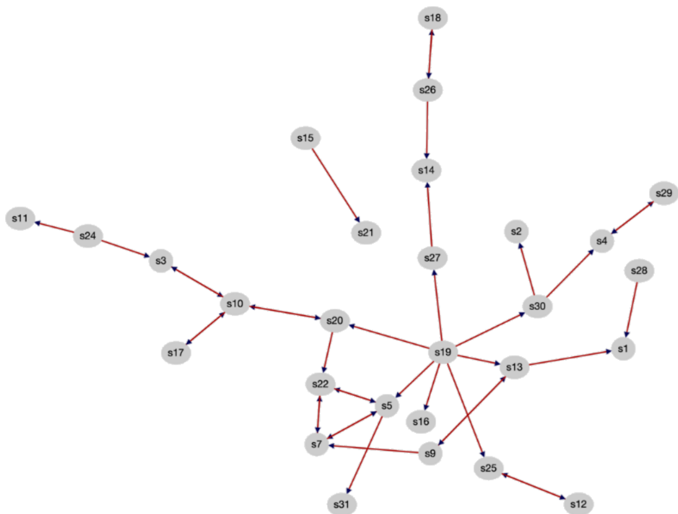

Figure 4. Visualization of learning interaction.

3.4. Procedure

Before the teacher gives the students the questions, he/she confirms the learning objectives with the whole class. In this case, the learning objectives were that all class members should be able to solve the given questions. This task aims to promote learning interactions throughout the class. This objective required that if one student was able to solve a question, he or she would collaborate by giving hints to others rather than ending the exercise.

After reviewing the learning objectives, the teacher gave the students a question. Initially, they solved the questions alone without any interaction. After that, the students interacted with each other for learning interaction. The decision whether or not to conduct a learning interaction was made by the learners, but if the teacher decided that there was a need for intervention, such as encouraging learning interaction or giving hints on how to solve the questions, they would intervene with the students. The exercise was terminated when the entire class or a sufficient number of students had reached a correct answer.

The system recorded the time from when the teacher gave the question to the student to when the exercise was completed. These series of operations were repeated as a single interval. As a result, we were able to conduct 8 intervals in this experiment, one of which was excluded due to insufficient time for the exercise.

3.5. Data Analysis Methods

In order to discover indicators for facilitating the exercise, which is the purpose of this paper, data analysis was conducted using the collected electronic data. A description of the data analysis used in this paper is presented in the next section.

3.5.1. Social Network Analysis

A social network analysis was conducted based on the network diagram drawn during the exercise time. There are several methods for social network analysis. In this study, we chose centrality analysis. The main reason for performing centrality analysis is to measure the degree of contribution of individuals when analyzing relationships belonging to an organization or society. By utilizing this analysis, it is possible to measure the importance of individuals in a social network. There are several indicators of centrality analysis. In this study, we used three of the most commonly used indicators: degree centrality, betweenness centrality, and eigenvector centrality.

Degree centrality is a measure that represents the ratio of nodes in a network that are connected to other nodes. This centrality is used with the idea that a node that is adjacent to many nodes is central. In this case, it is an indicator of the degree to which a given student interacts with other students. Thus, the higher the degree centrality, the more likely it is that the node is connected to other nodes. In other words, they can be considered to have many relationships. The value of degree centrality is often normalized by dividing the total number of other nodes connected in the network by the total number of nodes in the network, N, minus 1. The degree centrality DC_i at node i can be obtained using matrix A (N × N) as follows:

$$DC_i = \frac{\sum_j A_{ij}}{N-1}, A_{ij} = \begin{cases} 1 \text{ (There is an edge between node } i \text{ and node } j) \\ 0 \text{ (There is NO edge between node } i \text{ and node } j) \end{cases} \quad (1)$$

Betweenness centrality is an indicator used with the idea that a node that often appears on a path between two nodes is central (Freeman, 1977). In this case, it is an indicator for discovering students who serve as intermediaries between one group and another. Therefore, we can paraphrase that a node that functions as an intermediary in the network is central. The betweenness centrality BC_i at node i can be obtained as follows:

$$BC_i = \sum_{i,j \in V-\{k\}, i \neq j} \frac{\sigma(i,j|k)}{\sigma(i,j)} = \sum_{i,j \in V-\{k\}, i \neq j} \frac{\sigma(i,k)\sigma(k,j)}{\sigma(i,j)} \quad (2)$$

Note: V is the set of nodes, $\sigma(i,j)$ is the number of shortest paths from node i to node j, and $\sigma(i,j|k)$ is the number of shortest paths from node i to node j via node k.

Eigenvector centrality is a measure that is calculated by taking into account the centrality of neighbouring nodes (Bonacich, 1987). This centrality differs from previous centralities in that it includes the importance of the node. To summarize, this is the concept that anything connected to an important node is equally important. In this case, it is an indicator for discovering the dividers of a group. Thus, eigenvector centrality can be rephrased to say that nodes that are adjacent to other central nodes are central. The eigenvector centrality EC_i at node i can be found recursively using the adjacency matrix A as follows:

$$EC_i^{n+1} = \sum_j A_{ij} EC_i^n \quad (3)$$

For equation (3), using the adjacency matrix A and the column vector x

$$Ax = \lambda x \quad (4)$$

can be expressed as A. The λ in this case represents the maximum eigenvalue of the adjacency matrix A. Therefore, the process of setting the initial column vector EC_i^0, finding the eigenvalues λ and eigenvectors x using equation (4), and putting the obtained variables into equation (4) again is performed multiple times. Through this process, the converged eigenvector x corresponding to the adjacency matrix A can be calculated recursively. The value of this eigenvector is the eigenvector centrality.

3.5.2. Graph Approximation

In this paper, we use a method to approximate to a sigmoid function from the obtained data. In advance, the method of approximating to a sigmoid function is shown here.

The sigmoid function used in this study is shown in equation (5).

$$Sigmoid(a,b) = \frac{1}{1 + exp\big(-a(x-b)\big)} \tag{5}$$

Equation (5) is characterized by the output of a resultant value between 0 and 1, independent of the value of the input x. Some properties of the sigmoid function are:

- Monotonically increasing
- Symmetry
- Differentiable in all domains, extrema exist
- Only one inflection point exists

Setting the values of the parameters a and b in this function changes the behavior of the graph. For example, if the value of parameter a is increased, the graph rises rapidly. Also, as the value of parameter b is increased, the phase of the graph shifts to the right. Based on this equation (5), the given data is approximated to a sigmoid function. In other words, this is an optimization problem to find the optimal parameters a and b that yield the smallest error for the given data. To solve this problem, the Levenberg Marquardt method (Levenberg, 1944, Marquardt, 1963) was used to find the minimum error function. One of the advantages of this method is its improved convergence by combining the advantages of the steepest descent and Gauss-Newton methods. It should also be noted that what is guaranteed by this method is convergence to a local minimum, and the overall minimum may not be obtained.

3.5.3. Tools Used for Analysis

We used Python to analyze the data. The reason for using this language is that it is a comprehensive environment for performing the network diagrams, their analysis, and statistical analysis that we will create in this study. The version of Python used in this study was 3.9.16, the version of the graphviz module used for network diagram creation was 2.50.0, the version of the networkx module used for network diagram analysis was 2.8.4, the version of thelearn module used for statistical analysis is 1.2.0, the version of the Scipy module is 1.10.0.

4. Result

In order to analyze 7 intervals in this experiment, each interval was given the name shown in Table 1. Thereafter, the following names will be used to describe the subject of the analysis.

Table 1. Information for each interval

Interval	Date	Execise (min)	Students
Q.1	2/1/23	19	31
Q.2	2/1/23	9	31
Q.3	2/1/23	9	31
Q.4	2/3/23	11	31
Q.5	2/3/23	8	31
Q.6	2/3/23	9	31
Q.7	2/4/23	18	31

4.1. Prediction of The Students' Solution Achievement

This section analyses the trend in the number of students who were able to solve the problems from the beginning of the exercise to the end of the exercise. First, the relationship between the number of students who were able to solve the question and the duration of the exercise is shown in Figure 5. Here, the students who were able to solve the problems are called the "solution achievement group". This solution achievement group indicates the total number of students who indicate "Solved" or "Explainabled" among the system's function 1. Each point shown in the figure is the total number of solution achievement group for each minute from the beginning of the exercise. These points are connected in the line graph displayed in the figure.

Figure 5 confirms that all graphs are monotonically increasing functions. Only the last point in Q.4 was shown to be below the previous point. Examination of the logs indicated that one student moved from a state in which the question was solved to one in which the question was not solved. The reason for the move was unknown, but it could have been that the solution to the question was incorrect, or that the learner intentionally moved from one state to another in order to move on to the next question. Therefore, it is not considered to have a significant impact on the following analysis. Compare the degree of increase in these graphs. For Q.1 and Q.7, the graphs showed a rise from 10 minutes into the exercise. On the other hand, Q.2, Q.3, Q.5, and Q.6 show a sharp increase immediately after the start of the exercise.

These graphs show that the slope of the graph increases sharply at a specific point. From this fact, it can be predicted that connecting the points in the figure will give the appearance of a sigmoid function. For more information on the sigmoid function, see refer to Section 3.5.2. The sigmoid function is a scientifically important function. It is assumed that the relationship between exercise time and overall goal achievement is explained using the sigmoid function. Then, the properties of the sigmoid function can be used to explain the goal achievement status of the whole class. Therefore, we defined a sigmoid function as in equation (5) and fitted it to each question to obtain the optimal parameters a and b for each question. The results are shown in Table 2. An example of a fitted diagram is shown in Figure 6.

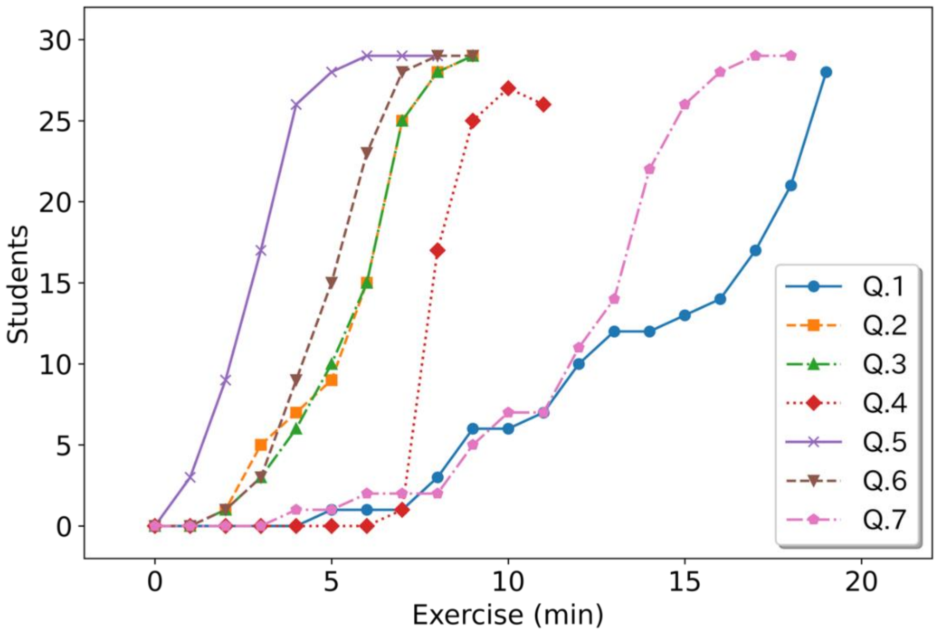

Figure 5. Relationship between solution achievement groups and exercise time

Table 2. Parameters and approximation function

Question	param a	param b	R^2
Q. 1	5. 673	0. 809	0. 956
Q. 2	7. 751	0. 641	0. 984
Q. 3	8. 259	0. 643	0. 993
Q. 4	19. 272	0. 734	0. 968
Q. 5	9. 448	0. 350	0. 990
Q. 6	9. 229	0. 556	0. 997
Q. 7	10. 435	0. 709	0. 989

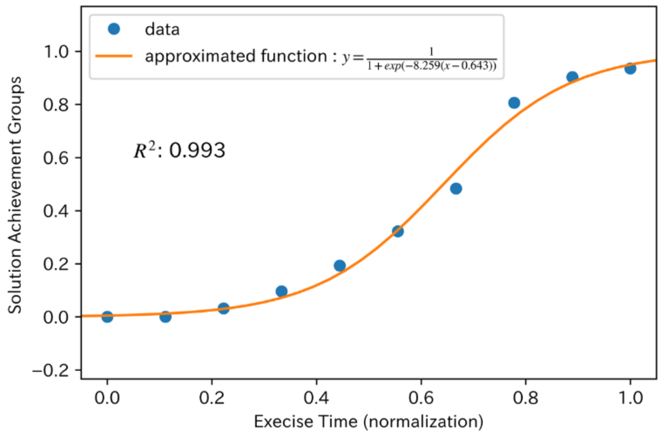

Figure 6. Example of fitting to a sigmoid function

Table 2 shows that the coefficient of determination exceeded 0.95 for all questions. As an example, Figure 6 shows the figure when the coefficient of determination showed the highest value. This figure shows that the data obtained are well adapted to the sigmoid function.

Although other candidate functions for fitting can be assumed, the results of the coefficient of determination values indicate that all questions could be fitted to the sigmoid function. From this result, we can use the properties of the sigmoid function to examine the relationship between exercise time and overall goal achievement.

4.2. Centrality Analyze for Social Network Analysis

From the data collected, we analyzed how many students had a learning interaction with each student during the exercise time of the question. For this analysis, we used the centrality analysis of social network analysis. See Section 3.5.1 for details on social network analysis. Learning interactions have a “teaching” and “learning” orientation, but in this study, the centrality analysis was conducted on an undirected graph in order to focus on with whom students interacted. The results of the seven-question analysis are shown in a box-and-whisker diagram for each indicator (Figure 7). Among the plotted values, the value x that satisfies the following conditions is indicated by a white circle as an outlier.

- $x >$ upper quartile$(Q3) + 1.5 \times IQR$
- $x <$ lower quartile$(Q1) - 1.5 \times IQR$

The figure confirms that there is no significant difference in the distribution of degree centrality for any of the questions. In addition, there were no significant differences in the distribution of the data for betweenness centrality, with the exception of question 7. For question 7, it can be confirmed that four students' values were detected as outliers. On the other hand, eigenvector centrality showed differences in the shape of the graphs from question to question. In questions 1, 3, 6 and 7, values of at most 1 or 2 students were detected as outliers. In the other questions, several students were detected as outliers. Next, Figure 8 shows the students detected as the top five eigenvector centrality students for each question, and Table 3 shows the total number of student appearances. Note that sX is the unique number given to the student. Given the characteristics of the eigenvector, the more appearances a student has in this table, the more likely the student is to show leadership during the exercise time. There are 21 students that appeared in this table. Thus, the results indicate that about 65% of the class engaged in the exercise with leadership.

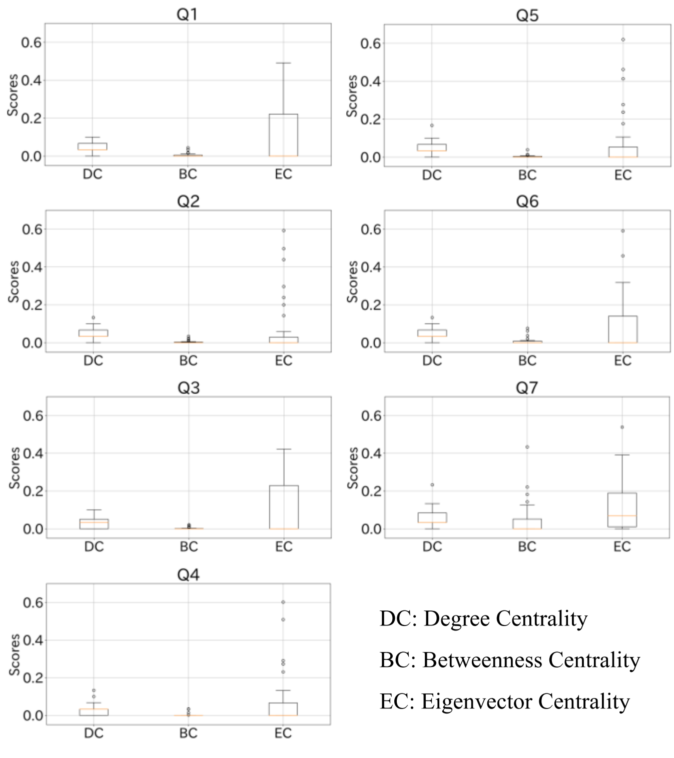

Figure 7. Centrality in Students Network

Rank	Q1	Q2	Q3	Q4	Q5	Q6	Q7
1	s15	s9	s6	s9	s13	s17	s19
2	s21	s5	s28	s17	s9	s2	s5
3	s31	s13	s10	s10	s7	s3	s20
4	s10	s12	s21	s7	s5	s14	s22
5	s24	s7	s1	s12	s2	s18	s7

Figure 8. Eigenvector Centrality (Top 5)

Table 3. Eigenvector Centrality Top 5 Appearances

Student	Appearances	Student	Appearances
s7	4	s6	1
s5	3	s14	1
s9	3	s15	1
s10	3	s18	1
s2	2	s19	1
s12	2	s20	1
s13	2	s22	1
s17	2	s24	1
s21	2	s28	1
s1	1	s31	1
s3	1		

5. Discussion

5.1. Assessment and Prediction in Learning Interaction

The relationship between exercise time and solution achievement group was fitted to a sigmoid function for the learning interaction data group, which was collected in time series for seven questions. This analysis showed that the coefficient of determination was extremely higher when parameters a and b were obtained. For all questions, there are three possible reasons for the high coefficient of determination.

The first factor suggests a possibility related to the distribution of information that occurs within a class. There is prior research regarding the role that people play in the actual distribution of information within a society. For example, Allen & Cohen showed that when new information flows within a group, there are people who have a role in bringing the information together and spreading it to those around them (Allen & Cohen, 1969). In this study, it was possible to identify students who demonstrated leadership during the exercise time by calculating eigenvector centrality. Students with higher values of eigenvector centrality reached the solution faster in the entire class. Thus, they were responsible for sharing the information leading to the solution with the entire class. Figure 8 also shows that the classes that collaborated in the experiment differed from question to question in terms of the students who showed leadership. This result indicates that the role of the students differed from question to question. The fact that we were able to collect data on these results is one example of the usefulness of this system.

The second factor is a possibility regarding the increase in the percentage of solution achievement groups. This possibility is easy to understand. Once students in the solution achievement group have gained sufficient understanding, they will not return to their original state. The transition in which a monotonic increase is expected indicates that the class progressed smoothly. Therefore, we can say that the factor causing the monotonic increase is the teacher. By utilizing these results, it may be possible to evaluate teachers' classroom management.

The third factor suggests that the individual student's own atonement may have been at work. Atonement is the act of agreeing with the opinions and arguments of others, which is different from collaboration, the act of collaborating with one another. Consider a situation such as the Share Screen (see Figure 1), where the class's goal achievement status is recognizable. When about half of the class occupies a solution achievement group, students who do not belong to that group will be willing to join it. It is then conceivable that they may have moved to the learning achievement group regardless of their degree of understanding. We need to conduct an experiment with and without the Share Screen. This experiment should be conducted as a future study.

It is necessary to continue to investigate the degree of fitting of the sigmoid function to the transition of exercise time and solution achievement groups. Assuming that the transition between exercise time and solution achievement group fits the sigmoid function, this can be used to estimate the time to discontinue the exercise time. If this estimation can be achieved, the exercise time can be appropriately managed.

5.2. Prediction of overall class goal achievement

A model was created to predict the subsequent transition in the ratio of students who achieve their goals based on the ratio of students who belong to the goal-achieving group. As a result, it was found that an approximate equation similar to the actual data was obtained when the percentage of students in the target achievement group exceeded 20% of the entire class.

Further research is needed to determine the true meaning of this 20% value, but the following can be expected. The number of students in this class is 31. Therefore, the actual number of 20% students is about 5. It is obvious that a certain number of students is necessary for the initial stage of information diffusion. Therefore, for information to be spread, a certain number of people who have reached the target is necessary. It is highly likely that this number is 20% of the total number of people. As a source of information to explain one hypothesis, we take up "Diffusion of Innovations" (Rogers, 2003). This is a measure of the percentage of diffusion of a new product or service in the market. It classifies the diffusion process of new products as innovators, early adopters, early majority, late majority, and laggards, in descending order of the timing of adoption by consumers. Those classified as innovators have high information sensitivity and curiosity to actively adopt new products. Early adopters are sensitive to trends in between and in the industry and are always on the lookout for information and make decisions. The early majority is strongly influenced by the early adopters and acts as a bridge to the market as a whole. Late Majority are those who tend to carefully listen to what is going on around them and consider hiring. Laggards are those who are the most conservative and have no interest in new things.

Reading the original paper (Rogers, 2003), we found that the combined percentage of innovators and early adopters is close to 20%. Based on this idea, about 15~20% of the population is needed for information to be widely spread. Transferring this indicator to this study, it is suggested that if 15~20% of the students reach the objectives, it may be possible to diffuse the information to reach the objectives to the entire class. Therefore, the emergence of early adopters may be a factor that determines the length of the exercise time. Figure 5 shows that questions 1 and 7, which took longer to reach six solution achievement groups (about 20% of the entire class), took longer exercise time than the other questions. Therefore, this idea could be used to provide facilitation assistance to teachers.

6. Conclusion

In this study, the data presented by the system suggested that new indicators may have been discovered. Specifically, the value of eigenvector centrality could be used to evaluate students as a measure of leadership. When learning objectives are achieved by about 20% of the students, the information that solves the question is widely diffused throughout the class. In other words, this indicator could be used to support teachers' facilitation during the exercise time.

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