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A SYSTEM TO ANALYZE AND SUPPORT LEARNERS' SPONTANEOUS INTERACTIONS

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Abstract. *There exist numerous learning activities wherein groups aim to build knowledge through problem-solving activities using computers. These activities are called computer supported collaborative learning (CSCL). The CSCL system allows learning analysis based on learners' motivations and movements. We thus developed a system that records interactive data on learners' interactions with each other. This system can also visualize the interactive data obtained from the system. We then used the "attention, relevance, confidence, and satisfaction" (ARCS) model to investigate the effectiveness of the developed system. The model confirms that the attention and confidence for teaching after the experiment was higher than that before the experiment. The results thus suggest that learner's attention and confidence in teaching can be improved by using our developed system.*
Keywords: Learning analysis, CSCL, ARCS model

1. **Introduction.** The spread of digital devices in schools has allowed the proliferation of e-learning systems. Educational systems support the learning activities of the learners. They also support learners' motivations and movements. These systems are aimed at supporting learners, teachers, and analysts in the learning process. For example, the learning management system (LMS) is a typical e-learning system that allows teachers to distribute

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handouts and assignments to learners online as well as monitor learners' work on assignments [1]. It is also used as a platform for discussions among learners and teachers. This system is used in universities for liberal arts lectures and classroom lectures on specialized subjects. Matsuzaki et al. [2] developed an educational system where students can easily observe the difference in motor responses when different control methods are used. Their research aims to bridge the gap between knowledge learned through university lectures and practical application of motors used in embedded systems'/electronics/mechatronics equipment.

In this digital learning milieu, cloud technologies have enabled learners to access online courses both synchronously and asynchronously. Massive online open courses (MOOCs) [3], for example, are typical online learning contents. MOOCs allow learners to take online classes in any location and at any time, as far as learners have Internet access.

Recent research on learning analysis has been focusing on the development of educational systems. In this discipline, learning analytics involves the measurement, collection, and analysis of learners' data and contexts for understanding and optimizing learning and environments thereof [4].

Sun et al. [5] developed a system for grasping the learning status of learners in remote areas during online classes. The feature of the learner's face is used to estimate his or her learning state. The learning state is estimated from the collected data using ensemble learning. Ji et al. [6] developed a learner activity model by using a computer supported collaborative learning (CSCL) system, and classified learning activities for each learner. Phielix et al. [7] investigated the effectiveness of peer feedback and reflection tools. In their study, learners had a positive attitude toward solving a collaborative problem when the learner used the given tools. This report describes the learners' relationships, that is, generally, learners' interactions change dynamically [7]. However, the current research does not consider this aspect.

Collaborative learning is a situation wherein two or more people learn together [8]. That is, learners interact with other learners to organize their knowledge and lead themselves to authentic learning, which, in turn, refers to a wide variety of educational and instructional techniques focused on applying taught knowledge to real-world scenarios [10]. This process of authentic learning is underpinned by a learner's motivation.

As noted above, Ji et al. developed a CSCL system in their study. This system refers to collaborative learning that is supported by computers [9]. CSCL systems allow learners to solve issues by communicating with each other. Despite their importance, few studies analyze these systems and their effectiveness in improving learners' motivation.

CSCL systems also help teachers provide appropriate information from the educational system. Even if such a system records a large amount of data during class and provides them to the teacher, there exists high possibility that teacher burden would increase. Chatti et al. [11] reported that an increase in the number of groups makes the amount of information available burdensome to the teachers. Therefore, the system should be designed to simplify the output of information in real time, wherein the system provides information to the teacher during the class. It is also necessary to design a system for visualizing learners' relationships in reflection activities for teachers.

In this study, we report on our CSCL system, which aims to achieve authentic learning and improve learners' motivation. The system can also visualize interactive data obtained from its own framework. Further, we investigate the effectiveness of the system using the "attention, relevance, confidence, and satisfaction" (ARCS) model.

The remainder of this paper is organized as follows. In section 2, we briefly explain the design of our system and the data flow thereof. In Section 3, we provide an overview of the experiment to investigate the effectiveness of the system. In Section 4, we show the results of the experiment in Section 3. It also discusses the effectiveness of the system based on the results. Section 5 concludes the study.

2. **Design of System.** Figure 1 shows the schematic view of the relationship between the system and learners. We develop the system to obtain data to determine whether learners engage in authentic learning. Each learner uses a tablet terminal to access the system.

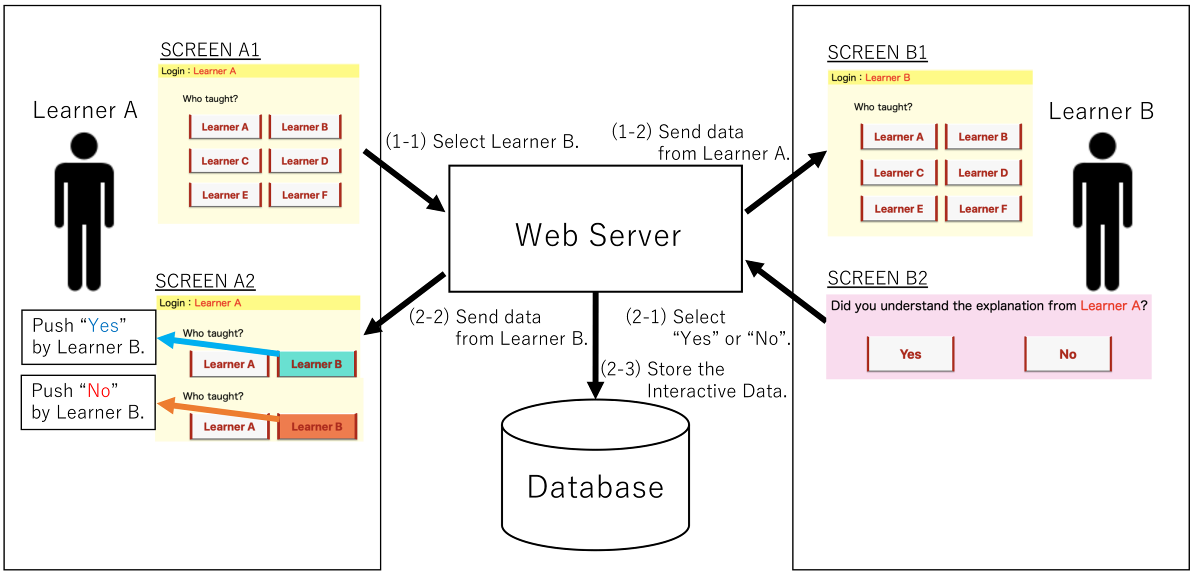

FIGURE 1. Schematic view of the relationship between the system and learners

In Figure 1, learner A already understands the lesson, and learner B does not understand the lesson. After learner A teaches learner B,

(1-1) learner A pushes the button labeled "Learner B" in SCREEN A1 of learner A's tablet; and

(1-2) the information that learner A pushes the button labeled "Learner B" is sent to learner B's tablet via a web server.

SCREEN B2 pops up on SCREEN B1 of learner B's tablet. Then,

(2-1) learner B selects "Yes" or "No" to answer the question "Did you understand the explanation from Learner A?" shown in SCREEN B2;

(2-2) the information that learner A pushes the button labeled "Learner B" is sent to learner B's tablet via a web server. When learner B answers "Yes", the background color of the button labeled "Learner B" changes to blue on learner A's tablet. In contrast, when learner B answers "No", the background color of the button labeled "Learner B" changes to red on learner A's tablet; and, finally,

(2-3) the system stores the following data as a .csv file: (I) teaching learner is learner A, (II) learning learner is learner B, (III) the time when learner B evaluates learner A, and (IV) whether learner B understands the contents of the lesson. The data in (I) to (IV) are recorded in the database on the server. Data (I) to (IV) are called "Interactive Data".

3. **Experiment.** To verify that the interactive data can be recorded and visualized, and to investigate the effectiveness of the system, we conducted an experiment in a mathematics class at an elementary school on March 12, 2019. We used the system in Section 2. There were 27 learners who had, at the time, used a tablet at least once a week. This class also followed an active learning style. A handout, as shown in Figure 2, was used in the class. This handout comprised three touched circles: two of similar size. Their centers were connected, creating a triangle. A field was included for learners to write the answer regarding the perimeter of the triangle and label the type of triangle. The goal of

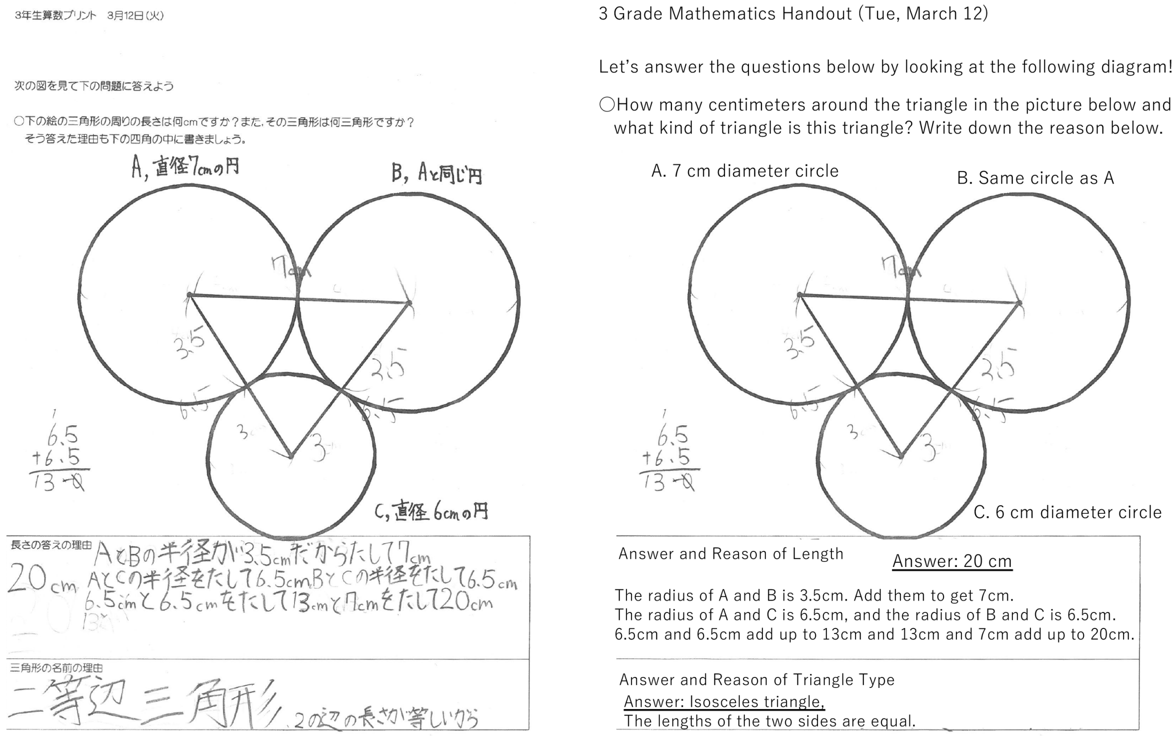

FIGURE 2. Example of the handout (Left: Original in Japanese; Right: Translation to English by the authors)

the lesson was to understand the answer to the handout and explain the reasons for the answer. These learners were required by their teacher to clarify if they could explain the lesson before teaching it to other learners. We recorded the number of learners who had achieved this goal in the evaluation sheet. Those learners that teachers considered proficient in presenting were allowed to explain to other learners. When the learner explained to other learners, the latter operated the system to record the learner who was teaching. Finally, 35 minutes out of the 45 minutes of the class were scheduled for exercise time.

We also conducted a pre/post-questionnaire survey based on the ARCS model [12] to verify for learners' motivation. Table 1 reports the questions used for this questionnaire. The question items were measured on a six-point Likert scale (1: negative $\sim$ 6: positive).

4. **Result and Discussion.**

4.1. **Visualization of interaction data.** In this experiment, the system collected 51 interactive data. The data were necessary to process the recorded data appropriately. The system is then expected to feed them back to the teacher. Note that visualization should be considered separately during the lesson and reflection.

During class, teachers are required to play multiple roles; therefore, information supplied to them should be minimized. By using interactive data during class, the system generates Figure 3. Figure 3 classifies the learners who seem to be engaged in authentic learning (Groups A, B) versus those who are not (Group C). Among the first groups of learners, the system further classifies learners who have reached their goals by themselves (Group A) and by interacting with others (Group B). These were categorized based on Zone of Proximal Development, proposed by Vygotsky [13]. si in Figure 3 represents a learner with attendance number i ($i = 1, \ldots, 28$) (Since s25 was absent, this learner was not shown in this paper.). Using Figure 3, only learners' status was presented to the teacher, and they were allowed to select the required intervention.

Table 1. Questionnaire survey

Questions	Factors	Contents
Q1	Attention	Do you like teaching to your friends?
Q2	Relevance	Is teaching your friends important?
Q3	Confidence	Are you confident in teaching your friends?
Q4	Satisfaction	Are you happy with teaching your friends?
Q5	Attention	Are you interested in teaching friends who were not able to solve the problems?
Q6	Relevance	Is teaching friends who are not able to solve problems important?
Q7	Confidence	Did you teach your friend, who could not solve the problem?
Q8	Satisfaction	Are you happy when you teach your friend, who could not solve the problem?
Q9	Attention	Do you like learning with your classmates?
Q10	Relevance	Does learning with your classmates give you a skill that would be useful in future?
Q11	Confidence	Are you confident of studying with your classmates?
Q12	Satisfaction	Are you happy to study with your classmates?

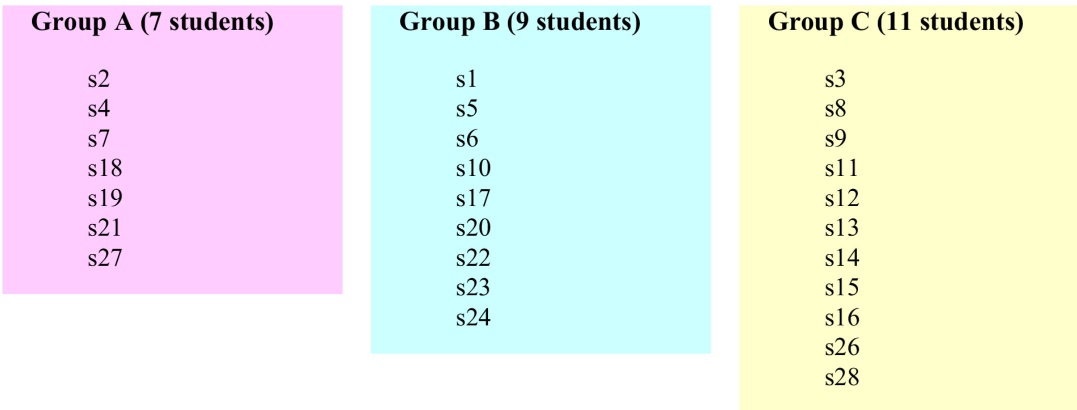

Figure 3. Visualization of the interaction data in real time during class

Table 2. Relationship between interactive data and teacher's evaluation

		Interactive data		
		Group A	Group B	Group C
Teacher's evaluation	Pass	s2, s4, s7, s18, s19, s21, s27	s1, s5, s6, s10, s17, s20, s22, s23, s24	s12, s16, s28
	Failure	non	non	s3, s8, s9, s11, s13, s14, s15, s26

Table 2 shows the interactive data and evaluation sheet summarized by the teacher. Here, s12, s16, and s28 did not teach anyone by analyzing interactive data, although the teachers judged them to pass. The result suggests that these learners might be reluctant to interact or have problems with interaction. This makes it necessary to carefully observe learners in this cell. Thus, the interactive data could grasp learners' interactive status during class.

On the other hand, in reflection activities, teachers are required to observe the class in a wide range of views. In retrospective activities, a method that provides more information than the method proposed during class is needed. The latter method extracts only the learners' status from interactive data. However, we use other interactive data and generate Figure 4. The lower-right legend shows the groups classified in Figure 3. The starting

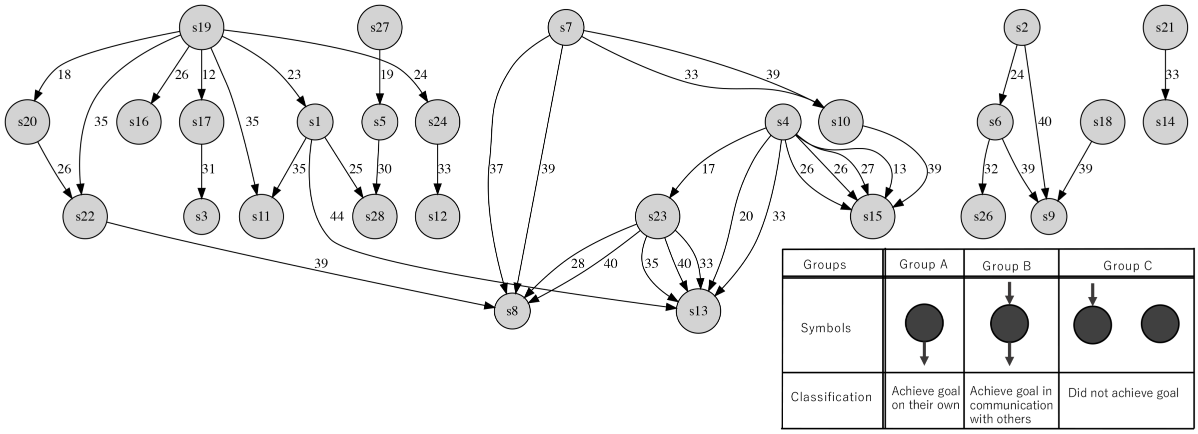

FIGURE 4. Visualization of interaction data for the reflection activities

point of the arrow represents the teaching learner, and the end point is the learning learner. The arrow line shows the evaluation of "Yes" by the learning learners. The evaluation of "No" by the learning learner was not used in the drawing in order to avoid complexity. The number beside the arrow indicates the time at which interactive data were recorded since the class started.

In Figure 4, an arrow indicates the direction of a learner belonging to Group A with respect to a learner belonging to Group B. Another arrow connects a Group A or B learner to a Group C learner. When checking the time while the interactive data were being recorded, we found that the time when the arrow is pointing from Group A or B to Group C is larger than when it is pointing from Group A to Group B. This result might represent the transmission of knowledge from Group A to Group B, and then to Group C. Thus, a teacher may refer to Figure 4 in order to determine whether the lesson was a planned movement.

These results suggest that visualization of the interactive data may clearly grasp learners' interaction. Further, Figure 4 can be used as a teaching support by teachers.

4.2. **Improvement of learners' motivation.** Learners' motivation was analyzed from the results of the pre/post-questionnaire survey. Each factor in Table 3 is based on the ARCS model [12] and Table 1. The number of full scores shows the number of learners who answered "6" in all questions of each factor in the pre-questionnaire survey. We observed full scores in the pre-questionnaire among three learners for "attention", 15 for "relevance", 5 for "confidence", and 13 for "satisfaction". Since we cannot investigate learners' improvements, we excluded this analysis. Then, the average value for each factor of the class was calculated. The analysis results are shown in Table 3.

We also performed a t-test on the average value for each factor: "Attention" and "confidence" for teaching after the experiment were significantly 10% higher than those before the experiment. In contrast, there was no significant difference in "relevance" and

TABLE 3. Results of the pre/post-questionnaire survey based on the ARCS model ($n = 27$)

Factor	Pre (S.D.)	Post (S.D.)	p value
Attention	4.85 (0.76)	5.07 (0.87)	*
Relevance	5.19 (0.50)	4.94 (1.63)	n.s.
Confidence	4.48 (1.23)	4.77 (0.93)	*
Satisfaction	5.14 (0.56)	5.02 (1.12)	n.s.

*: $p < 10\%$

"satisfaction" before and after the experiment. Therefore, the attention and confidence of learners significantly improved after the experiment (Although we also performed the t-test on the average value of each factor included for learners with full scores, these results did not change).

According to the model-view-presenter model [14], interest, curiosity, motives, and values are connected to the effort of direction, initiation, and persistence. The results show that the action of teaching was interesting for the learners. Further, the learners felt successful. We can thus infer that using this system significantly improves attention and confidence, and motivates learners to start and continue teaching.

5. **Conclusion.** We described the development of a system for recording and visualizing interactive data in collaborative learning. The information required by the teacher varies depending on the situation. Therefore, a method was introduced to visualize interactive data during class and for reflection activities. The results of visualizing interactive data from the experiment suggest that it is possible to clearly grasp the interactive status of learners. Based on the pre/post-questionnaire survey using the ARCS model, we verified improvements in attention and confidence for teaching. In the future, we plan to pursue the following. 1) We will use this system for other subjects to verify whether it is possible to clearly grasp the interactive status of learners, as in mathematics. 2) We will create an algorithm to find the key person in the class, as in Figure 4.

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