

Learning Visualization System to Improve the Community Sense and Learning Behavior in Class

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This study aimed to evaluate whether visualizing others' note-taking situations can help learners perceive a sense of community and influence their in-class learning behavior. We added a new marker feature to the Nudge for Note-Taking Assist System (NoTAS), a tablet-based note-taking support system developed based on the nudge theory, which provides small triggers to encourage people to change their behavior. NoTAS can visualize where learners have written using data collected in real time. NoTAS visualizations were categorized into three types: "notes," "important," and "unclear." We divided the 40 participants into two groups based on whether they used NoTAS visualization in class. The questionnaire results revealed that the visualization of others' note-taking situations improved learners' sense of classroom community and social presence. Despite no significant difference in the number of descriptions, the results of the correlation analysis demonstrated that the visualization types had varied effects on learning strategies. Nudges produced by visualizing important elements directly promoted note-taking, whereas nudges produced by visualizing notes and unclear elements promoted behaviors such as listening to the teacher's explanation and reading the material.

Keywords: Nudge, Learning Visualization, Note-Taking, Community Sense, Learning Behavior

Introduction

Self-Regulated Learning

In its Learning Compass, a vision for the future of education, the OECD (2019) indicated that learners need to develop self-regulated learning (SRL) competencies. Those with SRL have the ability to cycle through forethought, performance, and reflection on their own to learn effectively (Usher & Schunk, 2018). Learners plan through task analysis and control motivation in the foresight phase. In the execution phase, learners use learning strategies to monitor their learning while following the plan. In the reflection phase, learners reflect on their learning and improve their plans. These three phases enable learners to learn effectively. Furthermore, Hadwin et al. (2018) proposed co-regulated learning (Co-RL) as a recent trend in research on regulated learning. Co-RL refers to learning to regulate one's learning through interaction with others, such as temporary support, guides, and nudges.

Effective Learning Strategies for Developing Self-Regulated Learning

In-class note-taking is an effective learning strategy for developing SRL, particularly in the performance phase (Zimmerman et al., 1996). The two key features of note-taking are encoding and storage functions (DiVesta & Gray, 1972). The encoding function facilitates recognition

processing by combining the learning content with the learner's prior knowledge through note-writing. The storage function enables effective review via note reading, while in-class note-taking applies to the encoding function. Many studies on note-taking have concentrated on improving academic performance, and a meta-analysis conducted by Kobayashi (2006) suggested that storage functions associated with reviewing one's notes play an important role. On the other hand, many studies have been on encoding functions in recent years. Luo et al. (2018) found that longhand note-taking improves conceptual understanding because learners can relate and organize concepts using diagrams and symbols such as arrows. Furthermore, Frag et al. (2022) developed NoteCoStruct, a social system to support note-taking during video-based learning. NoteCoStruct allows learners to share comments with each other as the video progresses and facilitates critical and self-reflective note-taking. Thus, learners' constructive note-taking from a critical and reflective perspective is effective for review and SRL.

However, not all learners are capable of constructive note-taking that allows them to organize and relate content in class. Morehead et al. (2019) suggested that many learners take notes in class but cannot write what a teacher wants them to write because they have few opportunities to learn effective note-taking strategies. One way to support this is to distribute class materials that clarify the main points of the lesson (Kiewra, 1989). Writing directly on class materials can also facilitate students' understanding (Avval et al., 2013). However, Lannone and Miller (2019) suggested that even when teachers distribute materials, only a few learners take organized notes on the teacher's explanations. Therefore, support beyond the distribution of materials is needed to encourage learners to take notes.

Who Provides Feedback on Note-Taking?

It is challenging for teachers to teach content and learning strategies within the limited time allotted for a class (Nilson, 2013). Therefore, we propose a method in which learners support each other's learning behavior, such as note-taking, by sharing each other's learning situations in real time. One of the systems for visualizing others' learning situations is Metaboard, a learning analytics dashboard that supports learners' metacognition and SRL by visualizing the location of others' notes and highlights on class materials (Chen et al., 2020). Chen et al. (2020) focused on the acquisition of metacognition during SRL by individuals and revealed that learners promoted metacognition by visualizing the learning behavior of others using Metaboard. Therefore, the visualization and sequential feedback of learning behaviors such as note-taking by others can enable SRL, in which learners can monitor their own notes and understanding, making necessary regulations as required. However, it is not clear whether visualization of others' learning can promote interaction among learners and how it affects their learning behavior.

Ryan and Pintrich (1997) indicated that while the use of help-seeking strategies is essential for effective SRL, learners with low social motivation are unable to ask others for help. Therefore, for interactions among learners to be active, they must have a sense of classroom community. Rovai (2002) defines the sense of classroom community as the belief among members that their educational needs will be met by working on a common learning goal. If students get a sense of the classroom community in the class, they will feel a sense of humanity and help each other improve their learning behaviors. Furthermore, we assume that a favorable perception of other learners' presence is necessary to facilitate their interaction. This concept can be rephrased as social presence, which Short et al. (1976) defined as the level at which learners perceive the characteristics of others through interactions with them using media. Therefore, if learners' social presence is improved by visualizing others' learning behavior, they may be able to use the visualized information as a reference for their own learning and note taking. In summary, we need to evaluate

whether interaction among learners is promoted from the perspective of the sense of classroom community and social presence.

Nudge Theory for Promoting Behavioral Change

Enhancing learners' sense of community and promoting interaction, such as Co-RL, is crucial to foster learning behaviors that take high-quality notes to facilitate successful self-regulated learning. Thus, we focus on promoting interaction among learners using the "nudge theory," which has been studied extensively in the field of behavioral economics. Thaler and Sunstein (2009) define a "nudge" as any element of choice behavior that changes people's behavior predictably without narrowing the choice or significantly changing the economic stimulus. In other words, a nudge is a small trigger that encourages the behavior of a few people and then spreads to the whole group. Although this concept has been applied to educational studies, most of this research is confined to examining the policies of educational organizations, such as increasing the number of students who earn credits and reducing dropouts; few have applied nudges to support learning behaviors in class (Weijers et al., 2020). Mohammadhassan et al. (2022) suggested that scripted nudges that encourage students to refer to others' comments in response to the content of their writing could promote self-reflective and self-explanatory notes in video-based learning. However, checking others' writing may be ineffective in class because of its high cognitive load. For example, visualizing the location of others' notes and highlights on the class material, such as the Metaboard developed by Chen et al. (2022), could work as a nudge in class. Therefore, we hypothesized that real-time visualization of others' note-taking situations could play the role of a nudge, facilitating learners' interaction and improving their own note-taking.

Purpose

This study aimed to evaluate whether visualizing others' note-taking situations can help learners perceive sense of community and influence their in-class learning behavior. Specifically, we examined the following research question:

1. Does the visualization of others' note-taking situations improve learners' sense of classroom community and social presence?
2. Does the visualization of others' note-taking situations increase the amount of writing?
3. What types of visualizations contribute to in-class learning behavior?

System Design

In this study, we modified the Nudge for Note-Taking Assist System (NoTAS) developed by Kondo et al. (2021) for use in our experiments. NoTAS was designed as a note-taking application and system that allows learners to assist each other with note-taking and other learning behaviors. NoTAS achieves this by using color-coded visualizations of the number of notes and highlights made by other learners on everyone's materials using the collected notes and highlights logs. As this layer overlaps with the number of learners in the class, the color becomes darker as more learners fill in the same part. As a result, areas written by more learners were emphasized. Thus, NoTAS aims to improve note-taking through interactions among learners, with the visualization function acting as a nudge.

NoTAS includes a pen and marker feature for note-taking (Kondo et al. 2021). To allow learners to grasp each other's understanding of the class material, we added a marker feature specifically for unclear elements of the material and designed it to appear in a color different from that used for the existing pen and marker features. Figure 1 shows an example of the visualization function of the NoTAS. The dark red border shows one's own description, and the green border shows the

visualization of others' notes and highlights. The visualization colors indicate the following: The red areas indicate that other learners wrote notes. The yellow areas indicate that other learners highlighted important elements. The blue areas indicate that other learners highlighted unclear elements.



Figure 1. NoTAS note-taking and visualization interface

Methods

Participants

We recruited undergraduate and graduate students enrolled at a science university in Japan to participate in an educational system evaluation experiment. We selected the dates with the largest number of participants to determine experimental days and divided the 40 participants (24 males, 16 females; mean age of 22.5 years) into experimental and control groups. Although this study did not allow for random sampling, we assessed the bias of the two groups using a pre-questionnaire.

Procedure

Figure 2 illustrates the research procedure. This study was conducted in October 2021 and May 2022. This time gap is due to the difficulty in conducting face-to-face classes during the COVID-19 pandemic.

First, the participants listened to a description of the experiment and signed an informed consent form. Next, they completed a pre-test and pre-questionnaire administered using Google Forms. They then received a tablet device (iPad 6th) and a tablet pen and practiced using NoTAS. The experimental group took the class using the NoTAS visualization function and the control group took the class without it. The class content comprised four instructional design theories: andragogy, goal-based scenario theory, the jasper project, and a training procedure. Because the experimental and control groups were placed separately, a class video of approximately eight minutes was created for each content to ensure that there was no difference in the content between the classes. In the class video, the teacher displayed the class materials that had been distributed to the learners on

the screen, wrote on the board, and provided explanations. Learners watched the video on a projector and wrote on the class materials using NoTAS. Furthermore, the number of class materials was set to four for each content, and the types of descriptions that the teacher wanted the learners to write were standardized. We classified note-taking with reference to Luo et al. (2018), using the following items to determine the number of descriptions for each content: one teacher's writing on the board, one fill-in-the-blank, five oral explanations, four important highlights, one unclear highlight, and four symbols.

Furthermore, five collaborators (who were not participants) wrote what the teacher wanted the learners to write following the class progress because if none of the learners wrote notes or made highlights, no visualization would have appeared, and we could not have been unable to evaluate the effectiveness of the NoTAS visualization function. Thus, the collaborators wrote notes and intervened with the participants using the visualization function. Finally, they completed a post-questionnaire survey.

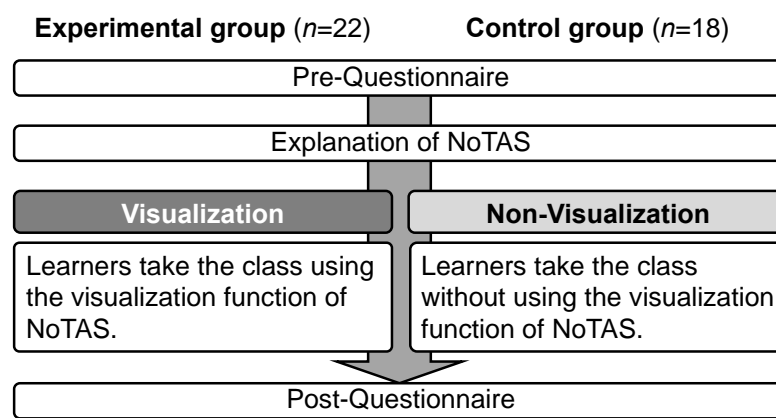


Figure 2. Research procedure

Data Collection

Quantitative data were gathered from the questionnaires answered by the participants before and after the class. The pre-questionnaire asked about the participants' age, sex, and experience with note-taking using a tablet. We incorporated three perspectives into the post-questionnaire.

Sense of Classroom Community. We used 15 items from the Sense of Classroom Community Index (SCCI) developed by Rovai (2002). We revised the items of the scale to be more consistent with this study's purpose. Furthermore, we created three new items related to in-class learning behaviors and learners' interaction in the class. All items were answered on a 5-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*).

Social Presence. We adopted three items proposed by Short et al. (1976) to measure social presence: unsociable–sociable, impersonal–personal, and warm–cold. It employed a semantic differential method with a bipolar 7-point scale, following Short et al. (1976).

Visualization. We created 14 items for the Visualization Scale to examine the impact of NoTAS visualization on learners. This scale consists of three visualization types: six items for the visualization of others' notes, four for the visualization of others' important elements, and four for the visualization of others' unclear elements. These items were answered only by the experimental group on a 5-point Likert scale. We also asked two open-ended questions regarding the advantages and disadvantages of the visualization function.

We evaluated the number of descriptions in the note-taking logs collected by NoTAS to confirm whether the visualization function improved the amount of note-taking.

Note-Taking Log. NoTAS can track what learners wrote, when they wrote or deleted notes, and which parts of the class materials they highlighted. We used this log to score each description that the teacher wanted learners to write on the class materials. The description types were transcriptions, notes, important highlights, unclear highlights, and symbols.

Guidelines for Analysis

We treated the reversal items for the results of the questionnaire items and modified them so that the higher the mean score, the higher each item. Second, we conducted a Shapiro–Wilk test for each item to check for normality. The results indicated no normality of the distribution. Therefore, we chose to use a nonparametric test.

We compared the SCCI and the social presence scale with and without visualization using a Mann-Whitney U test to investigate whether learners perceived others' awareness by using NoTAS visualization (RQ1). Next, we compared the amount of description scored from note-taking logs with and without visualization using a Mann-Whitney U test to assess whether NoTAS improves the amount of note-taking (RQ2). Finally, we analyzed the Spearman's rank correlation coefficients between the visualization scale and some SCCI items for the experimental groups to investigate how each type of visualization (notes, important elements, and unclear elements) affected learning behavior (RQ3). Furthermore, we summarize the advantages and disadvantages of NoTAS visualization using open-ended questions.

Results

The 40 participants completed the questionnaires. The 22 learners in the experimental group (who used the visualization function of NoTAS) consisted of 13 males and nine females, with an average age of 22.3 years. The 18 learners in the control group who did not use the visualization function consisted of 11 males and seven females, with an average age of 22.7 years. We conducted a chi-square test on the pre-question "Have you ever used a tablet device (iPad, Chromebook) and a tablet pen for note-taking in a class?" The results showed no significant differences between the experimental and control groups ($\chi^2(1) = 0.00$, n.s., $p = .01$). Furthermore, none of the learners studied the four theories of instructional design taught in the class.

Results for Sense of Classroom Community

Table 1 shows the results of the Mann–Whitney U test for the SCCI scores. The index was reliable, with a Cronbach's α of .88. The experimental group was denoted as "Visual" while the control group was denoted as "Non-visual." The results revealed significant differences in the sense of classroom community score and the 11 items, with a marginally significant difference for one item. The mean scores were higher in the Visual group than in the Non-visual group for all items.

Social Presence Results

Table 2 shows the results of the Mann–Whitney U test for the social presence scores. The index was reliable, with a Cronbach's α of .88. The results revealed significant differences in social presence scores and the three items; the mean scores were higher in the Visual group than in the Non-visual group for all items.

Table 1

Sense of classroom community comparison

Item	Visual		Non-Visual		$M_{vis}-M_{non}$	U	r
	M_{vis}	SD_{vis}	M_{non}	SD_{non}			
Sense of Classroom Community Score	3.45	0.54	2.38	0.45	1.07	23.00***	0.88
1. I felt that learners in this class cared about each other.	2.50	1.34	1.89	1.28	0.61	143.00	0.28
2. I felt that I was encouraged to ask questions.	2.59	1.14	2.22	1.00	0.37	160.50	0.19
3. I felt uneasy exposing gaps in my understanding. (R)	3.82	1.40	3.50	1.43	0.32	174.50	0.12
4. I felt connected to others in this class.	3.95	1.09	1.11	0.32	2.84	3.00***	0.98
5. I did not feel a spirit of community. (R)	3.45	1.26	1.61	0.78	1.84	48.00***	0.76
6. I felt that this class resulted in only modest learning because of NoTAS use. (R)	3.68	1.29	3.11	1.37	0.57	150.50	0.24
7. I felt that I received timely feedback on my notes and highlights in this class.	3.36	1.18	2.00	0.84	1.36	76.00***	0.62
8. I trusted others in this class.	2.95	1.29	2.67	1.14	0.28	175.00	0.12
9. I felt isolated in this class. (R)	4.32	1.00	2.94	1.16	1.38	75.50***	0.62
10. I felt that I could rely on others in this class.	3.36	1.18	1.44	0.71	1.92	41.00***	0.79
11. I felt that other learners did not help me learn in this class. (R)	3.95	0.90	2.72	1.23	1.23	88.00**	0.56
12. I felt that members of this class depended on me.	1.73	0.88	1.22	0.55	0.51	131.00*	0.34
13. I could feel how the other learners were listening to the teacher's explanation in this class.	4.23	1.11	2.50	1.30	1.73	63.00***	0.68
14. I felt uncertain about others in this class. (R)	3.59	1.26	2.78	1.40	0.81	132.50 [†]	0.33
15. I found that the other learners were taking notes very diligently.	4.55	0.60	3.67	1.03	0.88	99.00**	0.50
16. I felt confident that others would support me.	2.91	1.11	1.61	0.85	1.30	74.00***	0.63
17. I felt that I had enough opportunity to learn how to take notes in this class.	3.18	1.22	3.06	1.16	0.12	182.00	0.08
18. I was curious about others' note-taking behavior.	4.05	1.33	2.83	1.43	1.22	88.00**	0.56

Visual: $n = 22$, Non-visual: $n = 18$ [†] $p < .100$, * $p < .050$, ** $p < .010$, *** $p < .001$

(R): Reverse score, 5-point Likert scale

Table 2

Social presence comparison

Item	Visual		Non-visual		$M_{vis}-M_{non}$	U	r
	M_{vis}	SD_{vis}	M_{non}	SD_{non}			
Social Presence Score	4.71	1.04	3.46	0.79	1.25	63.00***	0.68
1. Unsociable - Sociable	4.23	1.27	3.39	0.78	0.84	118.00*	0.40
2. Impersonal - Personal	5.09	1.19	3.50	1.20	1.59	70.50***	0.64
3. Warm - Cold (R)	4.82	1.05	3.50	0.86	1.32	74.00***	0.63

Visual: $n = 22$, Non-visual: $n = 18$ * $p < .050$, *** $p < .001$

(R): Reverse score, Semantic Differential method

Note-Taking Log

Table 3 shows the Mann–Whitney U test results for the amount of writing. We compared the number of descriptions that the teacher wanted the learners to write between the two groups. The description type and number of units set by the teacher were eight transcribing, 20 notes, 16 important highlights, four unclear highlights, and 16 symbols. The amount of writing was higher in the visualization group, but the difference was not statistically significant.

Table 3

Comparison of the amount of descriptions

Type of description	Visual		Non-visual		M_{vis-} M_{non}	U	r
	M_{vis}	SD_{vis}	M_{non}	SD_{non}			
1. Transcribing	6.68	1.89	6.56	1.15	0.13	158.00	0.20
2. Notes	4.46	4.07	3.67	2.47	0.79	192.00	0.03
3. Important highlight	8.27	4.49	7.11	3.38	1.16	164.00	0.17
4. Unclear highlight	0.32	0.65	0.33	0.49	-0.02	183.00	0.07
5. Symbol	2.41	2.44	2.17	1.92	0.24	194.00	0.02
6. Total Score	22.14	9.97	19.83	6.24	2.30	176.00	0.11

Visual: $n = 22$, Non-visual: $n = 18$

Correlations between Visualization and Learning Behavior in Class

We used the NoTAS visualization scale and three items from the SCCI (which were related to helping others) to identify which types of visualizations facilitated the students' learning behavior. The three items used from the SCCI were as follows: "7. I felt that I received timely feedback on my notes and highlights in this class," "10. I felt that I could rely on others in this class," and "11. I felt that other learners did not help me learn in this class (R)." We chose No. 7 because it revealed the types of visualizations from which learners felt they received feedback on their learning. We chose Nos. 10 and 11 to identify which learning behaviors tended to be exhibited by learners who relied on the visualizations of others and felt helped.

Visualizing Other's Notes. The results of Spearman's rank correlation coefficients between the red visualization of others' notes and the three SCCI items are presented in Table 4. The item "Timely feedback" significantly correlated with two items, "Writing notes myself" and "Listening to the explanation." The item "Rely on others" significantly correlated with two items, "Listening to the explanation" and "Drawing figures and tables."

Table 4

Correlation between visualizing others' notes in red and in-class learning behaviors

	Timely feedback.	Rely on others.	Others helped me learn.
1. I thought to write notes myself.	.43 *	.33	.09
2. I thought about listening to the explanation.	.49 *	.50 *	.33
3. I was curious about what others were writing.	.34	.17	-.09
4. I thought to draw symbols such as arrows and enclosures myself.	-.05	.34	.17
5. It was helpful for me to write notes and highlight myself.	.39	.33	.16
6. I thought of drawing figures and tables myself.	.28	.43 *	.22

Visual: $n = 22$, 5-point Likert scale

* $p < .050$

Visualizing Others’ Important Elements. The results of Spearman’s rank correlation coefficients between the yellow visualization of others’ important elements and the three SCCI items are presented in Table 5. The item “Timely feedback” was significantly correlated with “Listening to the explanation,” while the item “Rely on others” was significantly correlated with three items, excluding “I was curious about what others were writing.”

Table 5

Correlation between visualizing others’ important elements in yellow and in-class learning behaviors

	Timely feedback.	Rely on others.	Others helped me learn.
1. I thought to highlight myself.	.32	.66 ***	.34
2. I was curious about what others were writing.	.08	.18	.17
3. I thought about listening to the explanation.	.45 *	.50 *	.31
4. It was helpful for me to write notes and highlight myself.	.39	.68 ***	.38

Visual: $n = 22$, 5-point Likert scale * $p < .050$, *** $p < .001$

Visualizing Other’s Unclear Elements. The results of Spearman’s rank correlation coefficients between the blue visualization of others’ unclear elements and the three SCCI items are presented in Table 6. The item “Rely on others” was significantly correlated with “Listening to the explanation.”

Table 6

Correlation between visualizing others’ unclear elements in blue and in-class learning behaviors

	Timely feedback.	Rely on others.	Others helped me learn.
1. I thought to highlight myself.	.29	.14	.14
2. I was curious about what others were writing.	.33	.11	-.27
3. I thought about listening to the explanation.	.25	.54 *	.22
4. It was helpful for me to write notes and highlight myself.	.27	.19	.19

Visual: $n = 22$, 5-point Likert scale * $p < .050$

Usability of the NoTAS Visualization Function

In the open-ended questions, we asked learners who had used the NoTAS visualization function for its advantages and disadvantages. The advantages of visualization include content understanding, note-taking facilitation, learning motivation, and awareness of others. Table 7 presents specific examples. The disadvantage of the visualization had three reasons: visualization opacity, note-taking suppression, and concentration in class. Table 8 presents specific examples.

Table 7

Advantages of visualization

Advantage	Comments
Content understanding	<ul style="list-style-type: none"> • Because the important parts were visualized clearly, it was easy to understand what was important, even if I missed an explanation. • I found what was important in the material because I could see roughly what others had written.
Note-taking facilitation	<ul style="list-style-type: none"> • There was no right answer to note-taking, but I confirmed that my notes and highlights were correct. • It helped me understand where and when I should be taking notes.
Learning motivation	<ul style="list-style-type: none"> • I could visualize the importance of explanations, making it easier to concentrate. • I enjoyed taking notes.
Awareness of others	<ul style="list-style-type: none"> • I could know whether other learners felt the same way about the points I thought were important. • Each visualization color had its meaning, so I knew what others thought.

Table 8

Disadvantages of visualization

Disadvantage	Comments
Visualization opacity	<ul style="list-style-type: none"> • Reading the class material was difficult because other people's notes and highlights darkened the colors. • Places where many learners were writing, became very dark in color, making it difficult to see my description.
Note-taking suppression	<ul style="list-style-type: none"> • Learners who were particular about note-taking might feel that the visualization was distracting.
Concentration in class	<ul style="list-style-type: none"> • I focused too much on taking notes rather than listening to explanations. • I sometimes missed explanations because when others were writing where I was not, I wondered, "Why are they writing here?"

Discussion

Does Visualizing Others' Note-taking Situations Facilitate Interaction with Others?

The results regarding the sense of classroom community suggest that the learners felt a sense of trust and connection with each other when using the NoTAS visualization function. The learners felt that they received sequential feedback on their writing through interactions facilitated by the NoTAS visualization. In addition, the open-ended question of note-taking facilitation indicates that visualizations allow learners to determine where and when to write notes and highlights on the material. Thus, we suggest that when NoTAS visualizes others' notes and important/unclear elements, learners use the visualized information to guide their note-taking and reading of the class materials. Furthermore, the results for the items "I felt that other learners helped me learn in this class" and "I felt confident that others would support me" indicate that the visualization helped their learning not only through note-taking but also by sharing important and unclear parts of the material. Finally, the results for the item "I could feel how the other learners were listening to the

teacher's explanation in this class" show that the visualization influenced the learners' note-taking behavior and their attitude toward listening to explanations.

The results for social presence suggest that the visualization function enabled learners to feel a sense of humanity and to be sociable without needing to talk to each other. Thus, they enjoyed the presence of others in class.

Ryan and Pintrich (1997) indicated that effective self-regulated learning requires the enhancement of social motivation and mutual support among learners. Our results revealed that the visualization of others' note-taking via NoTAS increased the learners' sense of classroom community and social presence and promoted learner interaction. The visualization function of NoTAS positively impacted the other learners' awareness, as they had their attention directed toward the teacher's explanations noted by other learners. Therefore, NoTAS is an effective system to increase learners' social motivation and make them feel that they are helping each other in class. However, a floor effect was observed for many of the items in the no-visualization group. Rovai (2002) pointed out that the physical distance between learners is greater in online classes than in face-to-face classes, which decreases the sense of community. Although the sense of community has been studied in many online courses, our results suggest that even in a face-to-face class, it is difficult to promote a sense of community and learner interaction when the class is simply a lecture type in which the teacher explains.

Does Visualizing Others' Note-taking Situations Increase the Amount of Writing?

The note-taking log results, with and without NoTAS visualization, showed that the amount of transcribing, notes, important/unclear highlights, and symbols were higher in the group with visualization, but there were no significant differences. Therefore, we found that NoTAS visualization did not cause learners to write according to their teacher's expectations. There are two possible reasons for this.

First, as this study was conducted in a 30-minute class, more time may be needed to improve note-taking. Some open-ended responses regarding the disadvantages of NoTAS indicated that the visualization function could interfere with learners' note-taking. Furthermore, university students may be particularly interested in note-taking because of their past experiences. NoTAS can visualize where others have written, but not the content, so we assume that some learners may need to learn what to write. Therefore, learners must use NoTAS visualization in the long term, look back at their own notes, and improve them.

Second, it is possible that the support provided through the visualization of NoTAS may be insufficient to enhance the quantity of note-taking. For instance, Frag et al. (2022) demonstrated the effectiveness of providing step-by-step notes written by others in video-based learning to facilitate constructive note-taking. However, it is anticipated that checking the contents of others' notes in a class could be a high cognitive load for learners. Therefore, it may be necessary to support learners in providing complete notes and the others' notes after the class so that they can improve their own notes. However, some learners used visualization information for their own learning in the class; for example, "It was easy to understand what was important, even if I missed an explanation," and "Each visualization color had its meaning, so I knew what others thought" in the open-ended responses. Therefore, we hypothesized that different visualization types in NoTAS (notes, important elements, and unclear elements) might affect learning behaviors.

What Types of Visualizations Contribute to In-Class Learning Behavior?

The results of the correlation analysis between the visualization scale and the three SCCI items with assistance from others suggest that the visualization of others' learning situations can have different effects on learning behavior depending on the type of visualization involved (i.e., notes, important elements, and unclear elements).

Visualizing important elements encouraged learners to listen to the teacher's explanations and directly facilitated note taking, such as writing notes and highlighting text. Furthermore, based on the open-ended comments on content understanding, we found that learners paid particular attention to the visualization of others' important elements. This might have occurred because important elements of the text are often highlighted; therefore, it is not burdensome for learners to highlight them independently.

Visualizing notes encourages learners to listen to the teacher's explanations. Additionally, learners who felt that they received timely feedback during class tended to be motivated to write notes. A possible reason why visualizing important highlights and visualizing notes promote different learning behaviors is that they may involve different cognitive processes. Mueller and Oppenheimer (2016) pointed out that memo writing, in contrast to transcribing and highlighting, encompasses a multifaceted process of comprehending an explanation, selecting and integrating relevant information, and articulating it using one's own words. Thus, by viewing the visualization of others' notes, learners may have reviewed the material and paid more attention to the teacher's explanations rather than taking notes to understand the learning contents and select information. Furthermore, since NoTAS does not display the specific contents of notes in its visualization, learners who could not write notes did not know what to write. In fact, in the disadvantageous comments on the visualization function, it is conceivable that visualization may be an obstacle for learners to write notes. Therefore, visualizing others' notes may influence learning behavior, such as encouraging students to pay attention to the teacher's explanations rather than promoting writing in the material.

Visualizing unclear elements encourages learners to listen to the teacher's explanations. NoTAS highlights class material elements that other learners do not understand. This feature allowed learners to check whether they had understood the material as they listened to the teacher's explanations. Therefore, the visualization of unclear elements can indirectly encourage note-taking. However, there was only one significant correlation for the visualization of unclear elements. It is possible that the learners did not use this highlighting because the teacher could not intervene in the areas that they did not understand in this video-based class. In the future, it is necessary to investigate how learners' note-taking and learning behavior changed when the teacher explained the lesson based on visualizing unclear elements.

In summary, the visualization of important elements directly promoted learners' note-taking, while the visualization of notes and unclear elements made them more willing to listen to the teacher's explanation. Therefore, we suggest that three visualization types—notes, important elements, and unclear elements—affect several learning behaviors in class, such as note-taking and paying attention. Furthermore, the open-ended responses indicate that the visualization function enabled the learners to understand when to write notes, when to listen to explanations, and whether others could understand the class content. These results suggest that NoTAS visualization functioned as a pacesetter for learners in the class. These findings appear to provide support for Yen et al.'s (2018) assertion that leveraging technology to visualize assessment and feedback is an effective approach for increasing learners' awareness of and enhancing their own learning behaviors. However, the open-ended responses also indicate that visualization may inhibit note-taking and

learning. It is important to set the opacity of NoTAS visualization and carefully select classroom situations in which learners use the visualization feature.

Conclusion

This study aimed to evaluate whether visualizing others' note-taking situations can help learners perceive a sense of classroom community and influences their in-class learning behavior. We added a new marker feature to NoTAS developed by Kondo et al. (2021) specifically for unclear elements in class materials that was designed to appear in a different color than that of the existing pen and marker. We divided the participants into two groups, those with and without the NoTAS visualization function, and conducted a class.

The questionnaire results revealed that visualizing others' learning increased the learners' sense of community and social presence. Therefore, in a class where learners take notes on class materials, immediate sharing of the others' learning situations is likely to promote interaction among learners and lead to the formation of a community of learners. However, the note-taking logs revealed that learners who used the visualization function of NoTAS wrote more, but without a significant difference. One potential explanation for this result could be that excessively dense visualization inhibits note-taking. Hence, when offering sequential visualization feedback on the learning progress of other learners during class, it is important to set the opacity of the visualization and carefully select the class context in which to provide feedback, such as the visualization. Furthermore, the results of the correlation analysis indicated that nudges produced by visualizing important elements directly promoted note-taking, whereas nudges produced by visualizing notes and unclear elements promoted behaviors such as listening to the teacher's explanation and reading the material. Therefore, the findings demonstrate that different types of visualization have varied effects on learning behaviors. These outcomes suggest that nudges can be employed to enhance learning behaviors in class as well as educational policies. In conclusion, it is evident that nudges, which visualize the note-taking of others, offer timely feedback within the constraints of classroom time and foster the development of a learning community, thereby promoting various learning behaviors.

This study has some limitations that suggest avenues for future research. First, this study was a 30-minute class, and the learners' note-taking did not improve. In the future, through the long-term use of NoTAS, it will be necessary to verify whether the visualization of others' note-taking effectively improves one's own note-taking. Second, this study focused on in-class learning behavior, especially during the performance phase of the self-regulation cycle. Future research should investigate the impact of NoTAS on the forethought and reflection phases and the application of NoTAS in the development of self-regulated learning skills.

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