An Analysis of Online Bulletin Board Discussions Using Posting Transitions

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Abstract: Online discussion transitions were analysed as a means of furthering the development of critical thinking disposition of students and their attitude toward disaster mitigation. The discussion was organised as an additional learning activity during a fully online course. The participant's posted messages were analysed using a network analysis technique in order to promote discussion and learning performance. The posting chain was represented as an adjacency matrix and posting relationships were analysed. The results suggest that discussant's activity shows a hierarchical structure, with some participants posting in response to lecturer's instructions. Posting participants were classified into several clusters, and these characteristics were analysed. Though single-posting participants were not active discussants, their characteristics, including their learning performance, could be readily recognised correctly during the analysis.

Keywords: Online discussion, Network analysis, Critical thinking, Student's characteristics, Learning activity

1. Introduction

The ability to think critically may help people make assessments during emergencies such as natural disasters or social unrest. In order to develop this ability, theoretical procedures have been discussed (Rychen and Salganik, 2003; Kikuchi 2018). A practical activity to train critical thinking disposition (CTD) is suitable for certain types of discussions, including online forums (Ekahitanond, 2013; Trehan et al., 2017) has been recognised. Since the effectiveness of online discussions has been demonstrated (Kusumi and Tanaka, 2008; Leh et al., 2012), the authors have been conducting surveys of participant's CTD abilities and individual characteristics (Nakayama et al. 2021, 2022a, 2022b, 2023). However, evaluation of discussion activity is not easy because the discussion depends on the mutual relationships between discussants or on the topic presented. Though some lexical content analyses were introduced to extract the quantitative contents of discussions, assessment of individual performance was not easy (Nakayama et al. 2016; Teranishi et al. 2017).

Student's discussion activities have been analysed using qualitative and quantitative approaches, in particular some issues of the discussion style are discussed discussion style are examined through the change of the lesson format from face-to-face to online (Smith, 2019; Julien and Dockwah, 2020). In order to promote the discussion activity, collaboration by students and procedures that support discussion groups are required. These points have been examined through practical analyses and case study assessments (Gasparic and Pecar, 2016). In addition to the conventional analysis of the progress of discussions, more dynamic assessments using mathematical analysis of the transitions of speakers or postings (Li et al. 2022), or lexical analysis of discussion contents (Zara et al. 2018) would be preferred. Also, more anatomical approaches are required to extract the structure of discussions (Han and Xu, 2022). These analyses may reveal the developing progress necessary to acquire CTD abilities.

As discussion activity may depend on the development of robust communication, some relationships involving speaking-out or posting and reviewing the opinions of others may provide information about participant's individual contributions. Therefore, any analyses of activity where participants present their own opinions in discussions shows the ongoing stage of development of the desired disposition rather than simply analysing overall posting frequency or posted sentences.

In this paper, participant's discussion activities on a bulletin board, such as posting transitions, were analysed in order to understand their learning activity. The following topics will be addressed:

- Online discussion activity during participant's message exchange process was analysed using a network analysis technique in order to examine discussion activity that would further the ability to develop critical thinking disposition.
- By extracting discussion characteristics from a bulletin board, individual posting behaviour was classified and **the** ability to participate in discussions was evaluated using measured individual characteristics.

In order to analyse relationships between posting behaviour and individual characteristics, survey data from two years of classes at a Japanese university was introduced.

2. Method

The development of critical thinking disposition was observed during a regularly scheduled on-demand style fully online course at a university in Japan (Nakayama et al., 2021, Nakayama et al. 2023).

2.1 Learning Settings

The course was entitled the Psychology of Natural Disaster Mitigation and Prevention, and consisted of 15 sessions. Learning performance of participants was evaluated using several activities, such as weekly confirmation tests and report assignments. The course has been provided in fully online style since 2020. The lecturer recorded videos of his lectures in advance, and the video clips for each session were delivered using an LMS. The main methods of learning assessment during the course were online tests and report essay writing. The participant's essay reports were evaluated by the course lecturer using a rubric which was presented to participants in advance. The number of registered students was above 400. The valid number of essay report submissions was 440 in 2022, and 364 in 2023. In order to encourage better understanding of the subject matter, all participants were invited to participate in online discussions. Online discussion boards were available throughout the course, and participants could obtain additional marks which contributed to their final mark. This opportunity represented a significant incentive for students.

2.2 Survey Metrics

In order to extract the characteristics of participants in the class, the following inventories were surveyed during the course. In addition to individual characteristics such as personality and literacy, these are the targeted scales for critical thinking and disaster prevention abilities. In this project most metrics were measured continuously (Nakayama et al. 2021, 2022b), and some new metrics were introduced for the purpose of the current research. Though every metric has an independent measurement scale, rating comparisons between scales are not intended as a purpose of the research. These ratings will be compared using metrics of online posting activities in the following sections of the paper.

2.2.1 Personality (Big5)

Scores of participant's personalities were measured using a shortened version of the Big5 inventories, which consists of 10 question items (Kawamoto et al. 2015). The factors which were extracted were Extroversion (P1), Conscientiousness (P2), Neuroticism (P3), Openness (P4), and Agreeableness (P5). The factor scores of the Big5 use 7-point scales (1-7).

2.2.2 Literacy of science and technology (LST)

Kawamoto et al (2013) developed an inventory of science and technology literacy which is based on a survey of scientific literacy. It consists of 10 questions, from which four factors were extracted from the answers: Life-centered (LST-1), Sciencephile (people who are interested in science and technology) (LST-2), Logic-oriented (LST-3), and Authoritarian (LST-4). The LSTs were scored using a 4-point scale (1-4). Four clusters of LSTs were also defined in order to compare behavioural attitudes toward Social Science issues using the four dimensional factor scores (Kawamoto et al. 2013).

2.2.3 Critical thinking disposition (CTD)

Hirayama and Kusumi (2004) developed a Japanese inventory of behaviour exhibited during development of critical thinking. Four factors from the inventory were extracted: Awareness of logical thinking (CTD-1), Inquiry-mindedness (Inquisitiveness) (CTD-2), Objectiveness (Objectivity) (CTD-3), and Evidence-based judgment (CTD-4). These CTDs were scored using a 5-point scale (1-5). These metrics were surveyed twice, during the first and second halves of the course. The differential scores between the two surveys are also used in the following analysis, and the sum of the four factor scores is referred to as the CTD meta metric.

2.2.4 Disaster-prevention consciousness (DPC)

These inventories were developed to measure attitude toward disaster-prevention consciousness, and consisted of 20 question items using a 6-point Likert scale (1-6) (Ozeki et al. 2017). The total score is defined as the summation of scores for the 5 aspects (imagination for disaster situations, a sense of crisis about disasters, the degree to which other participants were spoken to, interest in disaster, anxiety, with the minimum score

being 20 and the maximum score being 120. This metric was also surveyed twice during the course, and the two scores were compared.

2.2.5 Weekly test scores (WTS)

The lecturer recorded videos of his lectures in advance, and the video clips for each session were delivered using the university LMS (a Moodle learning management system). All communications such as assignment submissions, online tests, essay report reviews and follow-up surveys were conducted using the LMS. Learning performance was evaluated using online evaluations such as short written tests which asked about course session topics (WTS).

2.2.6 Essay Report and Comments

An essay report task was assigned in order to evaluate student's in class performance, and was to be marked as part of their overall final grade assessment.

2.3 Discussion Activity Measure

Transitions of messages posted on the bulletin board were recorded. The record can be extended to a path of messages responding to a previous posting. The relationship between participants who posted is summarised as an adjacency matrix, as shown in Figure 1. In this matrix, columns and rows show individuals and the frequency of their messages which are responses is noted as a component. If the initial posting seems to be a self-tweet, then the posting is recorded as a diagonal component.

The features of online discussions recorded over two years are summarised in Table 1. Both the number of participants and the level of activity posting threads in 2023 is less than in 2022, as the activity may depend on participant's level of interest in the course content and motivation, even though all course environmental factors are the same.

1	5	1	2	1	3	3	1	0	1	1	0
0	5	1	2	1	3	2	2	0	1	1	0
0	1	0	2	1	1	0	0	1	0	0	0
0	1	2	4	0	0	0	1	0	0	0	0
0	1	1	0	1	1	0	0	0	0	0	1
0	0	0	0	0	4	0	1	0	1	0	0
0	2	0	0	0	2	1	0	0	0	0	0
0	2	0	1	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	1	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	1	0

Figure 1: An example of Adjacency matrix (a part of transaction in 2023 survey)

Table 1: Basic features of online discussion activities in two years

Year	2023	2022
Active members	364	440
N of participants for discussion (% in total)	34 (9.3%)	127 (28.9%)
one posting participant (% of participants)	20 (58.8%)	64 (50.4%)
threads	20	62
mean post frequency	2.85	2.37
max posting	20	12

3. Results

3.1 Summarising Discussion Network

Network analysis was introduced in order to illustrate posting activity. Here, all transactions in 2023 are summarised as a directional graph in Figure 2(a). All nodes are labelled with the numbers of each participant. The number "1" shows a lecturer who has joined as a facilitator. A self-loop shows initial postings by participants. Most initial presenters seem to post frequently as participants. Participants with single postings are located in the peripheral region, as shown by a single arrow line. These participants simply followed the postings of others. The network illustration can be also converted into a circle layout. As Figure 2(b) shows, more than half of the participants are represented as followers of the initial postings. As Table 1 shows, more than half of the participants were participants with single postings. In all discussions during the course, the number of discussion participants is limited. Figures 3(a) and 3(b) show focused networks for frequent submitters (i.e., a frequency more than 1). Even these participants are divided into several groups by their posting frequency.

3.2 Participant Clustering

As shown in the previous section, the behaviour of participants varies between individuals. In order to extract features of posting behaviour, a clustering technique is applied to the summarised adjacency matrix using a measure of betweenness centrality for nodes on the graph (Ognyanova, 2016). The dendrogram in Figure 4(a) summarises sub-groups which are similar. The horizontal axis represents the number of participants. The number "1" indicates postings by the lecturer. The summarised clusters are marked using colours on the graph illustration in Figure 4(b). The frequent posting communication cluster which includes the lecturer's posts in the centre of the graph can be extracted and marked, and the remaining parts are presented as additional small clusters.

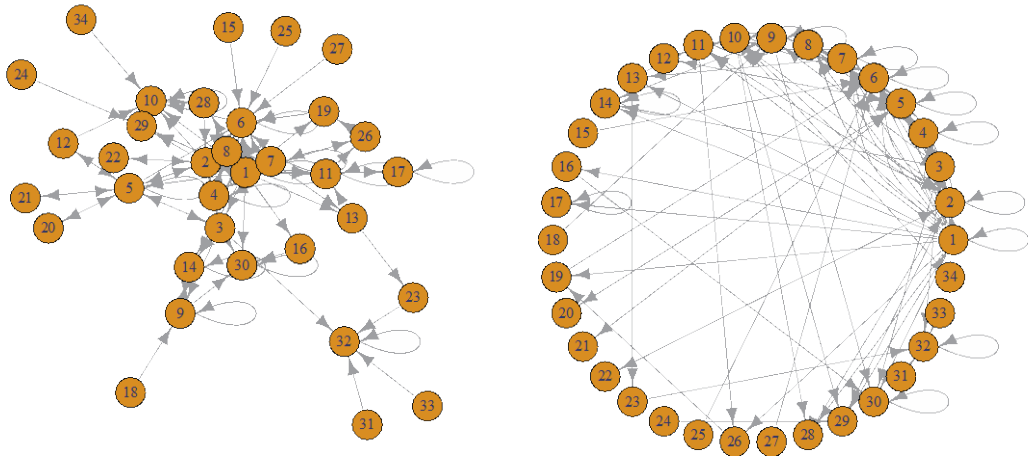

Figure 2: Network illustrations for all transaction in 2023 survey as a graph (a) and a circle layout (b)

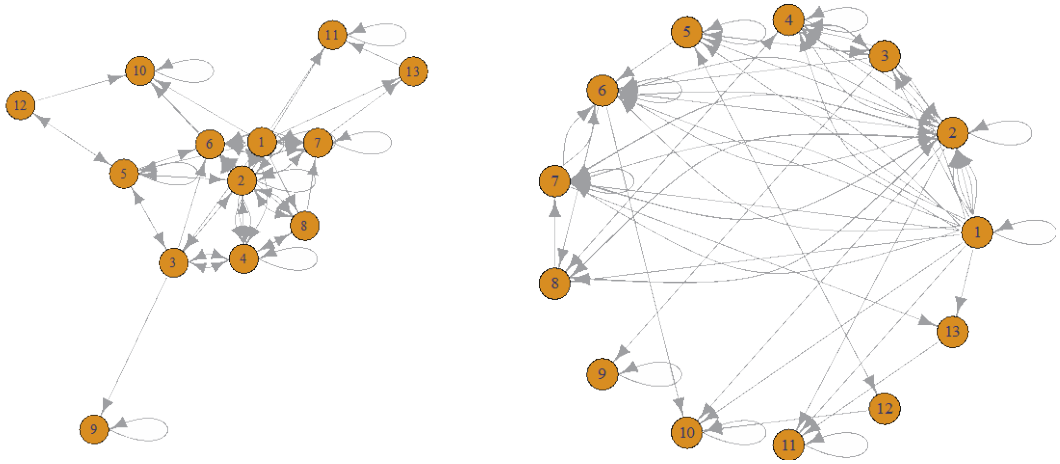

Figure 3: Illustration with selected participants (postings>1) in 2023 survey as a graph (a) and a circle layout (b)

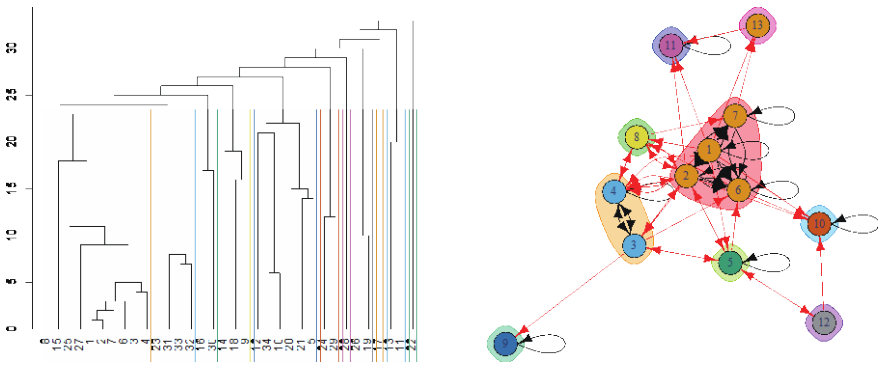

Figure 4: Illustrations of cluster analysis for 2023 survey, with dendrogram results in (a) and (b) showing cluster markings on Figure 3(a)

These analyses are applied to transactions of postings in the 2022 survey. The results are shown in Figures 5(a) and 5(b). In both results, the first major cluster includes the lecturer, as some participants responded to the lecturer's instructions. The sub-groups containing the most frequent communications were extracted as a cluster during the analysis.

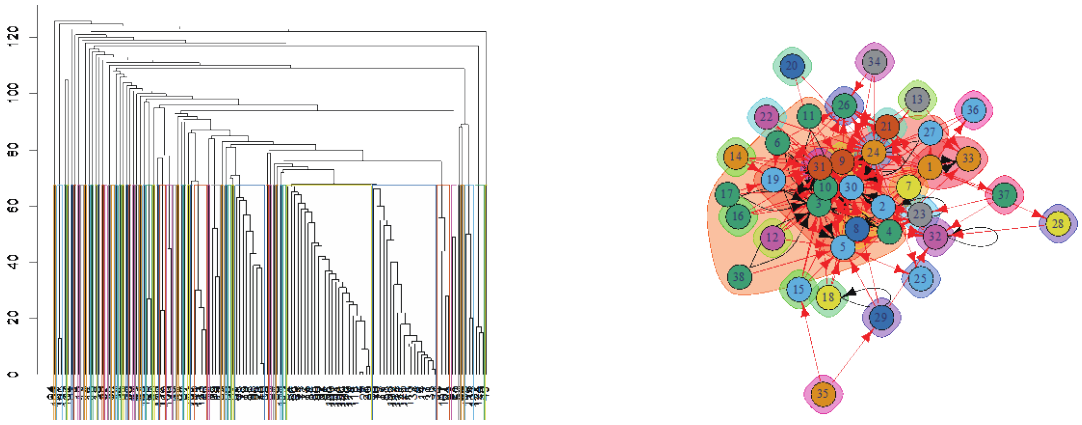

Figure 5: Illustrations of cluster analysis for 2022 survey, with dendrogram results in (a) and (b) showing cluster markings of selected posting participants.

3.3 Participant's Characteristics and Learning Performance

In order to extract features of classified clusters of postings by participants, surveyed metrics from individual responses are compared. In regards to the results of cluster analysis for the two surveys in 2023 and 2022, mean scores of metrics are compared between major clusters. Small clusters are merged as "Other" clusters. The results are summarised in Table 2 for the 2023 survey and in Table 3 for the 2022 survey. To confirm the differences between clusters, one-way ANOVA of each metric is conducted, however there are no significant differences because the number of participants is small. In comparing mean scores of metrics, the highest values are marked using bold face. The highest values appear mostly for clusters without clust:1, which includes the lecturer.

Table 2: Statistics of 2023 survey

Student's characteristics	Clust:1(10)	Clust:2(6)	Clust:3(3)	Clust:4(2)	Others(13)
PS1: Extroversion	3.4	5.0	**5.8**	3.3	4.5
PS2: Conscientiousness	3.0	3.0	2.8	**5.5**	2.8
PS3: Neuroticism	4.6	4.3	4.0	4.5	**5.1**
PS4: Openness	4.0	4.7	**4.8**	2.5	3.8
PS5: Agreeableness	3.3	2.8	**3.5**	3.0	3.2
KG1: Life-centered	3.7	3.4	**4.3**	4.0	3.9
KG2: Sciencephile	3.5	4.0	**4.3**	3.0	3.6
KG3: Logic-oriented	3.3	3.7	4.0	3.0	**4.1**
KG4: Authoritarian	3.2	2.9	3.2	3.0	**3.5**
CTD1: Critical Thinking Disposition-1st survey	14.1	13.9	**15.2**	**15.2**	13.8
CTD2: Critical Thinking Disposition-2nd survey	13.9	13.9	14.1	**16.1**	14.3
DPC1: Disaster-prevention Consciousness-1st survey	76.4	84.5	**94.0**	84.5	86.0
DPC2: Disaster-prevention Consciousness-2nd survey	76.6	81.0	73.5	75.5	**83.2**
WTS: Weekly Test Score	920.0	733.3	793.3	**940.0**	743.3
Report essay score	80.6	**84.1**	75.0	77.5	77.3
Mean posting frequency	8.4	2.5	2.0	2.0	1.0

Table 3: Statistics of 2022 survey

Student's characteristics	Clust:1(18)	Clust:2(25)	Clust:6(9)	Others(74)
PS1: Extroversion	4.2	**4.4**	3.4	4.0
PS2: Conscientiousness	3.8	3.5	**4.0**	3.4
PS3: Neuroticism	4.5	4.7	**5.0**	4.7
PS4: Openness	3.8	**4.0**	3.3	3.9
PS5: Agreeableness	**3.1**	2.6	3.0	3.0
KG1: Life-centered	3.7	**3.8**	3.5	3.7
KG2: Sciencephile	3.5	3.4	**3.6**	3.5
KG3: Logic-oriented	3.1	**3.4**	3.0	**3.4**
KG4: Authoritarian	3.3	3.0	**3.5**	3.3
CTD1: Critical Thinking Disposition-1st survey	**14.7**	14.4	13.5	14.2
CTD2: Critical Thinking Disposition-2nd survey	13.8	**14.3**	13.9	13.7
DPC1: Disaster-prevention Consciousness-1st survey	83.3	85.3	**85.6**	82.2
DPC2: Disaster-prevention Consciousness-2nd survey	84.9	85.0	**85.3**	81.5
WTS: Weekly Test Score	758.9	855.2	**875.6**	835.1
Report essay score	**80.3**	78.8	80.0	79.6
Mean posting frequency	3.1	2.0	1.9	2.4

It is interesting that the characteristics and performance of participants who responded to the lecturer's postings do not show higher numerical values. The highest scores for weekly tests (WTS) appear on a cluster which shows the highest score for conscientiousness (PS2). Also, the posting frequency of these clusters is not the highest of all of the clusters. This suggests that simple enhancement of participant's frequent postings of their own opinions may not contribute to a participant's understanding of critical thinking ability and learning performance.

4. Discussion

Discussion activity is believed to aid in development of critical thinking disposition and objectiveness, which are based on behaviour during disaster mitigation. To enhance discussion activity in response to the large number of participants, an extended community was organised using a bulletin board as a virtual space. Also, the lecturer used this to lead and to encourage discussion by participants.

In regards to the previous studies, frequent participation and posting activity in response to the lecturer's invitation were preferred during online discussions. Our previous study has also confirmed that participants with multiple postings show better performance during learning (Nakayama et al. 2023).

This paper examines the detailed relationship between posting behaviour and individual characteristics or learning performance, even though the number of participants was limited. In regards to our hypothesis, participants with frequent postings who sympathise with the lecture's postings were expected to show a better level of performance than with the previous results. Participant's performance within a cluster which includes the lecturer do not always show the highest averages for metrics. Participants in clusters without the most frequent number of postings also achieved better performance during the surveys in both years **these** were conducted.

Though there were no significant differences in survey metrics, the results reveal an interesting piece of evidence. Participants who did not post frequently also joined the discussions, and might have observed the activity of discussants who posted frequently while posting only a few times themselves. This phenomenon seems similar to the situation known as "legitimate peripheral participation" (Lave & Wenger, 1991). Since discussion participants may gain some actual knowledge without even postings any messages of their own, their participation activity should be evaluated affirmatively.

These procedures will be a subject of our further study.

5. Summary

Posting transitions between participants in online discussions were evaluated in order to extract the developmental progress of individuals regarding critical thinking disposition during a fully online course, using a network analysis technique to understand the progress of the exchange of opinions.

Participant's posted message transitions were summarised as an adjacency matrix, and the posting relationships were analysed. The results suggest that discussants joined as a hierarchical structure, and that some participants posted in response to the lecturer's instructions. Participants who posted were classified into several clusters, and the participant's characteristics and learning performances were analysed. The result suggests that participants whose postings frequently synchronised with the lecture's postings did not always show the highest levels of performance in the metrics surveyed. Since some of the remaining clusters of participants showed better performance, more multi-level support for participants is required.

As these results do not coincide with the hypotheses, a more detailed analysis will be required.

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