Effects of Communication for Conceptual Development in Online Discussion

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Abstract **– This study examined online disciplinary discussion by university students to determine how their shared ideas from personal experiences of conceptual change influenced the conceptual development of others. Collected messages in the resulting community were classified according to previously reported criteria. Subsequently, a dataset was analyzed using exponential random graph models to identify connection patterns in their communication. A state of connectedness provided students with a pathway that promote the acquisition of integrated concept types through access for shared content tailored to students' academic curiosity.**

Keywords **– concept acquisition, conceptual change, learning community, online discussion, message connection, threshold concepts.**

1. Introduction

Many students at universities around the world are trying to adapt online learning after the COVID-19 pandemic. In the online learning environment, students are required to have more self-regulation skills [1]. Subsequently, teachers need to consider providing a communicative online environment in which scholarly discussions that coordinate the conceptual development of the learning community can take place [2]. Assessing the processes of acquiring academic knowledge is becoming increasingly important [3].

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One approach focused on the fundamental concepts of knowledge and understanding integrated into the learning process through threshold concepts [4]. When students acquire threshold concepts, they can understand particular phenomena within the discussing area [5]. Threshold concepts are a sub-set of conceptual change on a framework of a thought.

Threshold concepts are regarded as a valuable tool for facilitating students' subject-matter understanding and supporting rational curriculum development in rapidly changing fields [6]. Researchers have proposed six types of threshold concepts as criteria for evaluating research activities, namely, argument, theorizing, framework, knowledge creation, analysis and interpretation, and research paradigm [7], [8]. In the current study, we use these criteria as indicators to extract the threshold concepts that appear in online messages.

With the spread of new digital technologies and the growing use of the internet for accessing information, threshold concepts are being increasingly used in online education [9], [10]. In particular, because asynchronous online communication is now considered for sharing ideas and the development of critical thinking skills, the collaborative learning process is designed to play an important role in the pedagogical experience [11]. Additionally, communication on social media, such as Twitter has reportedly been used to acquire threshold concepts [12], [13], [14]. Although learning to acquire threshold concepts was implemented in social media, the relationship between threshold concepts and community structure had not yet been identified. However, we tried to extract the noticeable structure of the threshold concept community as the purpose of this study.

2. Material and methods

We designed this study as an exploratory case study that allows for an in-depth investigation of the community communication through the analysis of message connectedness.

2.1. Target course

The course examined for this study was a general education course in which Japanese university students learn about world issues.

This international education course follows an organizational strategic approach inspired by the discussion of the sustainable development goals of 193 countries since 2016 [15], [16]. During May–June 2020, 73 first-year undergraduate students across three faculties (science, engineering and nursing) were recruited. All students were digital natives and used social media in their everyday lives.

Students participated in four consecutive sessions to study world issues. They were asked to write reports by accessing online information in each session. All reports were submitted to a Moodle discussion forum, where students could share reports with classmates and teachers. Since learning about world issues was a new experience for the students, the assignments were occasions to confront counterintuitive statistical facts and to impose unfamiliar or alien aspects of the country or their interpretation, which is understood as a provocative feature to induce threshold concepts [17].

An earlier study reported, an active student working on a self-directed assignment using the online data on world issues [18], and another earlier study demonstrated the emergence of active student behavior in the online discussion of world issues [19]. By leveraging the findings of these studies, we organized two emphases of transformative learning theory into the current lesson process, namely, instrumental learning, which includes controlling or manipulating the environment to improve performance or prediction, and communicative learning, which includes understanding a message from someone when communicating in a conversation [20].

2.2. *Activities on Twitter*

All students were asked to tweet about their experiences acquiring threshold concepts after each session. The teacher presented the following prompts to help students in tweeting how threshold concepts emerged and were recognized: explain a case when your perception of world issues changed after acquiring a new concept; explain a case where your recognition of knowledge changed after seeing a new perspective on a concept; explain a case where you initially believed that the indicators were not related but you found a clear relationship between them through your learning experience; explain a case where you encountered a new field that expanded with your conceptual recognition; and give an example of the information and concepts that you learned from the course and found difficult to accept. Students were also encouraged to tweet and share their own experiences, decisions and opinions, as well as to take stances, compare ideas, and make decisions.

This process of exchanging experiences via Twitter involves indispensable principles proposed by Timmermans and Meyer [21]: “reflective practice,” in which learners adjust observed aspects of the framework to their situational needs, and “encouraging communication,” in which feedback received from other users help students integrate insights from conversations into their work to integrate threshold concepts.

2.3. *Threshold concept types*

After collecting all descriptions of tweets with threshold concepts, five types (Table 1) from the types shown in introduction section appeared. The last type, research paradigm, did not appear in the collected tweets and was excluded.

Table 1 Types of threshold concepts

No.	Types of threshold concepts	Desirable competencies	Important concepts
1	Argument	Building a logical, cohesive scholarly argument	Framing a world issue’s argument
2	Theorizing	Recognizing when to bring theory into the study	Theoretical framework
3	Framework	Gaining critical value from the materials to the study	Data and materials review
4	Knowledge creation	Progressing from description to analysis	Competency in data collection
5	Analysis and interpretation	Credible, evidence-based analysis and interpretation	Analysis

Adapted from [8].

2.4. *Exponential Random Graph Models*

This study adopted an innovative method for analyzing the network structure of the community using exponential random graph models (ERGMs) [22]; it provides and tests the inferential hypothesis based on their exponential distribution form for calculation. The parameters for an individual covariate in the network (i.e., the number of posted tweets with threshold concepts) and structural properties of the network (i.e., reciprocity) can be used to predict the propensity of the entire network. Parameter estimation is conditionally dependent on the covariates contained in the model [23]. These elements are included in the analysis as independent variables and are known as terms.

One term adds one analytical statistic to ERGMs. ERGMs can predict the propensity of structures within a community being formed with statistical evidence. An ERGM also calculates the probability of tie formation in the network with the value from 0 to 1. The "statnet" and "stargazer" packages for R (ver. 4.0.3; the R Foundation) were used for the analysis.

2.5. *Ethical concerns*

All students created a new pseudonym account on Twitter, specifically for the course. Informed consent was obtained from all students. All students could also remain silent if they didn't want to tweet. All procedures in this study were executed in accordance with the ethical standards of the institution and complied with the 1964 Declaration of Helsinki and its subsequent amendments.

3. Result

Collected message records were classified into types of threshold concepts and user groups, and salient message connections were extracted using ERGMs.

3.1. *Types of threshold concepts in sessions*

A total of 1,402 tweets with course hashtags were extracted from Twitter, and 169 tweets from 56 students were identified as tweets with threshold concepts. The average number of threshold concept tweets per student was 2.32.

No statistically significant differences in the number of tweets with threshold concepts by session were observed (M = 42.25, 95% CI [29.8, 54.7]; Table 2); thus, there was no difference in the difficulty of session content when acquiring threshold concepts.

Table 2 presents the 4 sections × 5 types matrix we used to analyze the variables based on the numbers of tweets. The numbers of tweets with threshold concepts decreased as the threshold concept types integrated, with Types 4 and 5 occurring less often than the other types. This revealed differences in student performance according to difficulty integrating the threshold concepts.

Table 2 Numbers of tweets with threshold concepts by type and session

	Threshold concepts						
	Type 1	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Sum**	**Average/ student**
Session 1	12	13	11	5	2	43	0.59
Session 2	10	8	9	5	0	32	0.44
Session 3	17	17	11	5	1	51	0.70
Session 4	20	16	6	1	0	43	0.59
Sum	59	54	37	16	3	169	2.32

3.2. *Excerpt of threshold concept tweets*

There was an average of 18.3 tweets per student. Most tweets (99.01%) contained academic messages about the content of the sessions. The following statements show excerpts of selected tweets translated by the author according to the respective threshold concept type.

Type 1: Argument

Most students reported making new connections, both in conceptual structures and in other contexts, including their prior knowledge and familiar beliefs. Various data, photos, graphics and online links were attached to their tweets to help in developing their arguments and explain their concepts in detail. For instance, in session 1, one student wrote the following:

> *In Turkey, the collapse of the Turkish lira and local currency is a problem, but I learned that the devaluation of the local currency may increase the international competitiveness of local products. In the case of Turkey, a country of exports < imports, it can be said that this devaluation of the domestic currency is an opportunity to increase exports.*

Type 2: Theorizing

Students learned to shift perspective by incorporating content that was previously considered irrelevant. The attached excerpt shows how an acquired threshold concept underpins an individual report that is strongly associated with indicator-based scientific understanding. The following student statement from session 4 is an example:

> *I thought PM2.5 was caused only by air pollution from thermal power plants and factories, but it turned out to be caused by natural phenomena like forest fires and volcanic eruptions too. I reminded myself that preventing global warming is important to keep forest fire damage from spreading.*

Type 3: Framework

Critical thinking is an important skill that enables students to properly define problems because it provides the ability to see the future, which we believe to be common sense [24]. Students can master disciplines by building critical thinking through material selection, abandoning old beliefs and constructing new meanings with others [25]. The following student statement from session 1 is one example:

> *When I was studying South Sudan in a geography course, I thought that South Sudan's independence would have a positive impact on economic and political stability. In South Sudan, however, there were still internal conflicts and disruptions within the country even after independence. GDP per capita declined due to the division, and the proportion of people below the national poverty line rose.*

I learned that tens of thousands of victims and many refugees were killed. Even now, around nine years after independence, the situation is still difficult. I regretted that I simply saw the word "independence" and thought it was a happy situation.

Type 4: Knowledge creation

Students developed knowledge of facts and depth of their awareness by multidisciplinary indicators in their research questions. The following tweet from session 1 of the course illustrates this point:

In countries with so-called monoculture economies, where the proportion of certain mineral resources and agricultural products in exports is high, trade volumes depend on demand and GDP trends tend to be volatile. It turns out that the unemployment rate fluctuates accordingly.

Type 5: Analysis and interpretation

Students clarified definitions of concepts and developed rigorous analyses. The wealth of information collected, which included more indicators than those presented in the course, was analyzed and interpreted with critical thinking. The following sentences from session 3 of the course served as an instructive example:

Regarding disparity, even if the Gini coefficient looks normal, there may be more disparities than expected. Switzerland seems to be normal with a Gini coefficient of ~0.3, but on the "fixed property," for example, the disparity is growing below the surface due to the imbalance in wealth distribution. I was reminded that superficial numbers are not everything.

3.3. *Connectedness of the community*

There were 113 users in the resulting community: 73 students along with 23 social users, 7 news media site accounts, 4 non-course students and 6 self-promoters (Table 3). The self-promoters were users who tweeted unconcealed updates about activities, events and accomplishments. Across the community, 1,102 messages were duplicated out of a total of 1,402 messages, including 863 self-loops of isolated tweets.

Table 3 Measures of metrics on user groups in the scholarly community on Twitter

User group	User number	Average tweet number	Average followers	Average followed
S	73	18.3	28.38	31.8
A	23	0.30	1,624.3	372.0
N	7	0.14	1,338,453.2	87.0
P	6	0.83	2,660.5	1,719
F	4	12.8	70.0	85.0

S, students; A, social users; N, news media site accounts; P, self-promoters; F, non-course students.

The reciprocated user pair ratio, which is the ratio of users showing mutual relationship, was 0.237, and the reciprocated message ratio, which is the ratio of messages that have a reciprocal relationship, was 0.383. Both values reinforced the fact that there was an active sharing of tweets.

Furthermore, as a known measure of Twitter activity, the engagement rate was defined as the number of interactions divided by the number of times the user posted a tweet in a timeline [26]. There is a range of interaction ways, including replies, retweets, hashtags, followers, usernames, profile pictures, likes, links, cards, embedded media, and tweet expansions. Whereas the Twitter scholarly community at large was calculated to have an average engagement rate of 4.75% [27], this study had an average engagement rate of 14.0%. This high rate proved the active engagement of users in the resulting community.

3.4. *Exponential random graph models*

The tweets with threshold concepts occupied only 12.1% of all tweets and emphasized the importance of examining connectedness.

Table 4 shows the calculation results of the ERGMs. The results are interpreted based on the user's covariates. The effect of the "mutual" term was strongly positive in Model 1 and had statistically significant propensity (*Estimate* = 3.412, $p < .01$). The academic network created by this class showed more reciprocal connections than would be expected from a random network with 300 unique edges. The connection probability baseline was calculated to be 0.020. When "mutual" connections were included, the log odds of the connection increased and this new probability is 0.382, making the tendency to connect in this network 19 times stronger.

Table 4. Results of maximum likelihood estimation on exponential random graph models

	Dependent variable: Estimate		
Term parameters	**Model 1**	**Model 2**	**Model 3**
edges tweets	−3.893** (0.066)	−4.459** (0.091)	−5.025** (0.127)
mutual reciprocal tweets	3.412** (0.173)	3.102** (0.185)	2.929** (0.180)
nodecov.TC number of tweets with threshold concepts		0.172** (0.016)	0.106** (0.016)
absdiff.TC homophily in number of threshold concepts		−0.023 (0.021)	0.040* (0.023)
nodematch.Group same user group			1.074** (0.133)

*upper: parameter estimate value; lower: parameter standard error *p < .1; **p < .01*

Trends in the same user group showed a significantly higher score of propensity (*Estimate* = 1.074, $p < .01$) in Model 3. Summarizing the result of Model 3, an edge in this community has the propensity to make reciprocal connections and is influenced by connections from the same user group and users who tweeted a higher number of tweets with threshold concepts. This structural feature demonstrated on active connections between students. There is a significant positive association between the number of tweets with threshold concepts and likelihood of a connection, but the estimated value is small in Model 3 (*Estimate* = 0.106, $p < .01$). Homophily tendencies were also observed to be statistically significant in tweets with threshold concepts, but the value in Model 3 is smaller (*Estimate* = 0.040, $p < .1$).

A baseline for the connection probability was calculated as 0.00653 in Model 3, and the log odds of the connection increased when "mutual," "nodecov.TC," "absdiff.TC," and "nodematch.Group" were included; the updated probability was 0.294, making it 45 times more likely to be connected in this network.

4. Discussion

A range of our findings reinforces earlier studies. For instance, students who were given continuous point-of-need access to online resources were able to acquire threshold concepts and gain different understandings [28], which is reinforced by our conclusion that students had a triggering experience of threshold concepts through their online searches. Moreover, our research unravels that most students' tweets focused on course content echoing the study by Cyr et al [29], who concluded that students preferred digital sources focused on content. The higher probability of connecting with classmates than with users in other social networks and the unusually high percentage of interactions between students relative to social users are consistent with the reported tendency toward reciprocal connections [30].

Conversely, we found that each threshold experience transformed the perspective of other students. Regarding transformation, tweet messages were all situated in the same disciplinary content, and each identified varied types of knowledge; however, the conceptual architecture that incorporates and connects these types of knowledge is largely content-free and adaptable to other contexts [17]. We found that the students' experiences of crossing thresholds influenced their acceptance of further learning, and their encounters with diverse information stimulated their intellectual curiosity.

5. Conclusion

In this study, we investigated online communication and learning in the scholarly community, especially the connection structures of tweets with threshold concepts. The following were the main results of our study.

Whereas the scholarly community had many mutual connections, both connections with threshold concepts were few. Integrated threshold concept types were less common than others. Students experienced difficulties in connecting with users outside their community.

Threshold concepts have emerged in network connections across the community, rather than in communication. Online communication on Twitter was also argued that future-focused activities could integrate threshold concepts through access for shared content tailored to students' academic curiosity.

Additionally, our results contribute to the literature of online learning and conceptual transformation by showing how students' online communications are shaped by their connections, structural patterns, and mindsets associated with threshold concepts.

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