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Smaller or Smallest? Investigating the Optimal Small Group Size in Online Forums

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Previous studies have confirmed the benefits of small group sizes in asynchronous online discussions. However, there is no consistency in which small group size is the optimal option for maximizing students' discussion performance. Moreover, few researchers attempted to apply the smallest group size (i.e., one-on-one) to online discussions and examined its effects. This study focuses on comparing two small group size choices regarding students' discussion performances. 21 graduate students formed pairs in the first half of the semester, and in the second half, they formed groups of three to five. Paired-sample t tests were conducted to detect the performance differences between the two group sizes. The results showed that students significantly performed better in contributing interactions, providing information, engaging in social conversations, demonstrating cognitive engagement, and constructing knowledge. This study provided a new perspective of designing discussion activities in online forums.

Keywords: online learning, discussion forum, small group size, cooperative learning, higher education

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INTRODUCTION

Asynchronous online discussions have been known as common online learning activities in higher education (Luo et al., 2023). In the technology-enhanced online forums, students are often required to discuss their thoughts on an open-ended or assigned topic regarding the subject of the course, with or without the learning resources provided by the instructors (Koszalka, et al., 2021). To participate in online discussions, students need to write postings in the forums for the purpose of delivering their original ideas or replying to others. This process of exchanging postings leads to communication, which was recognized as a vital learning component that may contain multiple outcomes regarding students' performances (Amichai-Hamburger et al., 2016).

Communication inside online discussions can generate at least two types of learning outcomes: 1) students' behavioral engagement, denoting the quantity of their communication (Feng et al., 2021), and 2) students' social and cognitive engagement with their constructed knowledge, representing the quality of their communication (Yang et al., 2011; Koszalka, et al., 2021; Schindler & Burkholder, 2014). To gauge the quantity of students' communication, researchers often tracked how frequently students submitted their postings in the forum and how much information they provided in their postings (Ertmer et al., 2011; Guo et al., 2022). To delve into the quality of students' communication, analyses typically revolved around the levels of students' cognitive engagement with the Bloom's taxonomy as the reference, the degree of social presence as an indicator of how much students socially engage in discussions, and the accumulation of constructed knowledge types during discussions (Bloom, 1956; Rourke, 1999; Anderson et al., 2001; Yang et al., 2011; Luo et al., 2023).

However, the measured learning outcomes in online discussions fall short of instructors' expectations. A notable performance problem on the quantity of communication in online discussions was that students only contributed a minimum required number of postings and providing little information in their postings (Ding et al., 2017; Yang et al., 2022; [Authors], 2023). The underperformances also occurred when researchers switched their attention to the quality of communication. First, students' cognitive engagement often stayed at superficial levels in the forum, and thus failed to demonstrate students' deep thinking on the contents from conversations or assigned learning resources (Luo et al., 2023; Ouyang et al., 2021; Gao, 2014). Second, students seldom exerted their social abilities to manifest a higher level of social presence in the forum (Lowenthal & Dunlap, 2020; Wut & Xu, 2021). It implied that students could treat online discussions as independent tasks instead of cooperative tasks. Third, in terms of knowledge construction, some knowledge types, such as metacognitive knowledge, were rarely constructed when students communicated with each other in the forum (Ghadirian, et al., 2018; Yang et al, 2011). Thus, the knowledge scope of students' communication in online discussions could be unexpended.

To address the performance problems this study explores and discusses the instructional design of online discussions from the perspective of group size. Given the widespread belief that small group approaches are more effective than large grouping approaches (Vygotsky, 1978; Oxford, 1997; Johnson et al., 2014; Shaw, 2013; Yang et al., 2022; Luo et al., 2023; Wang et al., 2023), the research team narrow the scope of the research to only discuss small group sizes. Furthermore, this study investigates the optimal small group size through comparing a regular small grouping approach (i.e., three to five people in a group) with an exceptional one-on-one grouping approach (i.e., two people in a group), which was barely tackled in previous literature. Two research questions are constructed to achieve this research purpose.

1. Is a one-on-one grouping approach more effective than a three-to-five grouping approach regarding the quantity of students' communication (i.e., interaction frequency and information length)?
2. Is a one-on-one grouping approach more effective than a three-to-five grouping approach regarding the quality of students' communication (i.e., cognitive engagement, social engagement, and knowledge construction)?

LITERATURE REVIEW

THE THEORETICAL FOUNDATION OF SMALL GROUP DISCUSSION

The significance of group discussion in education had been defended by social constructivists such as Vygotsky (1978), who posited that learning was rooted in communication with others. In group discussions, students can not only have the opportunity to assimilate diverse perspectives, but also critically reflect on their own learning performances through a peer-modeling process (Oxford, 1997; Bruffee, 1993). Moreover, students cannot isolate themselves, because cooperative activities like group discussion can help them understand the intersubjectivity of a community, which is a cornerstone of being socialized (Dewey & Archambault, 1974). Therefore, group discussion was regarded as an indispensable instructional activity in various educational contexts.

Acknowledging the necessity of group discussion, educators attempted to develop descriptive theories investigating the factors that influence the effectiveness of group discussions. One of the prevalent theories is social interdependence theory, coining that group discussion is only successful when group members need to depend on each other's efforts to build up an informational and meaningful discourse (Johnson & Johnson, 1989; Deutsch, 1962). A group discussion can be productive and profound only if the group members rely on each other's continuous and active participation to develop the conversation. If someone participates in the discussion perfunctorily, the other group members' performance can be negatively impacted (Johnson & Johnson, 1989; Akcaoglu & Lee, 2016).

Relying on the social interdependence theory, researchers have formulated instructional theories, which can guide educators to integrate descriptive theories into educational practices (Ragan & Smith, 2005). Some researchers advocated for cooperative learning theory, which highlights the importance of small group discussion. Cooperative learning indicates that social interdependence can be obtained when the instructors carefully manage the group size of discussion (Johnson & Johnson, 2009; Oxford, 1997). In overly large groups, individual responsibilities of participation can be diluted or diminished. It means while a few students maintain the discussion, the others can be lurkers and rarely participate (Amichai-Hamburger et al., 2016). This unbalanced participation leads to the fact that social interdependence can only be achieved among a few active participants instead of all the group members. The larger the discussion group size, the less the social interdependence (Shaw, 2013; Fay et al., 2000).

With theoretical support, many researchers underscored the need to reduce the group size in discussions. Although there was no universally agreed definition of "small group", a group of 14 members or fewer was generally accepted as a conversative standard suggesting the minimum requirement for a small group discussion (Benton et al., 2015; Parks-Stamm et al., 2017; Luo et al., 2023).

THE PERFORMANCE VARIABLES IN SMALL GROUP DISCUSSIONS

Through reducing the group size, researchers expect students to promote at least two types of performances in the online discussion forum. The first type is related to the

quantity of students' communication, suggesting that students should contribute a decent volume of information to prove their invested efforts. The second type is related to the quality of students' communication, indicating that the contributed information in the forum should be not only plentiful but also meaningful (Schindler & Burkholder, 2014). Each type of performance can be presented by one or more variables. The communication quantity can be presented through interaction frequency and information length, while the communication quality can be presented through cognitive engagement, social presence, and knowledge construction.

Interaction Frequency. Interaction frequency refers to the number of gradable textual units in the discussion forum (Ouyang et al., 2021; Ertmer et al., 2011). In online discussions each gradable textual unit is often a posting, because it delivers a complete argument from a student compared to a sentence or a single word (Ertmer et al., 2011; Lee, 2008). In online discussions, a posting is easily to be observed by instructors, and thus reduces instructors' workload in terms of grading (Schindler & Burkholder, 2014). The method of measuring students' performance regarding interaction frequency is straightforward, counting how many postings that a student creates in the forum (Ouyang et al., 2021; Beuchot & Bullen, 2005).

Information Length. Students' interaction frequency is a direct indicator of the communication quantity, but it can threaten the equity inside a course if instructors solely rely on it for grading. Being aware of that instructors count postings, some students may tend to generate many postings while keep each posting short or even meaningless (Guo et al., 2022; Yang et al., 2011). It can be unfair to the students who generate a limited number of postings but make each posting fully developed. Therefore, another performance variable, information length, should be involved to evaluate students' communication quantity for the purpose of conducting a fair evaluation. Information length refers to the total volume of textual units that each student contributes to the discussions without considering if the textual unit is gradable or not (Ertmer et al., 2011; Guo et al., 2022). The textual unit can be a sentence, a word or even a character. Among them, a single word was often selected since it delivers a meaning while being easily counted by some software, such as Excel or a built-in forum function (Guo et al., 2022; Yang et al., 2011).

Social Presence. With respect to communication quality, a primary concern of researchers was if the students really interacted with their peers socially within the forum rather than simply generate their postings as their individual assignments (Garrison & Arbaugh, 2007; Rourke, 1999). To measure if students were socially interacting with each other, some researchers attempted to detect and count the social indicators hidden in students' postings. The social indicators were defined by Rourke et al. (1999), including affective indicators, interactive indicators, and cohesive indicators. Affective indicators include the expression of emotions, use of humor, and self-disclosure. Interactive indicators include continuing of a thread, quoting, referring to other postings, inquiring, appreciating, and agreeing. Cohesive indicators include using vocatives, using inclusive pronouns, and greeting. This framework of measuring social presence was validated repeatedly by numerous researchers (Hughes et al., 2007; Rourke et al., 1999).

Cognitive Engagement. As an objective of online discussions is to promote the levels of cognitive learning (Schindler & Burkholder, 2014), researchers also paid attention to students' non-social performance within the forum, such as their cognitive engagement. Cognitive engagement means the level of mental activity in students learning process, coming from the revised Bloom's taxonomy (Anderson et al., 2001; Bloom, 1956; Yang et al., 2011). There were six cognitive engagement levels in the taxonomy: remembering, understanding, applying, analyzing, evaluating, and creating. The six categories were often displayed in a pyramid scheme, which indicated that the remembering category was the lowest level of cognitive engagement, and the creating category was the highest level

(Anderson et al., 2001; Bloom, 1956). In online discussions, researchers or instructors used the cognitive engagement framework from Bloom's taxonomy to evaluate which level students finally achieved at each posting, and thus accumulate students' levels in a single discussion activity (Ghadirian et al., 2018; Zhu, 2006).

Knowledge Construction. Knowledge construction is another performance variable revealing students' communication quality from the perspective of constructivism (Gunawardena et al., 1997). Knowledge construction refers to the degree of constructing diverse knowledge types within communication (Gunawardena et al., 1997). Anderson et al. (2001) posited that there were at least four types of knowledge that are expected to be constructed during students' cognitive learning: factual knowledge, conceptual knowledge, procedural knowledge, and metacognitive knowledge. In online discussions, the different types of knowledge can be identified through specific indicators. Factual knowledge can be indicated by personal experience and public events; conceptual knowledge can be indicated by terminologies or theories; procedural knowledge can be indicated by the described steps; metacognitive knowledge can be identified by self-reflection (Anderson et al., 2001; Yang et al., 2011).

THE APPLICATION OF SMALL GROUP IN ONLINE FORUMS

Small group discussions have proven effective in the residential learning environment. Pollock et al. (2011) discovered that both students' participation levels and self-perceived performances in small group discussions were significantly higher than what they demonstrated in large group discussions. In a comprehensive review of 168 studies, Johnson, Johnson, and Smith (2014) examined the effectiveness of cooperative learning activities with small group discussion included. Their study summarized that small group discussion had potential to the improvement of students' cognitive engagement, knowledge construction, social presence, and psychological health. More recently, a study conducted by Chrisianita and Mandasari (2022) displayed that small group discussion would also directly benefit students' language competency.

With the rise of distance education in the 21st century, researchers began adapting small group discussions to online forums so that online learning environment could inherit the benefits of small group discussion in residential learning environment. Shaw (2013) incorporated a small group discussion into an online forum of an undergraduate programming course. Within a quasi-experimental research design, he compared students' small discussion performance with their large group discussion performance. The findings showed that when the group size was equal to or smaller than six members, students' interaction frequency and satisfaction rate would be significantly higher in the discussion forum (Shaw, 2013). Yang et al. (2022) assigned 90 graduate students to a small group online discussion including groups of eight, nine, or ten members, while 88 graduate students were assigned to a whole-class large group online discussion. After comparison, they found that both interaction frequency and information length in the small group discussion were significantly higher than the ones in the large group discussion (Yang et al., 2022).

The application of small group in discussion forums did not only promote students' performance regarding the quantity of communication (e.g., interaction frequency and information length), but also upgrade their performance regarding the quality of communication. Akcaoglu and Lee (2016) embedded a small group structure in an online discussion forum of a graduate-level research methodology course, and each small group contained four or five students. Rather than spotlight the small groups' impacts on interaction frequency or information length, they focused on understanding if the students of small groups were more inclined to demonstrate their social presence, which is a construct that assesses students' social competencies of engaging in discussions (Rourke

et al., 1999; Rovai, 2002). Their study proved that the students in small groups significantly outperformed another student cohort in large groups on providing affective support, establishing interactive space, and enhancing group cohesion (Akcaoglu & Lee, 2016). Besides, Hamann et al. (2012) examined an undergraduate student cohort's (n=175) cognitive engagement in both small group and large group online discussions of a political science course. Their study disclosed that students in small groups had higher levels of thinking skills that are related to their cognitive engagement. Correspondingly, a recent study conducted by Luo et al. (2023) shows similar results, implying that students in small group online discussions would report a higher cognitive engagement based on their experiences of participating discussions.

THE DEBATE ON OPTIMAL SMALL GROUP SIZE FOR ONLINE DISCUSSIONS

The success of small group online discussion has sparked researchers' further interests in refining its design. Relevantly, one of the attractive topics is the optimal choice for the small group online discussions. Table 1 shows the three main options for the optimal small group size, their supported studies, and the dimensions on which they could improve students' discussion performance.

Table 1. *Studies on Optimal Small Group Size in Online Discussions*

Optimal Size	**Supported Studies**	**Advantageous Dimensions**
Two	Wang et al. (2023)	Interaction frequency, cognitive engagement
Three to Five	Lowry et al. (2006) Shaw (2013) * Akcaoglu and Lee (2016) Luo et al. (2023)	Interaction frequency, information length, social presence, academic achievement (e.g., test or assignment scores)
Above Five	Qiu et al. (2014) Hamann et al. (2012) Parks-Stamm et al. (2017) Yang et al. (2022) Hew and Cheung (2011) *	Interaction frequency, information length, social presence, cognitive engagement, activity satisfaction, knowledge construction

*Note: * =Not all the groups fit the selected optimal group size due to contextual limitations.*

Table 1 unveils two gaps about research on optimal small group size. First, there is a lack of consensus on which size should be the most effective choice for educators. The debate is still ongoing due to the disparity of results and measured performance constructs. Second, the dyad (i.e., pair or one-on-one) grouping approach, which indicates the smallest group size, was rarely targeted in the studies. The dyad should not be ignored by researchers, because it is a unique option compared to other small group sizes. The dyad provides a stringent and zero-tolerance mutual communication format, which means there is little space for an unnoticed absence (Wang et al., 2023). The person who did not attend a dyad conversation would be easily detected, and possibly punished by the instructor. The triad (i.e., three people in a group), even though only one more person is involved compared to dyad, still provides some members a chance of "free riding" (Shimazoe and Aldrich, 2010; Wang et al., 2023). Therefore, the dyad format deserves more attention in research and should be compared with other small group size options, because it is a unique small group size maximizing the individual responsibilities in discussions.

Besides, despite the table above, students' performances in the optimal small group size studies were often measured by self-evaluation instruments (e.g., surveys) instead of externally evaluated instruments (e.g., instructor rubrics, coding frameworks). For example, the study of Akcaoglu and Lee (2016) compared students' social presence in

discussion forum across different small group sizes. The social presence data were collected from students' self-evaluated responses to survey items after the online discussions. Although survey data could be strong evidence supporting research conclusions, students' self-perceived performances might not always be matched with their actual performances (Neuendorf, 2017). Therefore, researchers' perspective can be another important lens of observing students' performances in the discussion forum. Methods like content analysis, which can quantify students' discussion performances from an expert perspective, should be adopted in parallel to the uses of self-evaluation instruments.

METHODOLOGY

RESEARCH DESIGN

To address the research questions and literature gaps, the research team applied a one-sample quasi-experimental design investigating if a same student cohort would deliver distinct performances when they were grouped in two different sizes within an online discussion forum. In the first half of the semester (i.e., 1-6 weeks), the student cohort was organized as pairs to participate the online discussions; in the second half of the semester (i.e., 7-12 weeks), the student cohort was organized as larger but still small groups (three, four, or five in each group) to participate the online discussions. The students' performance in the first six weeks was compared to their performance in the second six weeks. There was no contemporaneous control group.

PARTICIPANTS

This study employed a convenient sampling approach. The participants are a student cohort of a graduate-level educational technology course in a northeastern university of the United States. The instructional objective of the course was to help students understand and reflect on the possible issues of technological integration in the educational environment. A semester-long online discussion forum built in the learning management system (LMS) was launched to support the required weekly asynchronous discussions, which aimed at stimulating students' reflection on what issues could appear when diverse technologies (e.g., electronic games, mobile applications) were involved in education. In each week, students are required to participate in a discussion regarding the integration issues of an assigned technology topic. The minimum requirement for weekly participation was contributing at least one original posting to the assigned technology topic and one follow-up posting (i.e., a reply to a peer). The discussion activity was fully student-facilitated, and the instructor would not participate. 12 weekly discussions were held sequentially over the semester. 22 students who registered for the course became participants in this study. However, one of them never appeared in the discussion form so that only 21 students' discussion postings were collected after the whole course ended. Some demographic information of the 21 students was illustrated in table 2.

Table 2. *Demographic Information of Participants (n=21)*

Dichotomous Variable		**Frequency**	**Percentage**
Program	Ed-Tech/ID	10	47.6%
	Other	11	52.4%
Teaching Experience	Yes	14	66.7%
	No	7	33.3%
Gender	Male	9	42.9%
	Female	12	57.1%
Nationality	U.S. Local	11	52.4%
	International	10	47.6%

Degree in Pursuit	Master	16	76.2%
	Doctoral	5	23.8%

Note: Ed-Tech=Educational Technology; ID=Instructional Design.

PROCEDURES

As Figure 1 shows**,** this study includes eight main procedures.

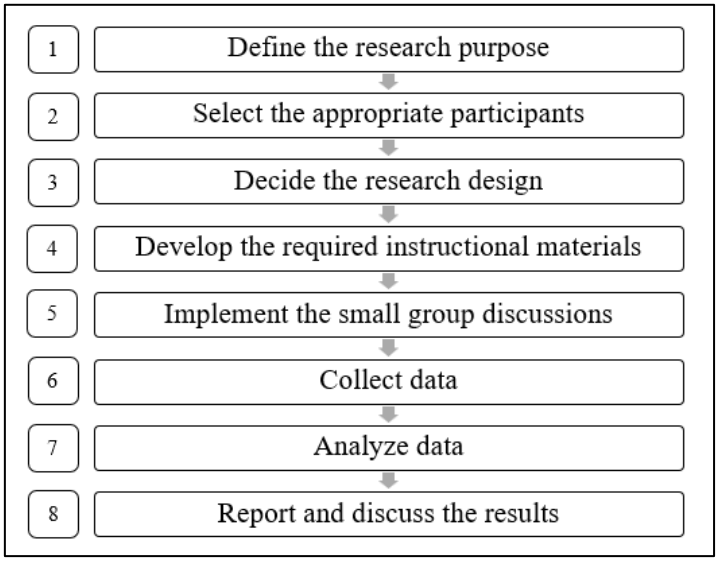

*Figure 1***.** Procedures of the study

Define the Research Purpose

This study began three months before the start of the course. The research team first defined the research purpose to narrow down the study scope. Through a literature review, the research team first decided to only explore the differences among small group sizes, because there were many studies that had investigated the differences between small group size and large group size (Luo et al., 2023; Wang et al., 2023). Secondly, pairs as the smallest group size were rarely applied and examined in previous studies. Therefore, a one-on-one grouping approach was selected as one of the compared small group choices. Third, since there was no consistency regarding which size can be mentioned as "small" (Shaw, 2013; Yang et al., 2022), the research team decided to select the conservative three-to-five grouping approach for securing the boundary between a small group and a large group. Fourth, after identifying five measurable online discussion performance variables through the literature review, the research team defined the research purpose as comparing the one-on-one grouping approach with the three-to-five grouping approach in terms of students' interaction frequency, information length, social presence, cognitive engagement, and knowledge construction.

Select the Appropriate Participants

The second step was to select the appropriate participants for the study. Since the context of this study is higher education, the participants could be either undergraduate students or graduate students. The research team finally selected graduate students as our participants, because the undergraduate students taking the same course could be more familiar with each other than the graduate students. The undergraduate students took many courses together and had many chances to stay with each other (e.g., lunch, social activity). The research team worried about the familiarity could neutralize the effects of different small group choices. Comparatively, the graduate students taking the same course could

not know each other because some of them were part-time students and they might take different courses before.

Decide the Research Design

The third step was to decide which research design should be utilized. The initial drafted research design was an experimental design with two separate student cohorts involved and compared. However, since there was no second student cohort available and the sample size of the available student cohort had been considered small (n=21), the researcher team decided to use a one-sample quasi-experimental design instead, recognizing the limits from reality.

Develop the Required Instructional Materials

To conduct the research design, some additional instructional materials were developed to help students understand and participate in this study. The instructional materials include 1) a syllabus including the instructions about the discussion activity with two different small group sizes, 2) a discussion forum with one-on-one threads in the first six weeks and three-to-five threads in the second six weeks, and 3) a list of assigned group members for each week.

Implement the Small Group Discussions

The research team implemented the one-on-one and three-to-five discussions through the whole semester. The research team did not facilitate or intervene in students' discussions. Only reminders about group assignment or discussion due dates were sent out.

Collect Data

After the semester ended, the research team regarded and collected students' postings as textual contents in terms of students' performance (Yang et al., 2011; Koszalka et al., 2021). Their postings were collected because previous literature suggests that students' postings are direct evidence of their performance in the discussion forum (Yang et al., 2011; Koszalka et al., 2021). All the identification information (e.g., names, IP addresses) of the postings was removed to protect students' privacy. The cleaned data was saved to an encrypted Excel file that only the research team members had access to.

Analyze Data

This study employed a directive quantitative content analysis approach, transforming textual contents (i.e., postings) to numeric values for the purpose of comparing students' performances in two group sizes.

The research team selected five variables that were frequently measured in previous studies: interaction frequency, information length, social presence, cognitive engagement, and knowledge construction (Ertmer et al., 2011; Anderson et al., 2001; Rourke et al., 1999). A single posting was chosen as the unit of analysis, which refers to the minimum codable object in a content analysis study (Neuendorf, 2017). The decision was made because posting was often seen as the common gradable unit for instructors in the process of evaluating students' discussion performances (Yang et al, 2011).

A directive method was utilized to build up the coding framework. The "directive" means that the coding categories inside the framework came from the validated categories developed by previous researchers (Hsieh & Shannon, 2005). Although this method does not allow researchers to generate innovative coding categories, it conserves the time and effort of researchers in validating the innovative coding categories (Hsieh & Shannon, 2005). As the focus of this study is not validation, the research team determined to utilize this directive method. Table 3 contained all the categories (i.e., variables and sub-variables) regarding students' performance on the quality of communication. Interaction frequency and information length were excluded from the coding framework because they refer to the

quantity of the communication, which can be counted through Excel functions without a coding process.

Table 3. *Coding Framework for Variables on Quality of Communication*

Variable	Sub-Variable	Definition
Social Presence (SP)	Affective	Expressing emotions, using humor, and empathizing.
	Interactive	Citing comments, posing questions, and appraising peers.
	Cohesive	Adopting inclusive language and respecting peers.
Cognitive Engagement (CE)	Remembering	Building connections between topics and memories.
	Understanding	Interpreting the content from others or learning materials.
	Applying	Presenting an application case of methods or tools.
	Analyzing	Structuralizing, distinguishing, and organizing information.
	Evaluating	Criticizing opinions or phenomena and
	Creating	Providing diverse or new ideas, solutions, or arguments.
Knowledge Construction (KC)	Factual	Personal experiences, and trackable public events.
	Conceptual	Abstract subject-sensitive terminologies and generalizations.
	Procedural	Steps of implementing a solution or plan.
	Metacognitive	Awareness of own characteristics, thoughts, and strategies.

Note: The coding framework combined the validated categories from previous studies (Anderson et al., 2001; Ertmer et al., 2011; Rourke et al., 1999; Yang et al., 2011).

The coding process was undertaken by two members in the research team. As two cooperative coders, they initially coded 10 percent of the postings to carry out the self-training procedure. Through comparing the coding results, the two coders discussed the inconsistent codes, modified their comprehension of the coding categories, and reached a full agreement on each coded posting. Then they continued to code the rest of postings through iterative comparisons until a full agreement was achieved on each coded posting. The interrater reliability coefficient, Cohen's Kappa, for each sub-variable in the last round of comparison was included in table 4, exceeding the minimum threshold of 0.60 (Strijobos et al., 2006).

Following up with the coding process, the researchers calculated the numeric values of the variables on each participant. The numeric values of the variables and sub-variables were utilized to conduct paired-t statistics for the one-sample comparative purpose. The Shapiro-Wilk test was conducted first to examine if the normality condition was met for each variable. The results indicated that among the variables only the interaction frequency variable and the remembering sub-variable failed to meet the normality condition ($p<0.05$). Thus, the research team attempted to use a data conversion approach to normalize their data distributions (Leech, et al., 2014). After being square rooted, the two data distributions successfully met the normality condition. Thus, the paired-t test continued to be implemented after its statistical assumption was secured. Since the paired-t test was conducted 18 times, the false discovery rates on the significance values were ultimately calculated to lower the risk of multiple hypothesis tests.

Table 4. *Interrater Reliability of Coding Under Each Sub-Variable*

Variable	Sub-Variable	Cohen's Kappa
Social Presence (SP)	Affective	0.91
	Interactive	0.93

	Cohesive	0.79
Cognitive Engagement (CE)	Remembering	0.82
	Understanding	0.94
	Applying	0.98
	Analyzing	0.79
	Evaluating	0.89
	Creating	0.77
Knowledge Construction (KC)	Factual	0.95
	Conceptual	0.93
	Procedural	0.87
	Metacognitive	0.77

CALCULATION OF VARIABLE VALUES

Before the inferential statistics were conducted, the variables' numeric values were calculated through a snowballing process scoping from the posting level to the participant level.

Interaction Frequency and Information Length

First, the research team calculated how many postings or words a participant generated in a single week. Second, the postings or words of the first or second six weeks were accumulated to achieve the value of interaction frequency or information length regarding either the participant's one-on-one or three-to-five performance. Table 5 includes an example:

Table 5. *How Interaction Frequency and Information Length Are Calculated at the Participant Level*

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Final value in the one-on-one group
Interaction Frequency	2	3	2	3	1	5	16 postings
Information Length	45	111	23	556	10	35	780 words

Social Presence and Knowledge Construction

The calculation of social presence and the calculation of knowledge construction were similar because they relied on the accumulated sub-variable codes. First, the research team calculated if a sub-variable of social presence or knowledge construction existed or not in a single posting. If it existed, the sub-variable value became "1", and its superset variable value increased by "1". Table 6 shows an example illustrating how a social presence value is calculated at the posting level.

Table 6. *How Social Presence Is Calculated at the Posting Level*

Affective	Interactive	Cohesive	Social Presence
0	1	1	2

Second, a social presence or knowledge construction value at the week level was calculated by summing up all the social presence or knowledge construction values at the posting level. Table 7 shows an example illustrating how a social presence value is calculated at the week level when a student generates three postings in a week.

Table 7. *How Social Presence Is Calculated at the Week Level*

	Affective	Interactive	Cohesive	Social Presence
Posting 1	0	1	1	2

Posting 2	1	1	1	3
Posting 3	1	1	0	2
Week	2	3	2	7

Third, a social presence or knowledge construction value at the participant level was calculated by accumulating six social presence or knowledge construction values at the week level. Table 8 shows how the final social presence value of a participant in the one-on-one groups is calculated.

Table 8. *How Social Presence Is Calculated at the Participant Level*

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Final value in the one-on-one group
Affective	3	4	1	0	0	0	8
Interactive	2	5	2	3	2	2	16
Cohesive	3	4	5	0	1	1	14
SP	8	13	8	3	1	5	38

Note: SP=Social Presence

Cognitive Engagement

The values regarding cognitive engagement sub-variables were calculated in the same way as calculating the social presence and knowledge construction sub-variable values, but the value of the main variable was calculated differently. Referring to Bloom's taxonomy (Bloom, 1956; Anderson, 2001), the sub-categories of cognitive engagement are hierarchical rather than equivalent, which means remembering is the lowest (i.e., 1st level) and creating is the highest (i.e., 6th level). Thus, to calculate the cognitive engagement value at the posting level, the research team assign the posting the highest level it reached rather than accumulate the occurrence of the sub-variable codes. Table 9 shows how cognitive engagement value is calculated at the posting level. It is observable that although there are four sub-variables found in the posting, the total cognitive engagement value at this posting is 6 instead of 4, because "creating" is the highest level that the posting reaches and is worth a value of 6.

Table 9. *How Cognitive Engagement Is Calculated at the Posting Level*

Remembering	Understanding	Applying	Analyzing	Evaluating	Creating	CE
0	1	1	1	0	1	6

Note: CE= Cognitive Engagement

With the cognitive engagement value at each posting, the research team calculated the cognitive engagement value at the week level. Table 10 shows how cognitive engagement is calculated when a student generates three postings in a week.

Table 10. *How Cognitive Engagement Is Calculated at the Week Level*

	Remembering	Understanding	Applying	Analyzing	Evaluating	Creating	CE
P1	0	1	1	1	0	0	4
P2	0	0	0	0	1	0	5
P3	1	1	0	1	0	0	4
W	1	2	1	2	1	0	13

Note: P=Posting, W=Week

In the end, the final cognitive engagement value at the participant level was calculated (see table 11). It should be reminded that the cognitive engagement value under each week is not calculated from summing up the values of the sub-variables, suggested by table 10.

Table 11. *How Cognitive Engagement Is Calculated at the Participant Level*

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Final value in the one-on-one group
Remembering	3	3	1	0	0	0	7
Understanding	2	2	2	3	2	2	13
Applying	3	4	5	0	1	1	14
Analyzing	4	0	8	4	1	5	22
Evaluating	1	5	0	5	0	1	12
Creating	5	1	1	0	0	1	8
CE	35	31	34	25	9	26	160

Note: CE=Cognitive Engagement

Through such a calculation process, the research team achieved all the variables' continuous values (see figure 2). It is apparent that in each ring or pie chart, the dark grey component always exceeds 50% of the total, indicating its dominant percentage over the light grey component. It is observable that the student cohort performs better on all the variables when the students discuss the assigned topics in one-on-one groups.

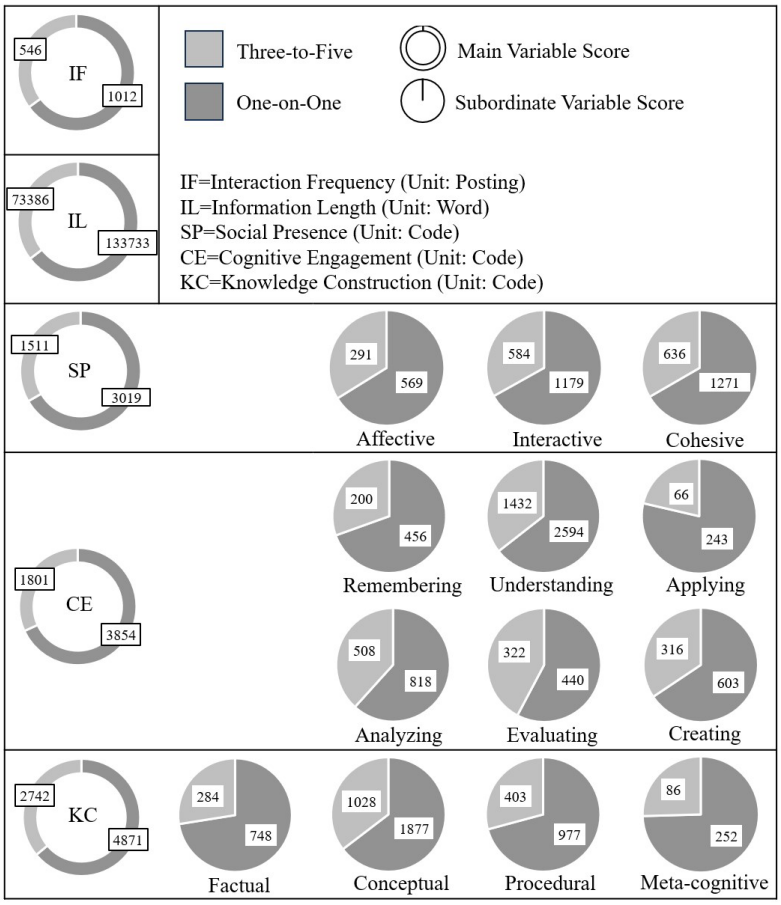

Figure 2. Values of variables

RESULTS

RQ1: IS A ONE-ON-ONE GROUPING APPROACH MORE EFFECTIVE THAN A THREE-TO-FIVE GROUPING APPROACH REGARDING THE QUANTITY OF STUDENTS' COMMUNICATION?

Paired-t tests were conducted to detect the significant differences regarding communication quantity. In terms of students' performance on interaction frequency (MD = -1.862, 95% CI [-2.269, -1.454], t (20) = -9.525, $p < 0.001$, d = -2.079), the one-on-one grouping approach (M = 48.191, SD = 14.576) is statistically better than the three-to-five grouping approach (M = 26.000, SD = 9.252). It means that when the small group size is two, students can generate more postings for the interactive purpose.

Students' performance on information length (MD = -2873.667, 95% CI [-3742.515, -2004.818], t (20) = -6.899, $p < 0.001$, d = -1.506) revealed a similar pattern. Students tended to provide more information in their postings when they converse in one-on-one groups (M = 6368.240, SD = 2350.410) instead of three-to-five groups (M = 3494.571, SD = 1740.500). Therefore, the one-on-one grouping approach is advantageous at extending the volume of information in the discussion forum.

RQ1: IS A ONE-ON-ONE GROUPING APPROACH MORE EFFECTIVE THAN A THREE-TO-FIVE GROUPING APPROACH REGARDING THE QUALITY OF STUDENTS' COMMUNICATION?

The results of the paired-t test conducted on the social presence variable proved that compared to the three-to-five grouping approach (M = 71.952, SD = 52.804), the one-on-one grouping approach (M = 143.760, SD = 65.137) could be easier to motivate students to regard the discussion form as an authentic social environment. Students' social presence score is significantly higher (MD = -71.810, 95% CI [-97.437, -46.182], t (20) = -5.845, $p < 0.001$, d = -1.275) when each of them only has only one partner to talk in the forum. Table 12 shows students' performance differences on the three subordinate categories of social presence. It uncovers that while significant differences ($p < 0.01$) occurred on students' performance of expressing emotions or feelings (i.e., affective) and employing dialogue techniques (i.e., interactive), the biggest difference (d = -1.309) was detected on the cohesive score, indicating that in one-on-one groups students could have a stronger sense of community making them feel socialized.

Table 12. *Paired-t Tests on Subordinate Variables of Social Presence*

Sub-Variable	t	Sig.	Mean Difference	SE	Cohen's d
Affective	-4.792	0.001**	-13.238	2.763	-1.046
Interactive	-4.916	0.001**	-28.333	5.764	-1.073
Cohesive	-5.998	0.001**	-30.238	5.041	-1.309

Note: **=significant level is smaller than 0.01.

With regard to students' cognitive engagement, the one-on-one grouping approach (M = 231.950, SD = 58.862) continues to surpass the three-to-five group approach (M = 130.571, SD = 43.121). Students' overall cognitive engagement score in one-on-one groups is significantly higher (MD = -101,381, 95% CI [-127.833, -74.929], t (20) = -7.995, $p < 0.001$, d = -1.745) than their score in three-to-five groups. The performance difference on cognitive engagement was further distinguished according to its six subordinate variables from the revised Bloom's taxonomy (Anderson et al., 2001). Table 13 discloses that the student cohort delivered better performances in one-on-one groups on all the variables, such as interpreting the meanings of assigned contents (i.e., understanding),

presenting the application cases of instructional technologies (i.e., applying), structuralizing arguments about technology integration issues (i.e., analyzing), criticizing others' opinions or public events (i.e., evaluating), and developing innovative ideas (i.e., creating). The biggest effect size (d = -2.134) was discovered on the remembering category. Thus, when students were grouped in pairs, there was a significant higher chance ($p < 0.01$) that they would connect what their peers had said, what the readings had stated, and what they recalled in memories with the ongoing discussion topic.

Table 13. *Paired-t Tests on Subordinate Variables of Cognitive Engagement*

Sub-Variable	t	Sig.	Mean Difference	SE	Cohen's d
Remembering	-9.779	0.001**	-1.654	0.169	-2.134
Understanding	-7.548	0.001**	-55.333	7.331	-1.647
Applying	-8.151	0.001**	-8.429	1.034	-1.779
Analyzing	-5.984	0.001**	-14.762	2.467	-1.306
Evaluating	-3.152	0.005**	-5.619	1.783	-0.688
Creating	-6.312	0.001**	-13.667	2.165	-1.377

Note: **=significant level is smaller than 0.01.

Lastly, students' performance was compared from the perspective of their constructed knowledge types in the discussion forum. The mean score of students' knowledge construction (M = 183.520, SD = 45.820) in one-on-one groups is higher than the mean score (M = 85.762, SD = 35.784) in three-to-five groups. The mean difference proved to be significant through a paired-t test (MD = -97.762, 95% CI [-115.434, -80.090], t (20) = -11.540, $p < 0.001$, d = -2.518). Delving into the specify constructed knowledge types, the research team found that students in one-on-one groups significantly ($p<0.01$) contributed more professional terminologies or theories (i.e., conceptual), technological integration methods or solutions (i.e., procedural), and awareness of their own personal characteristics or learning strategies (i.e., metacognitive). Besides, the largest students' performance discrepancy between the two grouping approaches (d = -2.345) is recognized on the factual knowledge. In one-on-one groups, students would be more included to share their personal stories or describe public events.

Table 14. *Paired-t Tests on Subordinate Variables of Knowledge Construction*

Sub-Variable	t	Sig.	Mean Difference	SE	Cohen's d
Factual	-10.745	0.001**	-22.095	2.056	-2.345
Conceptual	-8.455	0.001**	-40.429	4.782	-1.845
Procedural	-10.390	0.001**	-27.333	2.631	-2.267
Metacognitive	-9.264	0.001**	-7.905	0.853	-2.022

Note: **=significant level is smaller than 0.01.

RELIABILITY CHECK FOR MULTIPLE HYPOTHESIS TESTS

This study included 18 statistical comparisons and the paired-t test was conducted multiple times. Thus, the probability values (i.e., p-value) could be inflated due to multiple hypothesis tests (Perneger, 1998). The inflated p-values may threaten the reliability of this study. Therefore, the researcher team applied a Benjamini-Hochberg approach to

calculating the false discovery rates (FDRs) as the corrected p-values (Benjamini & Hochberg, 1995). Table 15 shows all the corrected p-values (i.e., FDRs) were higher than the expected α-level (i.e., 0.05). It proved that most of the original p-values were large enough to minimize the threats to the reliability of this study, originating from the multiple hypothesis tests.

Table 15. *False Discovery Rates (FDRs) of the Multiple Hypothesis Tests*

Variable	Rank	P-Value	FDR	Reject H_0
Knowledge Construction*	1	2.71E-10	4.87E-09	Yes
Factual	2	9.32E-10	8.39E-09	Yes
Procedural	3	1.66E-09	9.94E-09	Yes
Remembering	4	4.60E-09	2.07E-08	Yes
Interaction Frequency*	5	7.12E-09	2.56E-08	Yes
Metacognitive	6	1.13E-08	3.38E-08	Yes
Conceptual	7	4.91E-08	1.26E-07	Yes
Applying	8	8.73E-08	1.96E-07	Yes
Cognitive Engagement*	9	1.18E-07	2.35E-07	Yes
Understanding	10	2.83E-07	5.09E-07	Yes
Information Length*	11	1.00E-06	1.64E-06	Yes
Creating	12	4.00E-06	6.00E-06	Yes
Cohesive	13	7.00E-06	9.69E-06	Yes
Analyzing	14	8.00E-06	1.03E-05	Yes
Social Presence*	15	1.00E-05	1.20E-05	Yes
Interactive	16	8.30E-05	9.34E-05	Yes
Affective	17	1.11E-04	1.18E-04	Yes
Evaluating	18	5.02E-03	5.02E-03	Yes

Note: *=primary performance variables

SUMMARY OF THE RESULTS

As the corrected p-values for the t-tests were all below 0.05, students significantly performed better regarding both their communication quantity and their communication quality. When students were organized into one-on-one groups, students contributed more information by generating more postings and words. Moreover, they demonstrated a stronger social presence, achieved a higher level of cognitive learning, and constructed various types of knowledge. The smallest group size won the comparison.

DISCUSSION

The one-on-one groups created more and longer postings than the three-to-five groups in the online discussion forum. This finding is aligned with study of Wang et al. (2023), coining that the dyad group will produce more interactions than the quad groups in the collaborative activities. A potential reason behind this phenomenon is that the one-on-one grouping approach can free students from the pressure of interacting with multiple peers, thereby building up a comfortable communication environment for students. The study of Aderka (2009) suggests that interacting with an individual can maintain a minimized level of social anxiety compared to interacting with a group of people, consequently facilitating a student's behavioral engagement in communication. In one-on-one groups, students can redirect their energy from managing anxiety around multiple people to focusing on developing a sustained and iterative conversation with a single peer (Aderka, 2009; Wang et al. 2023).

Moreover, students in one-on-one groups tended to use more affective, interactive, and cohesive protocols to demonstrate their social presence in online discussions. This tendency can be understood through the lens of cooperative learning, the theoretical foundation of small group activities, which posits that students in one-on-one groups are more likely to treat and respect their partners as "real persons" by actively showing their social presence (Rovai, 2002). Cooperative learning suggests that social interdependence among students increases when group size decreases, because there are only a limited number of available peers maintaining the social activity (Johnson & Johnson, 1989; Deutsch, 1962). The one-on-one grouping approach means that only one peer is available when a student wants to maintain the discussion for achieving the academic success (Wang et al., 2023). Therefore, the students in a pair would value each other's efforts in the discussion activity and interact with each other in a sentimental, polite, and united manner.

In addition, one-on-one groups achieved higher levels of cognitive engagement and constructed more knowledge types than three-to-five groups. It suggests that students in one-on-one groups engaged in deep reflection on the content of conversations or the assigned readings rather than merely interact with peers for social purposes (Luo et al., 2023; Yang et al., 2011). This advantage of one-on-one groups might be attributed to the reduced likelihood of being overwhelmed by the excessive information provided by multiple peers. According to the cognitive load theory, students' cognitive engagement and knowledge construction can suffer when they must process information from numerous sources, which become more diverse and complicated (Plass et al., 2010; Sweller, 2023). In a one-on-one discussion group, a student processes the information from only one peer, and thus has a lower risk of being exposed to information overload. Consequently, students find it easier to immerse themselves in independent thinking and knowledge building.

Although the results highlight the positive effects of the one-on-one grouping approach on students' learning, the research team identified a potential disadvantage of the smallest group size that can harm students' online discussion experiences. Specifically, students can be easily demotivated when their partner in the group disappears. As noted in the data collection part, one of the 22 students never attended any discussion activity. It meant in each week there was a student who did not meet their partner, and thus had to conduct monologues instead of dialogues. The research team hypothesized that such isolation could depress the affected student and hinder his or her performance. In the future, more qualitative studies are expected to explore such a hypothesis. If confirmed, additional instructional design features may need to be involved to overcome the dilemma brought by this deficiency. For instance, several studies recommended that role assignment could be a flexible design feature which could help instructors ameliorate their online discussions (Schindler & Burkholder, 2014; Luo et al.,2023). Instructors may consider setting up a role whole are responsible for interacting with the isolated student when his or her partner fails to attend the one-on-one group discussion.

CONCLUSION

The significant paired-t statistical results of this study unveiled the victory of the one-on-one small grouping approach in the competition with the three-to-five small grouping approach within online discussions. The smallest group size proved its value on promoting students' online discussion performance on interaction frequency, information length, social presence, cognitive engagement, and knowledge construction in higher education, and thus is worth being considered as the optimal group size option in online discussions.

LIMITATIONS

The research team recognized the limitations of this research. Firstly, the sample size was small (n = 21) and threatened the reliability of the results. More participants can be

recruited in the future to solidify the reliability of the inferential statistics. One of the regrets is that the comparison was conducted on the same cohort of students (i.e., dependent comparison), not between two separate student cohorts (i.e., independent comparison). The paired-t tests cannot completely remove the carryover effects (Leech et al., 2014), which suggest students' first-half experience can influence their second-half experience in online discussion forum. Therefore, independent comparisons can be conducted later to support the results of this study. Also, other experimental design features, such as random assignment, can be added to enhance the research reliability in the future.

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ETHICAL STATEMENT

This study received approval from the Institutional Review Board (IRB) of the university to protect the participants.

DECLARATION OF INTEREST STATEMENT

The authors report there are no competing interests to declare.

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