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Challenges in assessing the nature of effective collaboration in blended university courses

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The ability to collaborate effectively face-to-face and online represents a critical skill for university graduates. However, there are still challenges regarding how to accurately assess this skill through traditional student learning measures. To better understand the nature of effective collaboration of university students in blended courses, the current study drew on the student approaches to learning framework and social network analysis techniques. We examined how student approaches to inquiry, approaches to online learning technologies, perceptions of the blended learning environment, different learning outcomes and configurations of collaboration are related. The methodologies commonly used in student approaches to learning research identified deep and surface approaches to inquiry and technologies, positive and negative perceptions of the integration of the learning environment, and of online workload, which also showed logical alignment with relatively better and poorer academic achievement in the course. Based on approaches, perceptions, and learning outcomes, students were divided into groups orientated towards understanding versus reproducing learning. The social network analysis techniques revealed features of different configurations of collaborations by different groups of students and their choices as to whether and with whom to collaborate during the learning process. Nuanced differences were found amongst different configurations of collaborations.

Implications for practice or policy:

- When assessing student experience of collaboration, social network analysis techniques may be able to describe nuanced differences amongst different collaborative configurations.
- To encourage students' collaboration, assessment tasks involving a large proportion of mandatory collaborative activities should be considered.
- To help student improve experience of collaboration, teachers may consider pairing students with a reproducing learning orientation with those having a deep disciplinary understanding.

Keywords: approaches to inquiry, approaches to using online learning technologies, perceptions of the blended learning environment, social network analysis, collaboration

Introduction

The Australian national higher education agenda of evaluating university student learning has shifted from a post-analysis of course experience (as one of the main thrusts of the framework) to the incorporation of a concurrent analysis of the student experience. Part of the rationale for this change is that the post-analysis of the Course Experience Questionnaire (typically results in a lag in data provision of up to 3 years after the graduation of the student cohort. The new Student Experience Survey, however, provides data at the beginning of the ensuing year on the first- and third-year experience of undergraduate courses of the previous year. This improvement in the availability of evaluation data will permit educators to act on results more quickly, but only if the measures are capturing meaningful differences of learning in the student experience. Amongst others, the Student Experience Survey assesses the graduate skill of group work through Likert-scale measures of collaboration between students – a key requirement of university graduates for employers and other stakeholders (Chambers & Burkhardt, 2015). A common strategy used

by university teachers to develop group work skills in learning is to design activities which require students to collaborate on learning tasks. From such strategies, teachers seek to develop fundamental graduate skills, such as negotiation, role-allocation, synthesis of ideas and shared responsibility.

Measuring the extent of effective collaboration and group work in experiences of learning is a difficult proposition as more collaboration does not necessarily mean better learning. Some students work hard in teams, others may contribute little or avoid teamwork altogether (Van den Bossche et al., 2006). Assessing collaboration and group work in blended courses becomes particularly challenging, because collaborative experience can occur in face-to-face contexts, online, or both. Thus, the accurate measurement of effective collaboration and group work in blended courses continues to be a methodological challenge for educational researchers and requires careful evaluation methodologies. These methodologies need to be able to capture those aspects of the experience which provide a rich description of collaboration other than frequency. To provide some possible solutions to the challenge, this study first aimed to use the techniques from social network analysis (SNA) to assess which configurations of collaborations are more successful than others. Furthermore, the study sought to understand how configurations of collaborations are related to students' approaches to, and perceptions of, learning, which have been consistently identified as key factors of experiences of learning in the student approaches to learning (SAL) framework in higher education (Prosser & Trigwell, 1999). To achieve these aims, we draw on three areas of research: research on student group work, SAL research, and educational research adopting SNA techniques.

Literature review

Research on student group work at university

Research into group work in blended courses at university has suggested a variety of reasons for the contextual success of group work. Some studies have attributed a key role to the teacher in linking the student in-class experience to that online (Anthony et al., 2019; Delialioglu & Yildirim, 2007; Díaz & Entonado, 2009). Others have focused on the way the teacher designs the content, communication and course activities (Kerres & De Witt, 2003), and the evaluation of designs for iterative improvement (Verkroost et al. 2008). Some other studies have attributed group work success to a sense of community amongst the students (Rovai & Jordan, 2004). Using the community of inquiry framework (Garrison & Arbaugh, 2007), perceived levels of collaborative learning has been found to be associated with the overall satisfaction of the blended courses and the degree of social presence, which is defined as psychological status of the connectedness and distance with teachers and peer learners when studying online (So & Brush, 2008). In these studies, the assessment of quality of teamwork and collaboration has predominantly used Likert-scale of questionnaires. Different from measures used in these studies, the current study evaluated the quality of collaboration using SNA techniques, which can visualise features of collaborative networks and describe quality through a number of key SNA metrics. Furthermore, the study also investigated how different configurations of collaboration are related to students' approaches to and perceptions of their experiences of learning, because there is little research on such associations, even though approaches and perceptions have been consistently reported as key factors in students' academic achievement (Prosser & Trigwell, 2017). The next section reviews relevant studies on approaches to, and perceptions of, learning in SAL research.

SAL research

SAL research (Biggs, 2011; Prosser & Trigwell, 1999) offers methodologies to identify differences in the university student experiences of learning. The research framework investigates conceptions of, approaches to, and perceptions of, learning at university and relates these to the prior characteristics of students, departmental variables, and academic achievement. A key outcome from these studies relevant to this investigation is the experiences of learning suggested by deep and surface approaches to learning. Deep approaches to learning have been shown to involve a focus on the meaning of the learning activities, suggesting that students understand how the activities are related to the learning outcomes of the course (Prosser & Trigwell, 2017). Students adopting deep approaches often use strategies, such as reflection, synthesis and critical thinking. In contrast, surface approaches to learning involve an intent which is more formulaic, reproductive and mechanistic. Strategies adopted in this type of approach to learning have little reflection, make use of cut-and-paste information from different sources into lists of ideas, and lack attempts to weave together concepts which reveal an informed position on the topics studied. In this area

of research, while there have been some studies into student experiences of learning in blended courses at university (e.g., Ellis & Bliuc, 2016, 2019; Ellis et al., 2012), there is still much not known about the relations amongst approaches to learning and to online learning technologies, perceptions of the blended learning environment, and academic achievement. In blended course design which integrates collaboration and group work, it is important to investigate how approaches, perceptions, and achievement are related to the quality of collaboration. The current study will add to this area of research.

Educational research adopting SNA techniques

Educational research using SNA techniques has been used to investigate education-related issues. This research has focused on how teachers discuss their work together (Quardokus & Henderson, 2015), how friendship amongst students relates to their learning (Brewe et al., 2012; Rienties et al., 2013), how students interact online (Rodríguez-Hidalgo et al., 2015), and how students' learning networks are related to their achievement in class (Tomás-Miquel et al., 2016). SNA adopts principles of graph theory using nodes (representing students) and edges (representing their interactions) as a way of identifying the configurations by which students interact in groups (Wasserman & Faust, 1994). This approach permits the visualisation and measurement of social, academic, and collaborative ties amongst the learners. The techniques provide useful tools to investigate configurations of group work amongst students and the quality of the collaborative networks they develop (Gašević et al., 2013). The current study aimed to understand how configurations of collaborations may differ amongst students with different approaches, perceptions, and academic achievement by using SNA to measure the quality of collaboration. The term *qualitatively different*, which is frequently used in the research field of SAL, refers to how combined aspects of the student experience, such as deep approaches, positive perceptions and relatively higher marks for one group in the population sample differ to surface approaches, negative perceptions and relatively lower marks for another.

Research questions

This study sought to understand the issues raised in the literature review. In doing so, the following three research questions were addressed:

- To what extent do students' approaches to inquiry, approaches to online learning technologies, and perceptions of the blended learning environment, relate to their academic achievement in blended course design?
- How are collaborations configured based on student approaches, perceptions, and achievement and their choice of collaboration?
- What are the differences amongst configurations of collaborations?

Method

Participants and recruitment

Our participants were recruited from 506 students who were enrolled in a first-year university course, "Introduction to Social Behaviour", in a large metropolitan Australian university. Recruitment of the participants strictly followed the ethical requirements of the researchers' institutions to ensure the voluntary nature of participation and an essential written consent procedure. One week before the study, students were informed about the purpose of the study and were invited to participate. They were given 1 week to decide whether they would like to be involved in the study. Those who expressed a willingness to participate were required to sign a written consent form. A total of 500 students consented and participated. Their ages were between 18 and 33 years old, with a mean of 21.83 and a standard deviation of 1.80.

The learning context

The course introduced students to concepts that explain how social behaviours and relationships occur in contexts such as family, school, work and leisure. The key outcomes of the course not only focused on deep understandings of the disciplinary knowledge of a range of theoretical orientations to the social settings of human behaviours across the lifespan but also included developing the generic skills of collaboration and

group work through communicating students' understandings of theories as well as applying theoretical concepts in practical analyses.

The learning activities were designed using the principle of the flipped learning approach, which is a form of blended learning design (Lee et al., 2017; O'Flaherty & Phillips, 2015; Pardo & Mirriahi, 2017). Blended learning design is "a systematic combination of co-present (face-to-face) interactions and technologically-mediated interactions between students, teachers and learning resources" (Bliuc et al., 2007, p. 234). Of the approaches in blended learning design, the flipped learning approach requires students to engage in "interactive content focusing on key concepts prior to class thus allowing class time for collaborative activities that clarify concepts and contextualise knowledge through application, analysis, and planning and producing solutions" (Karanicolas et al., 2018, p. 1). Building on these principles, the course was designed as a combination of weekly face-to-face lectures and tutorials, complemented by compulsory online activities. In the face-to-face classes, students were asked to discuss in pairs to prepare for a critical review task, as well as group work involving applying relevant theories and concepts covered in the lectures to analyse online artefacts such as videos, images, and online newspapers articles. There were three types of online learning activities: online research to discover information and ideas to illustrate the content covered in the lectures; online quizzes to test understanding of core concepts; and online discussions around shared interests, emerging understanding of the key issues, and ways of addressing the assessment tasks.

Instruments

Three instruments were used to collect data, namely a close-ended questionnaire, an open-ended questionnaire, and students' academic achievement. The close-ended questionnaire examined students' approaches to inquiry, approaches to using online learning technologies, and perceptions of the blended learning environment. The questionnaire had six scales and used 5-point Likert scales. The questionnaire designed using SAL literature was used in previous research in blended learning contexts (Bliuc et al., 2010; Ellis et al., 2007; Han & Ellis, 2019a). Table 1 provides a detailed description of the questionnaire.

Table 1
Descriptions of the close-ended questionnaire

Sections	Scales	Description
Approaches to inquiry	*deep approaches to inquiry* (5 items)	Assesses approaches to inquiry that are proactive, reflective, and involve the creation of revealing questions to promote thinking.
	surface approaches to inquiry (5 items)	Assesses approaches to inquiry that are formulaic, automatic, and are conducted with little reflection.
Approaches to online learning technologies	*deep approaches to online learning technologies* (7 items)	Assesses approaches to technologies that are used to promote understanding by fleshing out the key ideas of the course, looking at the ideas in new ways, and relating those ideas to real-world experiences.
	surface approaches to online learning technologies (5 items)	Assesses approaches that under-use the technologies in learning, tend to ignore the potential of the technologies to promote understanding, and use technologies in mechanistic ways for the purposes of reducing workload and effort in the course.
Perceptions of the blended learning environment	*perceptions of online workload* (5 items)	Assesses perceptions that the workload in the course is reasonable regarding the learning outcomes sought.
	perceptions of integrated learning environment (4 items)	Assesses perceptions of how integrated the physical and virtual learning environments are.

The open-ended questionnaire was designed based on methodologies used in SNA. It asked students to write down the following:

> In your learning in this course, with whom did you collaborate?
> (a) the most frequently
> (b) the second most frequently
> (c) the third most frequently

The students' final mark was used as their academic achievement in the course. It was an aggregated score of the five assessment tasks:

- a critical review of a journal article (10%)
- a plan of an analysis of human behaviours revealed in online artefacts (10%)
- a report on the theoretical and practical implications of the human behaviour analysis (40%);
- collaboration and participation in the tutorial activities (10%)
- an examination on the key concepts covered in the course using the short answer format (30%).

Data analysis

Data analysis involved three stages in order to answer the three research questions respectively. In Stage 1, SAL methodologies were used to examine the relations between approaches to and perceptions of students' learning experience and their final mark. The analyses started by conducting a reliability analysis of the scales in the close-ended questionnaire and calculating the descriptive statistics, followed by correlation analyses, which were used to assess the strength of the pairwise associations between variables. Then a cluster analysis was used to identify similar experiences reported by students in the population sample. The results of the correlation and cluster analyses were used to provide answers as to how students' approaches to inquiry, approaches to online learning technologies, and perceptions of the blended learning environment relate to their academic achievement (research question one).

To find out the configurations of student collaboration (the second research question), both SAL methods and SNA techniques were used. Using the cluster membership generated from the SAL methods in Stage 1 analysis, and students' responses to the open-ended questionnaire, the students' collaborations were configured, and the students were grouped into one of the five groups within the whole collaboration network: two groups did not collaborate, and three of them did. The SNA, which was conducted using the software package Gephi, enabled us to identify features of collaboration, such as number of collaborations and maximum number of collaborations for a student of different groups.

To investigate the differences amongst configurations of collaboration (the third research question), we first calculated the SNA metrics for the three groups representing the three different configurations of students' collaborations (we excluded the two groups which did not collaborate because it was not possible to calculate the SNA metrics), we then conducted one-way ANOVAs to compare the SNA metrics of the different groups.

Results

Stage 1 – the SAL analyses

For the SAL analyses, we first present reliability of the scales and descriptive statistics, followed by the results of correlation analysis, and then the results of cluster analysis and one-way ANOVAs.

Reliability of the scales and descriptive statistics
Table 2 presents the reliability of the six scales in the close-ended questionnaire as well as the descriptive statistics, including *M*, *SD*, and skewness of the scales and final mark. The values of Cronbach's alpha indicated that all the scales were within the acceptable reliability. Regarding the academic achievement, students obtained an average of 72.34 (*SD* = 11.23), which suggested that students' academic performance in this course was widely spread.

Table 2
Reliability and descriptive statistics

Variables	*M*	*SD*	skewness	reliability
Deep approaches to inquiry	4.02	0.56	-1.11	α =.71
Surface approaches to inquiry	2.42	0.62	0.67	α =.66
Deep approaches to online learning technologies	3.58	0.60	-0.29	α =.86
Surface approaches to online learning technologies	2.59	0.67	0.23	α =.73
Perceptions of online workload	2.88	0.69	0.10	α =.88
Perceptions of integrated learning environment	3.40	0.69	-0.31	α =.79
Final mark	72.34	11.23	-1.63	---

Results of correlation analysis

Before performing correlation analyses, the following assumptions were checked: (1) approximate normal distribution; (2) the linear relation between paired variables; and (3) homoskedasticity (Field, 2013). Table 1 shows that the values of skewness were between -1.63 and 0.10, which fell within the acceptable values ± 2 (Gravetter & Wallnau, 2014; Trochim & Donnelly, 2006), hence, all these variables were approximately normally distributed. Then all the scatterplots of the paired variables were checked to ensure the linearity and homoskedasticity assumptions were met. The pairwise associations between the scales in the close-ended questionnaire and course marks are displayed in Table 3.

Table 3
Results of correlation analysis

Variables	2	3	4	5	6	7
1. Deep approaches to inquiry	-.32**	.47**	-.28**	.18	.34**	.11*
2. Surface approaches to inquiry	---	-.19**	.44**	.33**	-.05	-.15**
3. Deep approaches to online learning technologies	---	---	-.36**	-.01	.53**	.09*
4. Surface approaches to online learning technologies	---	---	---	.46**	-.09*	-.09
5. Perceptions of online workload	---	---	---	---	.12**	.14**
6. Perceptions of integrated learning environment	---	---	---	---	---	.02
7. Final mark	---	---	---	---	---	---

Notes. $^{**}p < .01$, $^{*}p < .05$

Table 3 shows that deep approaches to inquiry scale had significant relations with all the other variables, except for the perceptions of online workload scale. More precisely, it was negatively related to the surface approaches to inquiry scale (r = -.32, p < .01) and the surface approaches to online learning technologies scale (r = -.28, p < .01). The correlation between the deep approaches to inquiry scale and the students' final mark was positive and weak (r = .11, p < .05). The surface approaches to inquiry scale was negatively and weakly related to the students' final mark (r = -.15, p < .01) and the deep approaches to online learning technologies scale (r = -.19, p < .01). The correlation between the surface approaches to inquiry and the surface approaches to online technologies were positive and moderate (r = .44, p < .01). So was the correlation between the surface approaches to inquiry and the perceptions of online workload (r = .33, p < .01).

The deep approaches to online learning technologies scale was negatively and moderately related to the surface approaches to online technologies scale (r = -.36, p < .01). The deep approaches to online learning technologies scale also positively (but weakly) correlated with the final mark (r = .09, p < .05). While the deep approaches to online learning technologies scale was positively and moderately associated with the perceptions of integrated learning environment scale (r = .53, p < .01), the surface approaches to online learning technologies had a negative relation with the perceptions of integrated learning environment scale (r = -.09, p < .01), but had a positive relation with the perceptions of online workload scale (r = .46, p < .01).

Results of cluster analysis and one-way ANOVAs

Based on the increasing value of the squared Euclidean distance between clusters, a two-cluster solution was retained using all the scales and the students' final mark. The raw scores were transformed into *z* scores in the analyses to facilitate interpretation of the results. A series of one-way ANOVAs were then performed to examine whether there were significant differences between the two clusters of students on the six scales and the final mark. The means and standard deviations of *z* scores, the results of ANOVAs, and the corresponding effect size are displayed in Table 4.

Table 4
Results of one-way ANOVAs based on cluster membership

Variables	Cluster 1: understanding (N = 113)		Cluster 2: reproducing (N = 387)		F	P	η^2
	M	SD	M	SD			
DAI	0.65	0.61	-0.16	0.99	67.94	.00	.12
SAI	-0.63	0.68	0.15	0.98	61.61	.00	.11
DAOLT	1.02	0.64	-0.29	0.90	209.66	.00	.30
SAOLT	-0.97	0.72	0.28	0.89	185.89	.00	.27
WL	-0.58	0.97	0.16	0.96	50.81	.00	.09
IENV	0.72	0.87	-0.20	0.93	89.48	.00	.15
FM	0.44	0.68	-0.13	1.04	29.74	.00	.06

Note. DAI = deep approaches to inquiry; SAI = surface approaches to inquiry; DAOLT = deep approaches to online learning technologies; SAOLT = surface approaches to online learning technologies; WL = perceptions of online workload; IENV = perceptions of integrated learning environment; FM = final marks

Table 4 shows that students in Cluster 1 had a relatively more successful learning experience and learning outcomes, referred to as the understanding cluster, and students in Cluster 2 had relatively poorer learning experience and learning outcomes, referred to as the reproducing cluster. The ANOVAs found all the scales and the final marks between the two groups of students were statistically significant: deep approaches to inquiry, $F(1, 498) = 67.94$, $p < .01$, $\eta^2 = .12$; surface approaches to inquiry, $F(1, 498) = 61.61$, $p < .01$, $\eta^2 = .11$; deep approaches to online learning technologies, $F(1, 498) = 209.66$, $p < .01$, $\eta^2 = .30$; surface approaches to online learning technologies, $F(1, 498) = 185.89$, $p < .01$, $\eta^2 = .27$; perceptions of online workload, $F(1, 498) = 50.81$, $p < .01$, $\eta^2 = .09$; perceptions of integrated learning environment, $F(1, 498) = 89.48$, $p < .01$, $\eta^2 = .15$; and students' final mark, $F(1, 498) = 29.74$, $p < .01$, $\eta^2 = .06$.

As Table 4 illustrates, students in Cluster 1 tended to adopt more deep approaches to inquiry and more deep approaches to online learning technologies. They also tended to view the face-to-face and online components of learning and teaching to be well integrated. At the same time, they obtained relatively higher marks compared with students in Cluster 2. In contrast, students in Cluster 2 adopted more surface approaches to inquiry and to online learning technologies. They perceived online workload as higher than their peers in Cluster 1. They also perceived the blended learning environment as not well integrated. Their academic outcome was also shown to be relatively poorer than that of Cluster 1 students.

Stage 2 – Configurations of collaborations

Using the cluster categorisation identified by approaches, perceptions, and achievement (in Table 4 in either the understanding or reproducing cluster) and students' answers as to with whom they collaborated, the SNA techniques identified five configurations of collaborations within the whole collaboration network.

Figure 1 visually presents the whole collaboration network and the five configurations, amongst which three collaborated and two did not. The three collaborating groups were labelled as the *understanding collaborative group*, the *reproducing collaborative group*, and the *mixed collaborative group*. The non-collaborating groups were labelled as the *understanding alone group* and the *reproducing alone group*.

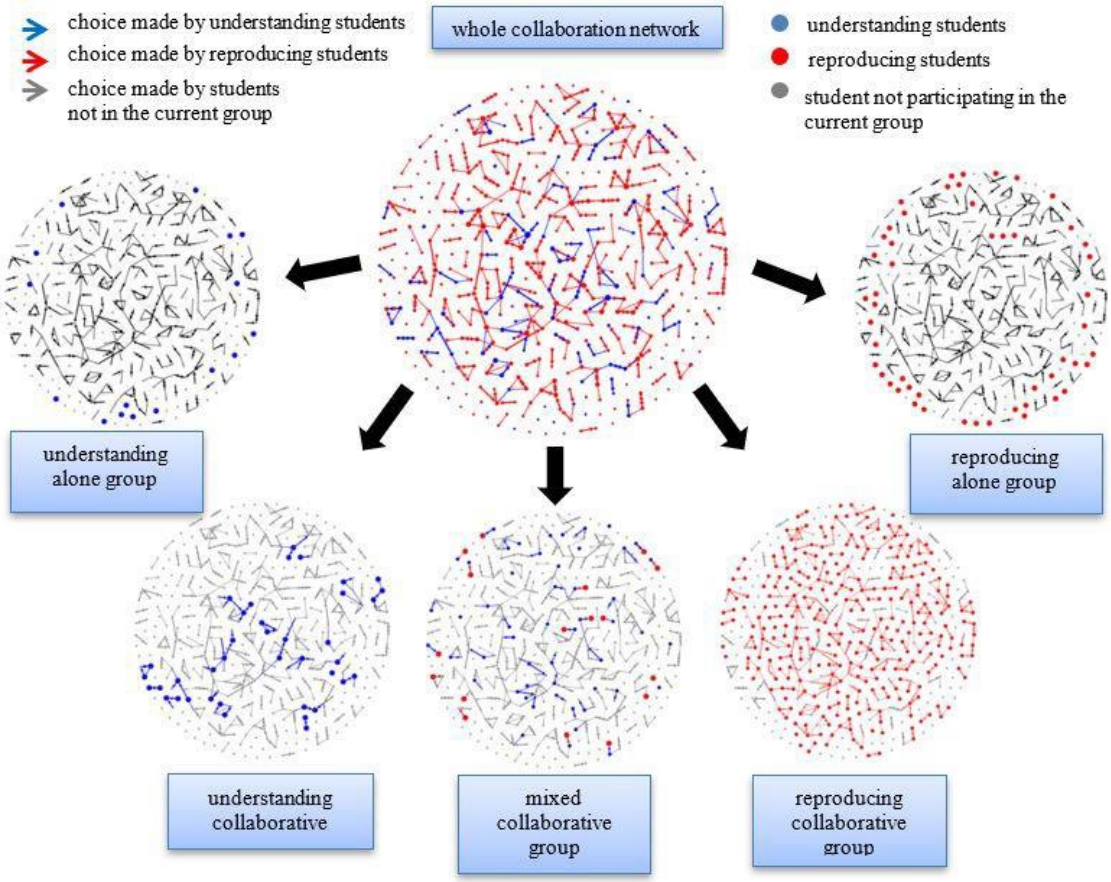

Figure 1. *Configurations of students' collaborations*

Table 5
Features of five configurations of collaborations

Measures	Whole network	UA	UC	IC	RC	RA
no. of students (nodes)	475	16	39	69	300	51
no. of collaborations (edges)	578	0	31	14	345	0
maximum no. of collaborations for a student	22	0	3	1	8	0
no. of students working alone	115	16	0	0	0	51
no. of groups	91	0	15	56	41	0

Note. UA = understanding alone group; UC = understanding collaborative group; IC = mixed collaborative group; RC = reproducing collaborative group; RA = reproducing alone group

Table 5 presents measures that describe the features of the five configurations of collaborations:

- *The understanding alone group* (N = 16): made up of understanding students who reported not collaborating with others
- *The understanding collaborative group* (N = 39): made up of understanding students who reported collaborating with other understanding students
- *The mixed collaborative group* (N = 69): made up of understanding students who reported collaborating only with reproducing students and vice versa
- *The reproducing collaborative group* (N = 300): made up of reproducing students who reported collaborating with other reproducing students
- *The reproducing alone group* (N = 51): made up of reproducing students who reported not collaborating with others.

Stage 3 – Comparison of the SNA metrics amongst three configurations of collaborations

Table 6 shows the results of one-way ANOVAs, which compared the SNA metrics amongst the three configurations of collaborations, namely understanding collaborative group, mixed collaborative group, and reproducing collaborative group.

Table 6
Results of one-way ANOVAs for comparing the SNA metrics amongst the three configurations of collaborations

SNA metrics	Group	*M*	*SD*	Post-hoc	*F*	*p*	η^2
weighted degree (average collaborations)	UC	7.44	3.43	UC > RC	6.28	.00	.03
	IC	4.88	3.12	UC = IC			
	RC	6.17	3.86	IC = RC			
weighted in-degree (average received collaborations)	UC	3.56	2.81	---	2.89	.06	.01
	IC	2.30	2.26	---			
	RC	3.14	3.13	---			
weighted out-degree (average initiated collaborations)	UC	3.87	1.98	UC > RC	4.91	.00	.03
	IC	2.58	1.97	UC > IC			
	RC	3.03	2.09	IC = RC			
closeness (weighted distance to reach other students in their collaborations)	UC	0.15	0.21	UC = RC	6.59	.00	.03
	IC	0.32	0.39	UC < IC			
	RC	0.19	0.27	IC > RC			
betweenness (the position of students to obtain information)	UC	0.024	0.028	UC > RC	7.74	.00	.04
	IC	0.007	0.013	UC > IC			
	RC	0.013	0.021	IC = RC			

Note. UA = understanding alone group; UC = understanding collaborative group; IC = mixed collaborative group; RC = reproducing collaborative group; RA = reproducing alone group

The results of one-way ANOVAs show that the understanding, mixed, and reproducing collaborative groups differed significantly in terms of weighted degree (average collaborations), $F(2, 432) = 6.28$, $p < .01$, $\eta^2 = .03$; weighted out-degree (average initiated collaborations), $F(2, 432) = 4.91$, $p < .01$, $\eta^2 = .03$; closeness (weighted distance to reach other students in their collaborations), $F(2, 432) = 6.59$, $p < .01$, $\eta^2 = .03$; and betweenness (falls on the paths between other pairs of collaborations), $F(2, 432) = 7.74$, $p < .01$, $\eta^2 = .04$. However, students did not differ in terms of weighted in-degree (average received collaborations), $F(2, 432) = 2.89$, $p = .06$, $\eta^2 = .01$.

Considering the unequal sample size in each group, we performed Gabriel post-hoc analyses for pairwise comparisons. For the weighted degree (average collaborations), students in the understanding collaborative group had significantly more collaborations ($M = 7.44$, $SD = 3.43$) than students in the mixed collaborative group ($M = 4.88$, $SD = 3.12$). But there were no differences between understanding collaborative group and reproducing collaborative group ($M = 6.17$, $SD = 3.86$); and between mixed collaborative group and reproducing collaborative group.

In terms of the weighted out-degree measure (average initiated collaborations), students in the understanding collaborative group ($M = 3.87$, $SD = 1.98$) initiated more collaborations than students in the mixed collaborative group ($M = 2.58$, $SD = 1.97$) and students in the reproducing collaborative group ($M = 3.03$, $SD = 2.09$). There was no significant difference in terms of the initiated collaborations between students in the mixed collaborative and reproducing collaborative groups.

As far as closeness measure (weighted distance to reach other students in their collaborations) is concerned, while students in the understanding collaborative group ($M = 0.15$, $SD = 0.21$) and reproducing collaborative group ($M = 0.19$, $SD = 0.27$) had similar level of distance to reach their collaborators, students in the mixed collaborative group ($M = 0.32$, $SD = 0.39$) had shorter distance to reach their collaborators. Lastly, the post-hoc test showed that students in the understanding collaborative group ($M = 0.024$, $SD = 0.028$) had significantly higher betweenness, which means that these students were more likely to be placed in the paths of information circulation, hence were more efficient in obtaining information than students in

the mixed collaborative (M = 0.007, SD = 0.013) and reproducing collaborative (M = 0.013, SD = 0.021) groups.

To summarise our main results, we found that in general, students in the understanding collaborative group tended to initiate more collaborations and occupied more strategic positions in the collaboration for obtaining information. These aspects of their approach to collaboration were more efficient than those in the reproducing and mixed collaborative groups. Compared to students in the mixed collaborative group, students in the reproducing collaborative group appeared to be less easily to be reached in terms of closeness.

Discussion

Before discussing the results of the study, it is worthwhile noting some of the limitations. This study is but one investigation into a large undergraduate social sciences course. Notwithstanding that previous related studies in the research program into a different discipline (engineering) have found consistent results (Ellis et al., 2018; Ellis et al., 2016), further research should be conducted in other academic disciplines and in courses with varying sizes in order for the robustness of the results and clarity of interpretation to be confirmed and disseminated. Furthermore, students' demographic information, in particular, their socio-economic status, might have different distribution in the understanding and the reproducing clusters. Future studies may explore the distribution of socio-economic status within each cluster and/or across clusters.

The purpose of this study was to better understand the nature of effective collaboration and group work of university students in blended course designs. It investigated how student approaches to inquiry and to online learning technologies, their perceptions of the blended learning environment, and the learning outcomes were related to different configurations of collaborations. The study used methodologies from SAL research and confirmed previous findings of the existence of deep and surface approaches to inquiry and technologies, and positive and negative perceptions of the integration of the face-to-face and online learning environment and the accompanying online workload (e.g., Bliuc et al., 2010; Ellis et al., 2007). Using the outcomes of the cluster analysis that identified groups within the population sample, students could be distinguished between those orientated towards understanding and those orientated towards reproducing. Based on these categorisations and students' choice of collaborations, SNA analyses revealed five configurations of collaborations within the whole class collaboration network. The SNA metrics of the configurations of the collaborations provide a clear picture of the ways the students interacted when learning.

Our findings suggest that not all students in the course had the same experience of the learning activities. The first cluster strongly engaged with the tasks, approaching the activities in class and online with the intent to get to the heart of what was going on, developing thoughtful questions to guide their inquiry and the way they used the online learning technologies. These students tended to perceive that the online environment was well integrated with their course and they did not report feeling overwhelmed by the course online workload. In general, this group performed at a higher academic level as measured by the course mark. In contrast, the second cluster tended to adopt a more mechanistic and reproductive way of learning, which reduced their engagement in class and online; they perceived the online learning environment of their course to be fragmented from what they were doing face-to-face and were overwhelmed by the workload. In comparison, they tended to obtain a relatively lower level of academic achievement. These results reveal systematic variations and logical alignments on students' approaches, perceptions, and academic achievement. Such variations corroborated previous studies in SAL literature on experiences of learning in blended course designs from other academic disciplines, such as science (e.g., Ellis & Bliuc, 2019), engineering (e.g., Ellis et al., 2019; Ellis et al., 2016), and business (e.g., Han & Ellis, 2019b). Jointly these findings seem to suggest that irrespective of the academic disciplines, levels of students' academic achievement are related to their approaches and perceptions in the learning processes, highlighting the important roles of these elements in university student learning.

When collaborating in groups, the SNA identified five configurations of collaborations, which were formed based on their cluster membership, and their choice as to whether studying alone, working with someone from their cluster, or working with someone from the other cluster. While students who were in the understanding alone group performed academically well, they reduced their opportunities to develop the generic skills of collaboration and group work by choosing not to engage with others. This was also the

case for students in the reproducing alone network, who not only missed the opportunity to learn from other students by engaging in group work but also did not have desirable academic achievement.

Implications for teaching practice

Enabling and encouraging collaboration in university learning is both a necessary and difficult aspect of the student experience. It is necessary because most universities seek to produce graduates who can work to solve problems in pairs or in groups using technology as these types of graduate outcomes are sought widely by employers (see, e.g., Tran, 2016). It is difficult because ensuring students take responsibility for parts of group work and engaging in supportive, collaborative behaviour is a nuanced combination of pedagogy and task design (Bower et al., 2017).

The implications of the different configurations and experiences of collaboration identified in this study are significant. In the current research context, collaboration was accounted only for a small percentage of the final course mark. This might explain why some students chose not to collaborate even they were asked to. To help students who avoid collaboration, a stronger link between assessment and collaboration participation would signal to the students the importance of engaging with others. One of the possible ways to encourage students' collaboration and group work can be achieved by the design of assessment tasks which involve a large proportion of mandatory collaborative activities, such as group projects, team presentations, and joint reports on reflections of collaborative experiences. The adjustment to the assessment schedule would help all students to develop their group work strategies and abilities to interact with others, particularly if those in the reproducing alone group could be paired up with students who reported an understanding orientation. Disciplinary knowledge alone without the ability to share insights and work with others in teams is no longer a sufficient outcome for university graduates if one takes the views of employers seriously (see, e.g., Erickson, 2017).

A similar teaching approach would benefit many of the students who did collaborate but were yet to report strategies that appeared to help them develop a deep understanding. The reproducing students in the mixed and reproducing collaborative groups may have both benefited from appreciating how and why the understanding students approached inquiry and online learning technologies.

It is clear in this study that even though teachers provide students with opportunities to develop both their disciplinary expertise and group work skills, it does not necessarily result in all students developing a deep disciplinary understanding as well as high-quality collaboration experience and skills.

Consequently, university teaching requires more innovative approaches to assess student experience of collaboration, such as a using the SNA techniques to identify configurations of collaborations and to describe nuanced differences amongst different collaborative configurations.

Statements

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