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Patterns of student collaborative learning in blended course designs based on their learning orientations: a student approaches to learning perspective

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Abstract

This study combines research methods from student approaches to learning research and social network analysis (SNA) to examine patterns of students' collaborative learning based on their learning orientations amongst 193 postgraduates enrolled in a blended course. The study identified two distinct learning orientations, namely 'understanding' and 'reproducing', which differed in approaches to learning through inquiry, approaches to using online learning technologies, perceptions of the online workload, and academic outcomes. On the basis of students' learning orientations and their choice of whether to collaborate and with whom to collaborate, five networks representing five patterns of collaborative learning were found. From these, two did not reveal any collaboration (Understanding Alone and Reproducing Alone networks); and three revealed collaborations (Understanding Collaboration, Mixed Collaboration, Reproducing Collaboration networks). A range of SNA measures were calculated and revealed different features of the three collaboration networks. Viewed together, the combined methodologies suggest that the Understanding Collaboration network has more desirable features of collaboration, such as the intensity of collaboration, having closely knitted groups who tended to seek out and welcome peers and who tended to engage more often in both face-to-face and online modes. The study suggests that helping students adjust their learning orientations, designing some compulsory collaborative assessment tasks, and configuring the composition of collaborative groups are productive strategies likely to improve students' experiences of collaborative learning.

Keywords: Patterns of collaborative learning, Approaches to learning, Approaches to using online learning technologies, Perceptions of the online workload, Social network analysis

Introduction

Evaluation of students' collaborative competence has long been an essential part in higher education quality assurance agenda across countries (Indiana University Center for Postsecondary Research, 2020; Neves & Hewitt, 2020). An ability to collaborate and work in teams are not only the skills that employers require when they look for workforce ready graduates (Hill et al., 2016; Holland et al., 2013; Norton et al., 2016), but also what students expect to develop in order for them to work competently in teams and to collaborate effectively with their colleagues (Christensen et al., 2014). While collaborative competence has been continually emphasized and highlighted in the assessment of students' learning experience in national frameworks in many countries, such as United States (Indiana University Center for Postsecondary Research, 2020), United Kingdom (Neves & Hewitt, 2020), and Australia (Department of Education, Skills & Employment, 2021); there is ongoing evidence that employers are dissatisfied with graduates' collaborative skills (Harder et al., 2014). One of the examples of the dissatisfaction is demonstrated in the Australian national Employer Satisfaction Survey, which consistently shows that graduates' collaborative skills are rated the second lowest of the five surveyed skills (i.e., foundation skills, adaptive skills, collaborative skills, technical skills, and employability skills) over the past five years from 2016 to 2020 (Department of Education, Skills and Employment). For instance, the 2020 survey results show that collaborative skills received a satisfaction rate of 88.1%, which was only above the rate for employability skills (86.8%), but was lower than technical skills (93.8%), foundation skills (93.7%), and adaptive skills (90.1%). To provide workforce ready graduates, higher education programs must develop strategies to address this educational need and to train this important attribute. Despite its importance, developing students' collaborative skills and fostering desirable experience of collaborative learning remains a challenging issue in higher education sector partly because collaborative learning is a complex activity, which involves many aspects and the interplay of these aspects in learning, such as the student factor and increasingly complex blended course designs.

As a consequence of the agenda for higher education and employer interest in the collaborative ability of graduates, it is valuable, if difficult, to examine different patterns of collaborative learning in order to tease out nuanced features of different patterns, so that these can serve as an evidence-base for teaching and course design strategies that are more likely to foster desirable patterns and collaborative behaviour. To achieve this aim of research, the current study draws on two complementary research areas into university student learning: student approaches to learning (SAL) research, which provides a sound theoretical basis of student learning experience in higher education (Ellis & Goodyear, 2013; Ramsden, 2003; Trigwell & Prosser, 2020); and methodologies in social network research, known as social network analysis (SNA), which is a set of empirically powerful techniques that can be used to reveal nuanced features in collaboration (Grunspan et al., 2014; Wasserman & Faust, 1994). The following literature first reviews previous research on collaborative learning in university settings, followed by SAL research and educational studies using SNA.

Literature review

Research on collaborative learning in university settings

While there are diverse definitions provided for the term 'collaboration', such as working constructively with others (Knight & Yorke, 2003); sharing unique ideas and experiences with group members (Hathorn & Ingram, 2002); or group members contributing to the whole to achieve a common goal (Roberts, 2004); these definitions share two important elements: that there is an agreed goal as well as a shared ownership of the final product

(Storch, 2013). While collaborative learning is often used interchangeably with cooperative learning, it is possible to distinguish between the two. Cooperative learning tends to focus on each portion of the task delegated to each individual in a group, whereas collaborative learning emphasizes more on the mutual engagement and the non-separable nature of the individual contribution to the task (Kozar, 2010).

Collaborative learning has attracted much attention in educational research because of the importance of collaborative competence for graduates expressed by national agendas, employers, and students themselves (Robbins & Hoggan, 2019; Williams, 2017). The existing studies on collaborative learning fall into two broad themes: one theme examines benefits of collaborative learning, and the other theme investigates factors which are related to quality of collaborative learning. Regarding the first theme, research has demonstrated that collaborative learning is beneficial to develop other important learning skills, such as higher-order metacognitive abilities, critical thinking, problem solving, and decision making (e.g., Gokhale & Machina, 2018; Jonassen & Kwon, 2001); to foster positive affect, attitudes, and motivation in learning (e.g., Zheng, 2017); to enhance level of engagement and in-depth learning (e.g., Zhu, 2012), and may also lead to better academic performance (e.g., Sung et al., 2017).

For the second theme, which concerns the factors associated with experience in collaborative learning, three broad categories of factors have been investigated: namely (1) the setting of collaboration, including group composition (e.g., Lee & Lee, 2016) and group size (e.g., Schellens & Valcke, 2006); (2) learning activities in collaboration: including types of activities (e.g., Zheng et al., 2015), structure of activities (e.g., Kapur & Kinzer, 2009), and the availability of scaffolding (e.g., Gu et al., 2015); and (3) student factors, including emotion and affect (e.g., Reis et al., 2018), self-efficacy (e.g., Wilson & Narayan, 2016), regulatory behaviors in collaboration (e.g., Kwon et al., 2014), and metacognition (e.g., Akyol & Garrison, 2011). Of these student factors, however, there has been little research into students' learning orientations, which have been systematically investigated in student approaches to learning research, showing there are distinct variations of learning orientations amongst students (Han & Ellis, 2020a, 2021; Lonka et al., 2004; Ramsden, 1988). The current research aims to fill this gap by investigating patterns of students' collaborative learning based on their learning orientations.

SAL research

SAL research is a well-recognized framework in higher education to investigate variations of student learning experience and how such variations are related to qualitatively different learning outcomes (Biggs & Tang, 2011; Herrmann et al., 2017). The collective body of research using SAL framework has identified key elements that are able to distinguish between relatively more successful and less successful experiences of learning. Of the identified elements, how students' go about learning (i.e., their approaches), how they perceive learning (i.e., their perceptions), and how the approaches and perceptions are related to learning outcomes, have been systematically researched (Entwistle, 2009; Trigwell & Prosser, 2020). Past studies have examined students' approaches in different learning designs, such as approaches to inquiry, approaches to discussions, approaches to problem-solving, and approaches to using online technologies in blended courses. Despite the differences in the learning designs, two broad categories of approaches to learning have consistently been confirmed, namely deep and surface approaches. While the former involves strategies that are proactive, reflective, and analytical with an intent to gain meaningful and in-depth understanding of the subject matter; the latter tend to aim to satisfy learning requirements or to complete the required tasks, involving mechanistic and simplistic strategies and that are often largely fragmented from meaning (Nelson Laird et al., 2014).

Students' approaches to learning are not a fixed personal trait, rather, they may vary depending on the learning contexts and are related to students' perceptions of learning and teaching (Entwistle, 2009). When students perceive teaching being high quality, being clear about learning goals, and encouraging students' independence in learning, they are more likely to adopt deep approaches. When students perceive the workload of study is not appropriate and the means of assessments do not match their learning goals, they tend to adopt surface approaches (Lizzio et al., 2002; Wilson & Fowler, 2005). These associations have been confirmed and extended to blended course designs. For example, positive perceptions of the online workload and an integrated learning environment, that includes both face-to-face and online learning experiences, have been found to be related to deep approaches to using online learning technologies; whereas perceptions of inappropriate online workload and fragmentation between face-to-face and online learning experiences in the same course are typically associated to surface approaches learning and to using online learning technologies.

SAL research has also shown that logical relations amongst approaches to learning and perceptions of learning and students' learning outcomes, which jointly reflect students' learning orientation. Students adopting deep approaches, having positive perceptions of learning and teaching, and achieving higher level of academic performance are referred to as having an 'understanding' learning orientation (sometimes 'meaning' learning orientation). On the other hand, those using surface approaches, holding negative perceptions, and attaining relatively poorer learning outcomes are known as having an 'reproducing' learning orientation (Ellis et al., 2016, 2017; Han & Ellis, 2020a; Han et al., 2020). While an individual student's learning orientation is relatively stable as reflected in the consistency across how student' conceive learning, approach learning, and perceive learning in one learning context or across a number of learning contexts. Nevertheless, "stability of orientations does not imply fixity", as orientations are relational, changeable, and responsive to learning and teaching contexts, hence, contextually dependent (Ramsden, 1988, p. 175).

While SAL research has revealed variations of students' learning orientations, the methods used in SAL are not designed to provide detailed measures of different patterns of students' collaborative learning. Hence, this study draws on methodologies from social network research, known as social network analysis (SNA) to complement SAL methods in order to reveal nuanced features of patterns of collaboration. The following gives a brief overview of the SNA methodology and education research using SNA.

Educational research using SNA methodology

SNA is a set of techniques that can be used to identify, detect, and interpret roles of individuals (i.e., actors) within a group and patterns of ties amongst individuals (De Nooy et al., 2011). In SNA, actors and ties are the two fundamental units, which can be visualised in terms of network graphs with mathematical measures to identify and analyse roles of actors and ties between them (Rulke & Galaskiewicz, 2000). In student learning research, for example, actors can be students and teachers, and ties can be student and teacher interaction or students' collaboration. SNA methodology is increasingly adopted in educational research in the areas such as network connections of teaching discussions amongst university lecturers (Quardokus & Henderson, 2015); patterns of research collaboration amongst faculties (Shields, 2014); interactions between students and teaching staff in courses or study programs (Cadima et al., 2012); students' social and friendship ties (Rienties et al., 2013); students' knowledge sharing networks (Tomás-Miquel et al., 2016); students' online discussion networks (Gašević et al., 2019); and networks of study partners (Stadtfeld et al., 2019). In this study, SNA is used to provide a set of measures about the student experience, which reveal nuanced features of the patterns of students' collaborative learning.

Methods

Participants and the learning context

The participants were 193 students (females: 160; males: 33) aged between 19 and 61 ($M = 25.20$, $SD = 6.95$). They were enrolled in a two-year Master program at one of Australian research intensive universities.

The learning context was a semester-long compulsory course, which ran 13 weeks. The course not only aimed to develop students' in-depth understanding of disciplinary knowledge, but also to equip students with a repertoire of generic skills and attributes, such as effective inquiry, the skills of discussion and collaboration, and the capability to critically evaluate sources of information. The course was designed as a blended course, which systematically combines technologically mediated interactions between students, teachers, and resources in learning and requires students to learn across in-class and online contexts in the pursuit of learning outcomes (Bliuc et al., 2007). The face-to-face part of the course consisted of lectures, tutorials, and laboratory classes, each of which were two hours per week. The lectures covered the key concepts and demonstrated their links to practical issues. Tutorials offered students opportunities to work in collaboration to discuss questions related to the key concepts and their applications in real contexts. In the laboratory classes, students were also asked to work collaboratively on an assigned weekly theme. To form collaborative groups, the teaching staff did not pre-assign students, rather, it was the students' own decisions with whom they would collaborate. The online learning component was self-paced independent study hosted in a proprietary Learning Management System (LMS), which held compulsory and supplementary readings; interactive learning activities; and assessment tasks. The course also had a compulsory 80-h work-integrated learning practicum.

Instruments

The close-ended questionnaire

The closed-ended questionnaire was designed using the SAL literature and instruments (Biggs et al., 2001). The questionnaire has been used in a number of previous studies on students' blended learning experience, demonstrating its validity and reliability (Ellis & Bliuc, 2016; Ellis et al., 2016, 2017; Han & Ellis, 2020a, 2020b). It consisted of five scales:

- *The deep approaches to learning through inquiry* scale (4 items, α = 0.64) describes approaches as taking initiative, using multiple sources, and thinking deeply and critically (e.g., I often take the initiative when pursuing a line of questioning in research").
- *The surface approaches to learning through inquiry* scale (6 items α = 0.70) describes approaches as relying heavily on teachers and classmates, and following formulaic learning activities only to complete the task (e.g., I only use the directions my teacher gives me when researching something for a task").
- The *deep approaches to using online learning technologies* scale (5 items, α = 0.83) assesses using online learning technologies as a way to facilitate understanding of subject matter and to promote in-depth reflections in the course (e.g., "I find interacting with learning technologies in this course promotes deeper understanding of key ideas").
- The *surface approaches to using online learning technologies* scale (5 items, α = 0.68) describe approaches as limiting use of online learning technologies in learning or using them only to satisfy course requirements (e.g., "I only use the learning technologies in this course to fulfil course requirements").
- The *perceptions of the online workload* scale (5 items, α = 0.88) assesses levels of students' perceptions of the appropriateness of the online workload in the course. The scale had 4 negatively worded items which were reversed when performing the analysis so that higher scale scores indicate more positive perceptions (e.g., "The online activities in this course made the workload too heavy").

The open-ended questionnaire

The open-ended questionnaire adopted a commonly used format in SNA, which asked students to write down maximum three collaborators in the course according to the frequency of collaboration, and to specify the main mode of the collaboration, either face-to-face or both face-to-face and online.

The most frequent collaborator	___________	face-to-face	both
The 2nd most frequent collaborator	___________	face-to-face	both
The 3rd most frequent collaborator	___________	face-to-face	both

Students' academic performance

The course marks were used as an indicator of students' academic performance. Students' final scores in the course were between 13 and 85.30 ($M = 66.34$, $SD = 8.93$) out of 100. The marks were made up by aggregating three formative assessment tasks (55%) and the end-of-semester summative examination (45%). The formative assessment tasks were: (1) five reflective journals of the lectures; (2) critically analysis of two selected journals from the five using teacher feedback and peer-reviewed journal articles; and (3) a poster and a report on the process of creating an online portfolio using Pebblepad.

Data collection

The study was approved by the ethics committee of the researchers' university. The ethical procedure and requirements were strictly followed. Students were informed of the voluntary nature of participation and an essential written consent. They were ensured that the decision as to participation of the research or not would not affect their course marks and all the data would be anonymised and used only for the research purposes. Those who assigned the written consent were provided the questionnaires in one of their laboratory classes towards the end of the semester. Their final marks were obtained upon completion of the course.

Data analysis

To identify students' learning orientations, a hierarchical cluster analysis using mean scores of the five scales in the close-ended questionnaire and the course marks were used. To examine variations of learning orientations, that is the extent to which approaches, perceptions, and course marks differed by learning orientations, one-way analysis of variance (ANOVA) was conducted. One-way ANOVAs determine if there are any statistically significant differences between the means of independent groups. The one-way ANOVAs used cluster membership as an independent variable, and the means of students' approaches, perceptions, and course marks as dependent variables. Then based on the identified learning orientations and students' responses to the open-ended questionnaire, the SNA was applied using Gephi software to generate different collaborative networks representing distinct patterns of students' collaboration. To reveal features of different collaborative networks, both visualizations and SNA descriptive statistics (i.e., number of students, number of collaborations, maximum number of collaborations for a student, and biggest group size) were calculated and reported. In addition, z-tests were conducted to compare the proportions of: (1) group sizes (i.e., in pairs; in triads; and in groups of more than three); (2) types of collaborators (i.e., reciprocal—both nominated others and being nominated by others as a collaborator; active—only nominated others as a collaborator; and passive—only being nominated by others as a collaborator); and (3) collaborative modes (i.e., face-to-face mode and dual modes involving both face-to-face and online) amongst different collaborative networks. Lastly, a number of actor-level (i.e., average degree, betweenness, closeness, eccentricity, and eigenvector) and network-level (i.e., network clustering coefficient, network density, and network modularity) SNA measures were calculated and compared across different collaborative patterns. As these SNA measures were standardized, direct comparison was permitted.

Results

Variations of students' learning orientations as shown by the cluster analysis and one-way ANOVAs

To facilitate the interpretation, all the variables were transformed into z-scores ($M = 0$, $SD = 1$) in the cluster analysis and one-way ANOVAs, and the results are displayed in Table 1 and visualized in Fig. 1. The hierarchical cluster analysis produced a range of two-cluster to four-cluster solutions. The values of Squared Euclidean Distance revealed a relatively large increase in the value of a two-cluster solution compared to the three-cluster and four-cluster solutions, suggesting a two-cluster solution was more appropriate. The labelling of the two clusters was in accordance with the SAL literature (Trigwell & Prosser, 2020). Cluster 1 had 103 students and cluster 2

Table 1 Results of the cluster analysis and one-way ANOVAs

Variables	1: Understanding ($N=103$)		2: Reproducing ($N=90$)		*F*	*p*	η^2
	M	*SD*	*M*	*SD*			
DAI	0.31	0.84	− 0.32	0.95	23.95	0.00	0.11
SAI	− 0.63	0.75	0.70	0.73	153.20	0.00	0.45
DAT	0.43	0.82	− 0.51	0.95	54.32	0.00	0.22
SAT	− 0.54	0.76	0.62	0.88	97.45	0.00	0.34
POW	0.28	1.04	− 0.29	0.87	16.59	0.00	0.08
CM	0.19	0.92	− 0.21	1.06	8.01	0.04	0.04

DAI deep approaches to learning through inquiry, *SAI* surface approaches to learning through inquiry, *DAT* deep approaches to using online learning technologies, *SAT* surface approaches to using online learning technologies, *POW* perceptions of the online workload, *CM* course marks

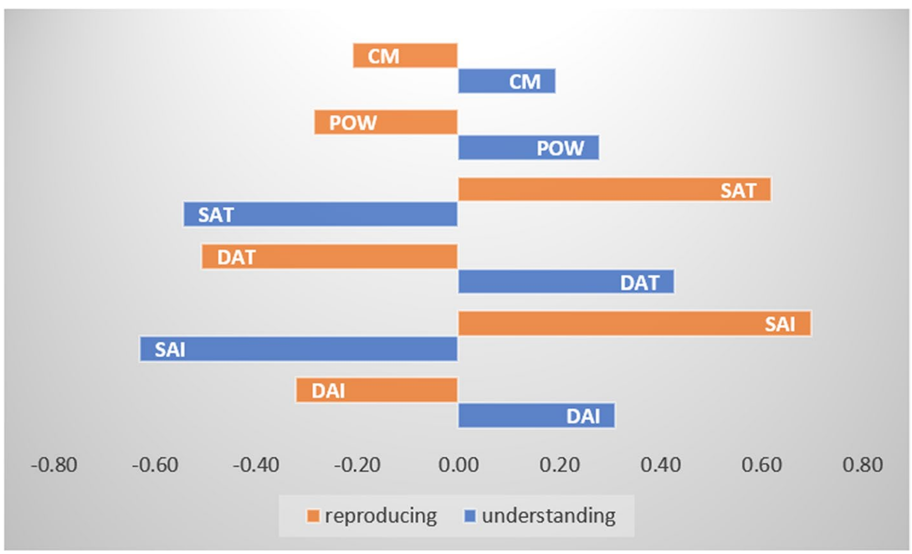


Fig. 1 Students' approaches, perceptions, and academic performance by learning orientations. *DAI* deep approaches to learning through inquiry, *SAI* surface approaches to learning through inquiry, *DAT* deep approaches to using online learning technologies, *SAT* surface approaches to using online learning technologies, *POW* perceptions of the online workload, *CM* course mark

consisted of 90 students. The results of one-way ANOVAs suggested that there were significant differences for the five scales as well as course marks between two clusters: deep approaches to learning through inquiry: F (1, 192) = 23.95, $p < 0.01$, $\eta^2 = 0.11$; surface approaches to learning through inquiry: F (1, 192) = 153.20, $p < 0.01$, $\eta^2 = 0.45$; deep approaches to using online learning technologies: F (1, 192) = 54.32, $p < 0.01$, $\eta^2 = 0.22$; surface approaches to using online learning technologies: F (1, 192) = 97.45, $p < 0.01$, $\eta^2 = 0.34$; perceptions of the online workload: F (1, 192) = 16.59, $p < 0.01$, $\eta^2 = 0.08$; and academic performance: F (1, 192) = 8.01, $p < 0.05$, $\eta^2 = 0.04$. Students in cluster 1 used more deep approaches to learning through inquiry, deep approaches to using online learning technologies, had positive perceptions of the online workload, and obtained higher scores in the course; whereas students in cluster 2 reported using more surface approaches to learning through inquiry, surface approaches to using online learning technologies, negatively perceived the workload required online, and attained relatively poorer academic performance. The variations in students' reported approaches, perceptions, and their academic performance indicated that the learning of cluster 1 students were directed towards understanding the subject matter (the 'understanding' learning orientation); whereas the learning of cluster 2 students were oriented towards reproducing facts and formulas (the 'reproducing' learning orientation).

Patterns of collaborative learning based on students' learning orientations and their choice of collaborations

Students' learning orientations and their responses in the open-ended questionnaire jointly formed five networks representing five distinct patterns of collaborative learning, namely:

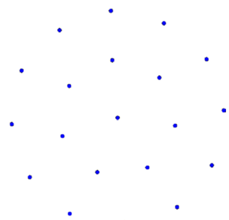
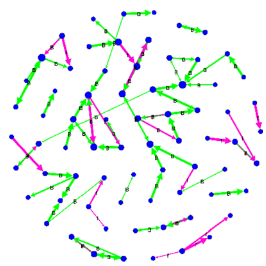
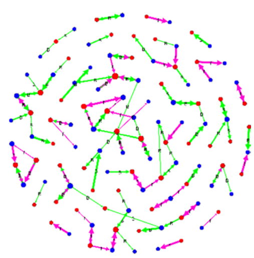
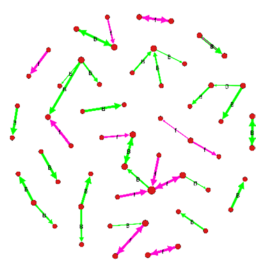
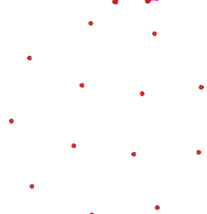
- Understanding Alone (UA): this pattern was formed by 'understanding' students who worked alone
- Understanding Collaboration (UC): this pattern was formed by 'understanding' students who collaborated with 'understanding' students
- Mixed Collaboration (MC): this pattern was formed by both 'understanding' and 'reproducing' students, who collaborated with those having a different learning orientation
- Reproducing Collaboration (RC): this pattern was formed by 'reproducing' students who collaborated with 'reproducing' students
- Reproducing Alone (RA): this pattern was formed by 'reproducing' students who did not collaborate

The visualization and the descriptive statistics of the five patterns are displayed in Table 2. The students in the UA and RA networks did not overlap with those in the UC, MC, and RC networks. However, those presented in the UC, MC, and RC networks were not mutually exclusive, as an individual was allowed to list more than one collaborator in the course, hence, some of them collaborated with students having the same learning orientation as well as with those having a different learning orientation. As the UA and RA networks did not have any collaboration, they were excluded in the subsequent analysis.

Comparison of the proportions of group sizes

The comparison of the proportions of different group sizes, namely collaboration in pairs, in triads, and in groups of more than three people, in the UC, MC, and RC were conducted using two-sample *z*-tests, whose results are presented in Table 3. It shows that there was no significant difference in terms of the proportion of collaboration in pairs, in triads, or in groups of more than three between UC and MC. However, RC

Table 2 Visualization and description of the five networks

Pattern	Visualisation	No. of students	No. of collaborations	Maximum no. of collaborations of a student	Biggest group size
UA		20	–	–	–
UC		72	85	6	13
MC		110 U:57 R:53	122 U → R:64 R → U:58	7	12
RC		56	45	5	8
RA		13	–	–	–

UA Understanding Alone pattern, *UC* Understanding Collaboration pattern, *MC* Mixed Collaboration pattern, *RC* Reproducing Collaboration pattern, and *RA* Reproducing Alone pattern

(26.79%) had significantly higher proportion of collaborations in triads than UC (*8.33%*) and MC (13.64%), whereas RC (37.50%) had significantly lower proportion of collaborations in groups of more than three than UC (77.78%) and MC (68.18%). RC did not differ from the UC and MC in terms of the proportions of collaborations between two people.

Table 3 Comparison of the proportions of group sizes

Collaborative sizes	UC		MC		RC		Pairwise comparison	*z*	*p*
	No	%	No	%	No	%			
Pairs	10	13.89%	20	18.18%	10	17.86%	UC = MC	0.80	0.45
							UC = RC	0.60	0.54
							MC = RC	0.10	0.96
Triads	6	8.33%	15	13.64%	15	26.79%	UC = MC	1.10	0.27
							UC < RC	**2.80**	**0.00**
							MC < RC	**2.10**	**0.04**
Groups of more than three	56	77.78%	75	68.18%	21	37.50%	UC = MC	1.40	0.16
							UC > RC	**4.60**	**0.00**
							MC > RC	**3.80**	**0.00**

The significant results are bolded

UC Understanding Collaboration pattern, *MC* Mixed Collaboration pattern, *RC* Reproducing Collaboration pattern

Table 4 Comparison of the proportions of types of collaborators

Types of collaborators	UC		MC		RC		Pairwise comparison	*z*	*p*
	No	%	No	%	No	%			
Passive	16	22.22%	27	24.55%	19	33.93%	UC = MC	0.40	0.72
							UC = RC	1.50	0.14
							MC = RC	1.30	0.20
Active	18	25.00%	24	21.82%	19	33.93%	UC = MC	0.50	0.62
							UC = RC	1.10	0.27
							MC = RC	1.70	0.09
Reciprocal	38	52.78%	59	53.64%	18	32.14%	UC = MC	0.10	0.91
							UC > RC	**2.30**	**0.02**
							MC > RC	**2.60**	**0.00**

The significant results are bolded

UC Understanding Collaboration pattern, *MC* Mixed Collaboration pattern, *RC* Reproducing Collaboration pattern

Comparison of the proportions of types of collaborators

Two-sample z-tests were also applied for pairwise comparison of the proportions of different types of collaborators amongst UC, MC, and RC, and the results are displayed in Table 4. Table 3 shows that there were no significant differences of the proportions of passive and active collaborators amongst UC, MC, and RC. However, the proportion of the reciprocal collaborators in RC (32.14%) was significantly lower than those in UC (52.78%) and MC (53.64%). No difference was found between UC and MC.

Comparison of the proportions of collaborative modes

The results of the two-sample *z*-tests for pairwise comparison of the proportions of different collaborative modes are shown in Table 5. It shows no significant differences either between UC and MC or between RC and MC for the proportions of face-to-face collaborations or collaborations in dual modes. However, RC (43%) had a significantly higher proportion of collaborations occurred mainly in face-to-face mode than UC (28%) did, whereas UC (72%) had a significantly higher proportion of collaborations in both face-to-face and online modes than RC (57%) did.

Table 5 Comparison of the proportions of collaborative modes

Collaborative modes	UC		MC		RC		Pairwise comparison	*z*	*p*
	No	%	No	%	No	%			
Face-to-face	20	28%	39	35%	24	43%	UC = MC	1.00	0.32
							UC < RC	**3.30**	**0.00**
							MC = RC	1.00	0.32
Dual modes	52	72%	71	65%	32	57%	UC = MC	1.00	0.32
							UC > RC	**3.30**	**0.00**
							MC = RC	1.00	0.32

The significant results are bolded

UC Understanding Collaboration pattern, *MC* Mixed Collaboration pattern, *RC* Reproducing Collaboration pattern

Table 6 Comparison of the standardized SNA measures

n	Standardized SNA measures	UC	MC	RC
1	Average degree (average collaborations)	2.361	2.218	1.607
2	Betweenness (capacity of students to gather information)	0.0025	0.0006	0.0007
3	Closeness (total distance to reach other students)	0.545	0.606	0.775
4	Eccentricity (distance to reach students in the furthest in the network)	3.625	3.064	1.911
5	Eigenvector (connection strength to neighbourhood nodes)	0.233	0.249	0.163
6	Network clustering coefficient (tendency to form closely knitted groups)	0.323	0	0
7	Network density (collaboration intensity)	0.025	0.015	0.024
8	Network modularity (discernibility of collaborative groups)	0.872	0.920	0.937

UC Understanding Collaboration pattern, *MC* Mixed Collaboration pattern, *RC* Reproducing Collaboration pattern

Comparison of the standardized SNA measures

The standardized SNA measures were calculated using the undirected networks because when two students collaborated, their collaboration was the same irrespective of who was the initiator of the collaboration. The standardized SNA measures were produced in Gephi and displayed in Table 6. Of these measures, rows 1–5 are actor-level measures, and rows 6–8 are network-level measures. The average degree shows that on average students in UC (2.361) had more collaborations than those in MC (2.218) and RC (1.607). Rows 2–4 show that the students in UC had higher betweenness (0.0025) and eccentricity (3.625) than those in MC (betweenness: 0.0006, eccentricity: 3.064) and in RC (betweenness: 0.0007, eccentricity: 1.911). However, the students in UC had lower closeness (0.545) than their counterparts in MC (0.606) and RC (0.775). Taken together, these measures suggest that the collaborative groups in the UC network were long-chained structure, hence, a student in the UC network needed to pass more students to reach the students positioned furthest in the network. The results for the eigenvector measure show that RC (0.163) was the lowest amongst the three (UC: 0.233 and MC: 0.249), suggesting that the connection strength to the neighbourhood students was the weakest in the RC network.

In rows 6 to 8, it is observed that UC had higher network clustering coefficient (0.323) and network density (0.025) than MC (clustering coefficient: 0, density: 0.015) and RC (clustering coefficient: 0, density: 0.024), but UC (0.872) had lowest network modularity among the three (MC: 0.920, and UC: 0.937). These three network measures jointly reflect that collaborations in the UC network tended to be more intense and in closely knitted groups, which were less easily to break into smaller collaborative groups.

Discussion and conclusion

The current study investigated features of different patterns of student collaborative learning based on variations of students' learning orientations amongst a cohort of postgraduate students enrolled in a compulsory blended course using the methods in SAL research and techniques of SNA. Consistent with previous SAL research (e.g., Ellis et al., 2016, 2017; Han & Ellis, 2020a; Han et al., 2020), two distinct learning orientations, namely 'understanding' and 'reproducing' have also been found in this population sample. The students having an 'understanding' and a 'reproducing' learning orientation could be clearly distinguished by how they approached learning and how they perceived the workload required online in this blended course. The different learning orientations identified in this student sample and students' choice as to whether to collaborate or not, with whom to collaborate have produced five distinct patterns of collaborations.

While group work competence and collaboration skills are essential qualities for workforce-ready graduates, students in UA and RA (together accounting for 17.1%) did not take the opportunities in this course to practise this important generic attribute. At least two possible reasons could explain such results. First, in this course, students were not pre-assigned to a collaborative group, rather, they were given freedom to choose their own collaborators. Hence, some students avoided collaborations and worked alone. The second possible reason could be a lack of compulsory assessment which required students to complete the tasks collaboratively. This also seemed to suggest a problem of the mismatch between the course objective of developing students' collaborative skills and the assessment design in this course. To prevent students from not participating in collaborative learning, the teaching staff of the course may consider redesigning the learning and assessment tasks, which should include some mandatory collaborative activities, such as team presentations and group portfolio, which will not only signal to students the importance of collaboration in the course but also create opportunities for them to practise the skills (Barkley et al., 2014). Even if the assessment design required individual students to complete the tasks, modifications can be made to the instructions about the process which make it mandatory for students to work with others in the course. For instance, a reflective section in the final essay on the process of collaboration that helps complete the assessment item may be included in the instructions.

For those students who reported collaboration, on the basis of their learning orientations, UC, MC, and RC were identified depending on whether students collaborated with their peers who shared a similar or had a different learning orientation. The three networks, which represent the three patterns of student collaborative learning, exhibit different features shown by a number of SNA measures. Collaborations in the RC network were lower in quality, notably with the features of less collaborations (degree) and collaborations being less intense (network density). In addition, the RC network had a smaller proportion of reciprocal collaborators and when they occurred, they tended to be in face-to-face mode only.

Comparatively, collaborations in the UC network have more desirable features. The UC network had more collaborations (degree), which were not only more intense (network density); but also tended to be closely knitted (network clustering coefficient) and were less likely to break into smaller, disconnected groups (network modularity). Moreover, the UC network also had a higher proportion of reciprocal collaborators who both initiated collaborations and were chosen as collaborators by their peers. The collaborations in the UC network resembled the collaborative patterns of collaborations between "dominant" learners in Storch, 2002, 2004), which also showed reciprocity between collaborators and a high equality in the process of collaborating. While previous studies reported that high achieving students preferred to collaborate in learning (Stadtfeld et al., 2019), our study further demonstrated that the collaborations between the high ability students learned were also more strategic and of higher quality.

As the study show more desirable features when students with an 'understanding' learning orientation collaborated with each other, how to move students' learning orientation from 'reproducing' to 'understanding' can be thought of as a key pedagogical strategy to improve the quality of students' collaborative learning. This could be achieved by inviting 'understanding' students to share their experience as to how they went about learning, their approaches to using online learning technologies to support their learning through inquiry, what they did and why they did, how they handled the course workload, and what they did in collaborations. Pairing students with different learning orientations may be another strategy for the teaching staff to use so that the group composition can be purposely reconfigured in order to foster desirable experience of collaborative (Lancellotti & Boyd, 2008). Teachers may also consider incorporating learning activities which are more likely to encourage deep learning, such as designing tasks involving real experiences for students to create and use new knowledge. In addition, building students' confidence and motivation through feedback and formative evaluation cycles in the learning process may also to be effective (Fullan & Langworthy, 2014).

Collaborative learning in higher education remains a key strategic pedagogical goal for the sector internationally. Only by discovering evidence of features of different patterns of collaboration which can provide actionable knowledge such as that discussed in this study, can the field move forward in this important area.

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FH and RE have made substantial contributions to the conception and design of the work; the acquisition and analysis of data; the analysis and interpretation of data; have drafted the work and substantively revised it. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets generated and analysed during the current study are not publicly available due to ethics requirement, but are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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