Received: 4 July 2021 | Revised: 28 August 2022 | Accepted: 2 October 2022

DOI: 10.1111/jcal.12747

ARTICLE

Journal of Computer Assisted Learning WILEY

Patterns of students' collaborations by variations in their learning orientations in blended course designs: How is it associated with academic achievement?

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Funding information
Australian Research Council, Grant/Award Number: DP150104163

Abstract

Background: While a number of learner factors have been identified to impact students' collaborative learning, there has been little systematic research into how patterns of students' collaborative learning may differ by their learning orientations.

Objectives: This study aimed to investigate: (1) variations in students' learning orientations by their conceptions, approaches, and perceptions; (2) the patterns of students' collaborations by variations in their learning orientations and (3) the contribution of patterns of collaborations to academic achievement.

Methods: A cohort of 174 Chinese undergraduates in a blended engineering course were surveyed for their conceptions of learning, approaches to learning and to using online learning technologies, and perceptions of e-learning, to identify variations in their learning orientations. Students' collaborations and mode of collaborations were collected through an open-ended social network analysis (SNA) questionnaire.

Results and Conclusions: A hierarchical cluster analysis identified an 'understanding' and 'reproducing' learning orientations. Based on students' learning orientations and their choices to collaborate, students were categorized into three mutually exclusive collaborative group, namely Understanding Collaborative group, Reproducing Collaborative group and Mixed Collaborative group. SNA centrality measures demonstrated that students in the Understanding Collaborative group had more collaborations and stayed in a better position in terms of capacity to gather information. Both students' approaches to learning and students' average collaborations significantly contributed to their academic achievement, explaining 3% and 4% of variance in their academic achievement respectively. The results suggest that fostering a desirable learning orientation may help improve students' collaborative learning.

KEYWORDS
blended course designs, Chinese undergraduates, learning orientations, patterns of students' collaborations, social network analysis, student approaches to learning research

1 | INTRODUCTION

Modern society is facing increasingly complex issues and tasks in different professional sectors. As a result, it places higher demands for workforce-ready graduates to work together closely and efficiently to tackle these challenges. An important graduate attribute in higher education to address workplace challenges is the development of teamwork and collaboration skills. This quality of graduates has received much attention worldwide in recent years (De Wever et al., 2015; Ellis & Han, 2020). In blended course designs, where interactive and web-based technologies have become an indispensable part of learning experience in addition to face-to-face learning (Ma & Lee, 2021), understanding the patterns of students' collaborative learning and factors which may impact such experience becomes even more complex; as such experience involves an interplay of a wide range of factors related to students' cognition (e.g. conceptions, approaches and perceptions in learning) (Trigwell & Prosser, 2020) and their choices of social interactions in learning (e.g. with whom to collaborate) (Hadwin et al., 2018); and their engagement with the material elements in the physical and virtual learning spaces (e.g. their choice of mode of collaborations: face-to-face and/or online) (Laurillard, 2013). To improve our insights into patterns of students' collaborative experience in blended course designs, the current study drew on three areas of research: research on university students' collaborative learning (Senior & Howard, 2014); student approaches to learning (SAL) research (Trigwell & Prosser, 2020); and the application of social network analysis (SNA) in student learning research (Grunspan et al., 2014).

1.1 | Research on university students' collaborative learning

Collaborative learning is perceived as a social process of joint knowledge construction and development of shared understanding through group interaction (Senior & Howard, 2014). Collaborative learning may take different forms; ranging from groups or teams formed in a formal learning environment assigned by lecturers or tutors with specific aims to achieve some learning objectives, to collaborations in informal settings where students work together towards an agreed learning goal by their own will (Davies, 2009).

Collaborative learning has attracted much attention in higher education because of the importance of collaborative competence for graduates expressed by national agendas and employers in many countries. The Organization for Economic Co-operation and Development (OECD) recognizes the capabilities to work effectively in collaboration with others as one of the important 21st Century skills and competencies (Ananiadou & Claro, 2009). In Australia, 'Being Work Ready' offers insights on skills and behaviours that employers expect their incoming recruits, with collaboration, critical analysis and problem solving skills being ranked as the top three (Business Council of Australia, 2016). The proportion of job advertisements that require collaborative skills has also grown dramatically from 19% to 158% between the year 2012 and 2015 (Foundation for Young Australians, 2018). In China, the Central People's Government of People's Republic of China (2010) directed tertiary institutions to embed essential group work activities and collaborative learning experience in the design of curricula, aiming to improve students' collaborative competence and social interaction skills.

In some disciplines, such as nursing, medicine and science, technology, engineering, and mathematics (STEM), collaborative skills are valued even more because of the interdisciplinary nature of their professional practice. In nursing, National Competency Standards for the Registered Nurse requires registered nurses in Australia to establish and maintain effective and collaborative working relationships with other members (Nursing and Midwifery Board of Australia, 2013). In medical education, collaboration and teamwork are amongst the 13 core professional activities that American medical students are expected to perform competently prior to entering residency (Association of American Medical Colleges, 2017). In the STEM disciplines, the 2017–2018 Accreditation Board for Engineering and Technology (ABET, 2016) requires students to demonstrate the ability to complete collaborative work in team-based projects.

Previous research has demonstrated that collaborative skill is not only an important graduate attribute itself, but collaborative learning is also beneficial to develop other important graduate attributes, such as higher-order metacognitive abilities, critical thinking, problem solving, decision making, and interpersonal skills (Gokhale & Machina, 2018; Jonassen & Kwon, 2001; Zhang & Cui, 2018). Moreover, through collaboration in learning, positive affect and motivation can be enhanced (Zheng, 2017); level of engagement and in-depth learning can be fostered (Zhu, 2012), which may in turn lead to better academic learning outcomes (Sung et al., 2017).

The benefits of collaborative skill development are important in some particular disciplines, such as in STEM, because of the practical need for such skills when entering the workplace. In a meta-analysis of 225 studies in STEM education, Freeman et al. (2014) found that active learning, such as collaboration-based activities, increased academic performance by approximately half a standard deviation compared with traditional lecture-based pedagogies. In a more recent study by Micari and Pazos (2021), significant gains in the socio-cognitive skills were found in collaborative learning environments at university, leading to improved interpersonal engagement, meaningful approaches to study and overall confidence of learning the course.

Due to the importance of collaborative learning for university student outcomes, researchers have investigated the factors, which may influence students' collaborative learning. These factors can be categorized into non-learner factors and learner factors. The non-learner factors include group composition (Lee & Lee, 2016), group size (Schellens & Valcke, 2006), types of activities (Zheng et al., 2015), and structure of activities (Kapur & Kinzer, 2009). In a meta-analysis, Pai et al. (2015) reported the benefit of collaboration in smaller groups than in larger groups. When collaborations are amongst friends, the information exchange and sharing often involve off-topic discussions (Le et al., 2018).

The learner factors include students' collaborative competence (Castillo et al., 2017), use of collaborative strategies (Stump et al., 2011), emotional awareness and personality trait (Reis et al., 2018), students' self-efficacy (Wilson & Narayan, 2016), self-regulation (Kwon et al., 2014), belief about the interpersonal context (Van den Bossche et al., 2006), and their perceptions of the social presence (Qureshi et al., 2021). Of these learner factors, however, there has been little research into students' learning orientations, which have been systematically investigated in SAL research (Lonka et al., 2004; Ramsden, 1988; Trigwell & Prosser, 2020). To contribute to our understanding in this area, the current research aims to investigate patterns of students' collaboration based on their learning orientations using methodologies from SAL research.

1.2 | SAL research

SAL research is one of the guiding frameworks to explain factors which impact on variations in students' academic achievement in higher education (Trigwell & Prosser, 2020). This line of research has repeatedly found that variables, such as how students conceive of learning (*conceptions*), how students go about learning (*approaches*), and how they perceive the learning context (*perceptions*) relate to their learning achievement (Entwistle, 2009). Two broad categories of conceptions of learning have been systematically identified: coherent and fragment conceptions. The former views learning as a way of developing new understandings and novel concepts, integrating new knowledge with existing ideas and restructuring them into a whole. The latter sees learning as a mechanistic phenomenon, such as following rules, reproducing facts formulaically, and accumulating knowledge from pieces (Bliuc et al., 2010; Yang & Tsai, 2010). Two broad categories of approaches have also been found across a range of disciplines. Deep approaches to learning are directed towards meaningful understanding of subject matters and have characteristics of being proactive, reflective, and analytical. In contrast, surface approaches go about learning by involving simplistic activities, such as relying heavily on textbooks and course notes and fulfilling the minimal learning tasks as required (Nelson Laird et al., 2014). In the online learning environment, two broad categories of approaches to using online learning technologies have also been identified (Ellis et al., 2012). Deep approaches to using online learning technologies employ technologies to facilitate learning and to deepen understanding of the subject matter; whereas surface approaches adopt technologies mostly to fulfil practical purposes, such as downloading files and/or meeting course requirements (Ellis & Bliuc, 2016).

The SAL research has consistently demonstrated logical associations amongst cohesive conceptions and deep approaches, likewise, fragmented conceptions tend to relate to surface approaches (Vermunt & Donche, 2017). In blended course designs, positive relations between cohesive conceptions, deep approaches to learning, and deep approaches to using online learning technologies have also been found (Ginns & Ellis, 2007; Han & Ellis, 2019). Similarly, studies have reported significant associations between fragmented conceptions, surface approaches to learning and to using online learning technologies (Bliuc et al., 2010). Approaches to learning should not be confused with learning styles. The former is defined as "context-specific ways of tackling learning tasks" and involves both learners' motives, strategies, and learning processes; whereas the latter is referred to as 'relatively consistent preferences for adopting particular learning processes, irrespective of the task or problem presented' (Entwistle & Peterson, 2004, p. 537). These definitions mean that approaches to learning originated from the work of Marton and Säljö (1976) and are conceptualized on the assumptions that they can be consciously chosen on the basis of the contexts and situations of learning. Learning styles, on the other hand, are largely dependent on students' psychological attributes which determine their preferences for understanding their experiences and transforming them into knowledge. Hence, learning styles are more about personal traits and are unlikely to show short-term changes (Rajaratnam & D'cruz, 2016).

Research has shown that the approaches to learning adopted by students are related to how they perceive the contexts of learning and teaching and its constituent elements (Entwistle, 2003). For instance, in blended course designs, when students perceive that face-to-face and online elements are well integrated, the online learning workload is appropriate, and online contributions are of value, they tend to adopt deep approaches to learning as well as to using online learning technologies. When students do not see the relevance between face-to-face and online learning, they are more likely to approach learning at a surface level, and limit their use of technologies in learning (Ellis et al., 2018; Ellis & Bliuc, 2019).

When jointly considered, deep approaches and positive perceptions are characteristics of an 'understanding' learning orientation; whereas surface approaches and negative perceptions are typical features of a 'reproducing' learning orientation (Lonka et al., 2004). Similar to approaches to learning, learning orientation is not a trait-like characteristic of students. Rather it is also relational, changeable, and contextually dependent, which are responsive to learning and teaching contexts (Entwistle & Peterson, 2004; Ramsden, 1988). Research has shown that variations in learning orientations are related to academic achievement, with the 'understanding' learning orientation being associated with higher achievement and the 'reproducing' orientation with poorer performance (Han et al., 2020; Han & Ellis, 2019, 2020a, 2021).

SAL research is yet to systematically studies how students' variations in learning orientations may impact on patterns of students' collaborative experience. This gap has motivated the design of the current study, which adopted SNA to measure patterns of collaborations, as SNA is a robust methodology to provide measures that are able to reveal key features of patterns of students' collaborative learning and nuanced differences of students' collaborative experience (De Laat et al., 2007).

1.3 | The application of SNA in student learning research

Adopting principles from graph theory, SNA is commonly used to detect and interpret roles of individuals and patterns of ties amongst individuals in interactive networks in different social contexts (De Nooy et al., 2011; Wasserman & Faust, 1994), SNA has been increasingly applied in researching student learning, in particular students' collaborative learning (Gašević et al., 2013); as SNA is able to both visualize patterns of collaborations at the level of network; and to provide a number of useful centrality measures at the level of individual.

In the context of student learning research, SNA has been used to investigate the patterns of online threaded discussions (Zhu et al., 2015), student–teacher interaction (Cadima et al., 2012), assignment helping behaviours (Vargas et al., 2018) and peer knowledge construction networks (Heo et al., 2010). It has also been used to investigate the relations between patterns of learning networks and academic achievement. For instance, in a distance education programme, Cadima et al. used SNA to measure the degree centrality of knowledge sharing networks between students and advice seeking networks between students and their teachers. The results showed positive association between values of degree centrality and the average grades in the four courses of the programme.

Tomás-Miquel et al. (2016) used SNA to examine the contribution of patterns of students' knowledge sharing network to their academic achievement in the two disciplines: design and business. The study found that coreness (i.e. the position of the students in relation to the centre of the network) significantly predicted the academic achievement, even though such predictions differed by disciplines. In business, the coreness positively predicted the academic achievement after controlling for gender and age; whereas amongst design students, there was a non-linear, inverted U-shaped relation between the coreness and the learning achievement. In a more recent study, Stadtfeld et al. (2019) used SNA in a longitudinal design to investigate the changes of study partner networks amongst 226 undergraduates over 1 year. Using the logistic regression, the study found that the students having at least one studying partner tie (degree centrality) were more likely to pass the exit exam of the programme.

While these studies provide important information on how SNA can be applied to measure patterns of different formal and informal learning networks amongst students, none of them uses SNA to specifically investigate patterns of students' collaborative networks. Hence, the current study adds to the literature by adopting SNA to examine patterns of students' collaborative learning in blended course designs.

1.4 | Aims and research questions

The current study aimed to investigate: (1) variations in students' learning orientations in blended course designs by using their conceptions of learning, approaches to learning and to using online learning technologies, and perceptions of e-learning; (2) patterns of collaborations by variations in students' learning orientations and (3) the contribution of collaborations to academic achievement. Specifically, it sought to answer the following three research questions:

(1) What are the variations in students' learning orientations in blended course designs?

(2) To what extent do patterns of collaborations differ by variations in their learning orientations in blended course designs?

(3) To what extent do patterns of collaborations contribute to their academic achievement in blended course designs?

2 | METHODS

2.1 | Participants and the learning context

The participants were 174 Chinese undergraduates who were enrolled in a mechanical engineering course. They were predominantly male students (males: $n = 161$, 92.5%; females: $n = 13$, 7.5%), because mechanical engineering major tends to attract male students in China.

The research was conducted in a Chinese national university specializing in science and technology. The learning context was *Theoretical Mechanics*, which was designed as a blended course lasting for a semester of 16 weeks. The course was compulsory for all students who majored in a Bachelor of Mechanical Engineering. The face-to-face learning, which aimed to address theoretical difficulties of the course contents, included weekly lectures (2 h on Mondays and 1 h on Fridays), and weekly 1-h student-led tutorials. Student-led tutorials were designed as group learning activities, in which the key concepts and practical exercises were discussed in groups. Before each student-led tutorial, the topics and exercises were announced in the learning management system (LMS). As the format of the tutorial was student-led, therefore, students were not pre-assigned into different groups. Students were asked to take initiatives to choose their own collaborator(s) and to form study groups. The teaching assistants listened to students' discussions and answered their questions if they had. When the teaching assistants found students did not participate in the group discussions or other collaborative activities, the teaching assistants encouraged (but not forced) them to participate as one of the important learning objectives in the course was to develop students' collaborative competence and social interaction skills.

Being an integral part of the course, the online learning required compulsory participation each week before and after the lectures and student-led tutorials, functioning as preparing, reviewing, and extending face-to-face learning. The online learning took place in the LMS—Tsinghua Education Online (THEOL), which was developed by Educational Technology Institute Tsinghua University and widely adopted by Chinese tertiary institutions. The online learning comprised five parts:

- Learning materials had a wide range of formats, including essential and supplementary readings; bibliography of key concepts; links to webpages related to the contents of the course; and video clips, which had detailed presentations of certain topics or demonstrations of problem solving tasks in an interactive manner.

- The discussion board consisted of three sections: (1) threads which continued and extended face-to-face discussions; (2) threads on topics not part of class discussions and (3) threads on issues about assignments.
- Announcements and notifications outlined the main course topics, difficulty points, and preparation requirements before the lectures and student-led tutorials. This part also included notifications of the assignment due dates, and other important events in the course.
- Comments and feedback had comments from the teaching staff addressed to the students, and the feedback of assignments and other assessment tasks.
- Online quizzes consisted of mathematical calculations, model constructions, definitions of terminologies and problem solving tasks.

To fulfil the online learning requirements, students were instructed to do the following in the LMS using computers or laptops at their own pace: read online materials; watch video clips; actively participate online discussions, including reading, responding and commenting on others' posts as well as writing their posts; regularly check announcements and notifications to follow course updates and requirements; hand in assignments online and view the feedback in the system; and complete the online quizzes.

2.2 | Instruments

Three types of data were collected. To capture students' conceptions, approaches, and perceptions in the blended course, a self-report 5-point Likert scale questionnaire was employed. To collect data on students' collaboration, an open-ended SNA questionnaire was used. The final course marks were obtained as an indicator of their academic achievement.

2.2.1 | The 5-point Likert scale questionnaire

The questionnaire had eight scales (i.e. two scales on 'conceptions of learning', two scales on 'approaches to learning', two scales on 'approaches to using online learning technologies', and two scales on 'perceptions of e-learning'), all of which were designed using the SAL literature (Biggs et al., 2001). These scales were developed to examine different aspects in university students' learning experience in blended course designs and consistently demonstrated good reliability in a number of previous studies (Ellis & Bliuc, 2016, 2019; Ginns & Ellis, 2007; Han & Ellis, 2020b). The details of the eight scales, including the descriptions of the scales, number of items and example items of each scale, and the reliability of the scales in the current study, are described below:

- *Cohesive conceptions of learning* scale (8 items, $\alpha = 0.95$) views learning about theoretical mechanics as a practical proposition to real engineering problems; and recognizes that learning of theoretical mechanics has a connection to broader engineering fields (e.g. The learning activities for this subject allow us to better understand the topics from a number of perspectives).
- *Fragmented conceptions of learning* scale (7 items, $\alpha = 0.78$) conceives of learning theoretical mechanics as formulaic processes involving mechanistic activities, such as finding answers, following textbooks, and remembering facts (e.g. The purpose of learning for this subject is mostly to help us remember facts for our tasks).
- *Deep approaches to learning* scale (9 items, $\alpha = 0.93$) describes approaches to learning as engaging and reflective processes, in which students often take initiatives to critically evaluate key ideas and concepts covered in the course (e.g. I test myself on important topics until I understand them completely).
- *Surface approaches to learning* scale (8 items, $\alpha = 0.88$) captures learning approaches that focuses heavily on rote memorization and fulfilling minimal course requirements (e.g. I see no point in learning material which is not likely to be in the examination).
- *Deep approaches to using online learning technologies* scale (6 items, $\alpha = 0.89$) has items about using technologies to facilitate learning and to deepen understanding of the subject matter (e.g. I try to use the online learning technologies in this course to achieve a more complete understanding of key concepts).
- *Surface approaches to using online learning technologies* scale (8 items, $\alpha = 0.80$) describes using technologies in limited and superficial ways, such as passing examination and satisfying practical purposes (e.g. I use online learning technologies in this course mainly to download files).
- *Perceptions of online interactivity* scale (4 items, $\alpha = 0.80$) recognizes the importance of the interactivity in the online learning environment; and highlights the value of feedback from teachers and the online contributions made by peers (e.g. The teacher's responses online motivated me to learn more deeply).
- *Perceptions of online learning design* scale (6 items, $\alpha = 0.92$) focuses on the design of online learning, such as contents of online materials and navigation of the online site (e.g. The online activities helped me to understand the face-to face activities in this course).

2.2.2 | The open-ended SNA questionnaire

The open-ended SNA questionnaire asked students to list up to three classmates in the order of the frequency of collaborations and to specify the predominant mode of collaborations: whether the collaborations were mostly face-to-face or a combination of face-to-face and online (known as blended).

> Please write down with whom you collaborated in the order of frequency and specify the mode of such collaborations (F = face-to-face, B = both face-to-face and online):
> (1) The most frequent-F B
> (2) The second most frequent-F B
> (3) The third most frequent-F B

Students' academic achievement.

The final course marks were used as an indicator of students' academic achievement. The marks were aggregated scores of both summative and formative assessments. The summative assessment was the close-book final examination, which accounted for 70% of the final course marks. The formative assessments, which took the rest of 30%, were made up by three assessments: (1) three problem solving tasks each week (10%); (2) a report on the reflection of the student-led tutorials (10%) and (3) the quality of postings in the online discussion board (10%). In order to motivate students to complete formative assessment tasks of high quality, at the beginning of the semester, students were informed that the quality of their completion of the formative tasks would be converted to grades at the end of the semester and would account for a maximum of 30% in their final grades. But during the semester, the evaluation of the formative assessment tasks was in the form of qualitative feedback.

2.3 | Data collection procedure

The data collection was undertaken towards the end of the semester before the completion of the course. This ensured that: (1) the participants had relatively comprehensive learning experience of the course to reflect upon and (2) the participants still had fresh memory as to whom they collaborated during the course in order for them to report in the open-ended SNA questionnaire. One week before the data collection, each student in the course was given a Participant Information Statement and Participant Consent Form, which explained in detail that participation in the study was completely voluntary, and participation required completion of a close-ended and an open-ended questionnaire. They were also asked to give permissions to access to their course marks should they participate. Students were given 1 week to decide if they would like to participate. Those with signed consent forms were given access to the online questionnaires held in the LMS. After completion of the course, the participants' final course marks were obtained from the teaching staff.

2.4 | Research design and data analysis methods

The research was designed as a quantitative study, which combined the methods used in SAL and SNA research. Similar to most SAL studies, a hierarchical cluster analysis was conducted using students' responses on the eight scales in the close-ended questionnaire in order to identify students' learning orientations. To examine variations, one-way ANOVAs were performed using cluster membership as a grouping variable to see the extent to which students differed on the eight scales and academic achievement.

To examine patterns of collaborations by students' learning orientations, the commonly used SNA procedure was adopted. First, SNA was performed in Gephi to visualize the patterns of collaborations and to calculate the commonly used SNA centrality measures (i.e. degree, betweenness, eccentricity and local clustering coefficients). The degree centrality concerns with the average collaborations of a student in the network, the other centrality measures are different ways to reveal the relative position of a student in the collaborative network (Wasserman & Faust, 1994). Second, on the basis of students' learning orientations and their choices as to with whom to collaborate, students were categorized into one of the following three collaborative groups, which were mutually exclusive:

- Understanding Collaborative group (UC), which consisted of 'understanding' students who collaborated with 'understanding' students;
- Reproducing Collaborative group (RC), which had 'reproducing' students who collaborated with 'reproducing' students;
- Mixed Collaborative group (MC), which had students who collaborated *only* with students with a different learning orientation (i.e. 'understanding' students collaborated *only* with 'reproducing' students; and 'reproducing' students collaborated *only* with 'understanding' students).

Third, comparisons were conducted amongst the students in the three collaborative groups, which represented three patterns of collaborations. Pairwise comparison of the proportions of the two collaborative modes (i.e. the proportions of face-to-face or blended collaborations) amongst different collaborative groups were performed using two-sample proportion tests. Comparison of the SNA centrality measures amongst different collaborative groups were achieved by using one-way ANOVAs and the post-hoc analyses.

To provide an answer to the contribution of patterns of collaborations to academic achievement, hierarchical regressions were performed using academic achievement as the dependent variable, SNA centrality measures and SAL variables (controlling for variations in students' conceptions, approaches, and approaches) as independent variables. Before the regression analyses, a series of assumption tests were performed. First, to ensure the linear relationship between independent and dependent variables, correlation analyses were conducted between SAL variables, SNA centrality measures and academic achievement. Second, the values of Tolerance were screened to see if there was multicollinearity. Third, the Durbin-Watson statistics was calculated to check if there was auto-correlation, which generally observed in time series data. However, the misspecification of relations or the presence of measurement errors in the dependent variable may also introduce the autocorrelation in the data (Field, 2017). Thus, it is important to ensure no auto-correlation before performing the hierarchical regression analyses.

Two hierarchical regression models were constructed. The first model only used SAL variables as independent variables as there is established literature of the contributions of the SAL variables to academic achievement. On the basis of the first model, the second model added the SNA centrality measures to examine whether the SNA measures make extra contribution to the achievement.

TABLE 1 Variations in students' learning orientations

Variable	Cluster 1 Understanding ($n = 84$)		Cluster 2 Reproducing ($n = 90$)		*F*	*p*	η^2
	M	*SD*	*M*	*SD*			
Conceptions of learning							
CC	0.55	0.52	−0.52	1.07	70.73	0.00	0.29
FC	−0.45	0.73	0.41	1.04	40.22	0.00	0.19
Approaches to learning							
DAL	0.48	0.71	−0.45	1.03	48.56	0.00	0.22
SAL	−0.53	0.65	0.50	1.03	62.01	0.00	0.26
Approaches to using online learning technologies							
DAT	0.58	0.61	−0.54	1.00	78.65	0.00	0.31
SAT	−0.58	0.66	0.54	0.96	81.57	0.00	0.32
Perceptions of e-learning							
POI	0.46	0.76	−0.43	1.01	43.94	0.00	0.20
POD	0.57	0.62	−0.53	1.00	76.90	0.00	0.30
Academic achievement							
FM	0.26	0.78	−0.23	1.12	10.98	0.00	0.06

Note: *z*-scores were used for all the variables.
Abbreviations: CC, cohesive conceptions, DAL, deep approaches to learning, DAT, deep approaches to using online learning technologies, FC, fragmented conceptions, FM, final mark, POD, perceptions of online learning design, POI, perceptions of online interactivity, SAL, surface approaches to learning, SAT, surface approaches to using online learning technologies.

3 | RESULTS

3.1 | Results of variations in students' learning orientations

The hierarchical cluster analysis produced a range of two-cluster to four-cluster solutions. The values of Squared Euclidean Distance measure revealed a relatively large increase in the value of a two-cluster solution compared to three-cluster and four-cluster solutions, suggesting a two-cluster solution was more appropriate. The distribution of clusters and the results of the one-way ANOVAs are displayed in Table 1.

As shown in Table 1, the one-way ANOVAs results found that all the eight scales and academic achievement differed significantly between the two clusters: cohesive conceptions: $F(1, 172) = 70.73$, $p < 0.01$, $\eta^2 = 0.29$; fragmented conceptions: $F(1, 172) = 40.22$, $p < 0.01$, $\eta^2 = 0.19$; deep approaches to learning: $F(1, 172) = 48.56$, $p < 0.01$, $\eta^2 = 0.22$; surface approaches to learning: $F(1, 172) = 62.01$, $p < 0.01$, $\eta^2 = 0.26$; deep approaches to using online learning technologies: $F(1, 172) = 78.65$, $p < 0.01$, $\eta^2 = 0.31$; surface approaches to using online learning technologies: $F(1, 172) = 81.57$, $p < 0.01$, $\eta^2 = 0.32$; perceptions of online interactivity: $F(1, 172) = 43.94$, $p < 0.01$, $\eta^2 = 0.20$; perceptions of online learning design: $F(1, 178) = 76.90$, $p < 0.01$, $\eta^2 = 0.30$; and academic achievement: $F(1, 172) = 10.98$, $p < 0.01$, $\eta^2 = 0.06$. Specifically, cluster 1 had 84 students, who reported positive ratings on cohesive conceptions of learning, deep approaches to learning and to using online learning technologies. They also had positive ratings on perceptions of online interactivity and online learning design, and achieved relatively better in the course. In contrast, the 90 students in cluster 2, reported positive ratings on fragmented conceptions, and surface approaches to learning and to using online learning technologies. They were negative on how they perceived online interactivity and online learning design, and achieved relatively poorly in the course. Viewed together, the learning of the students in cluster 1 was directed towards meaningful understanding of the subject matter (i.e. the 'understanding' learning orientation), whereas the learning of the students in cluster 2 was oriented towards a more surface level (i.e. the 'reproducing' learning orientation).

3.2 | Results of patterns of collaborations by students' learning orientations

The SNA visualization of the whole class collaborative network is presented in Figure 1, where the nodes represent students; and the edges are students' collaborations. Each student was in one of the following collaborative groups; Understanding Collaborative group (no. of students = 61; no. of collaborations: 64), Reproducing Collaborative group (no. of students = 63; no. of collaborations: 53), and Mixed Collaborative group (no. of students = 50; no. of collaborations: 132).

The results of the two-sample proportion tests for pairwise comparison of the proportion of the collaborative mode amongst UC, MC, and RC are displayed in Table 2. It shows that the proportion of face-to-face collaborations in the UC group was significantly lower than that in the RC group: $z = 2.70$, $p < 0.01$; whereas no differences were found between UC and MC, and between MC and RC. On the other

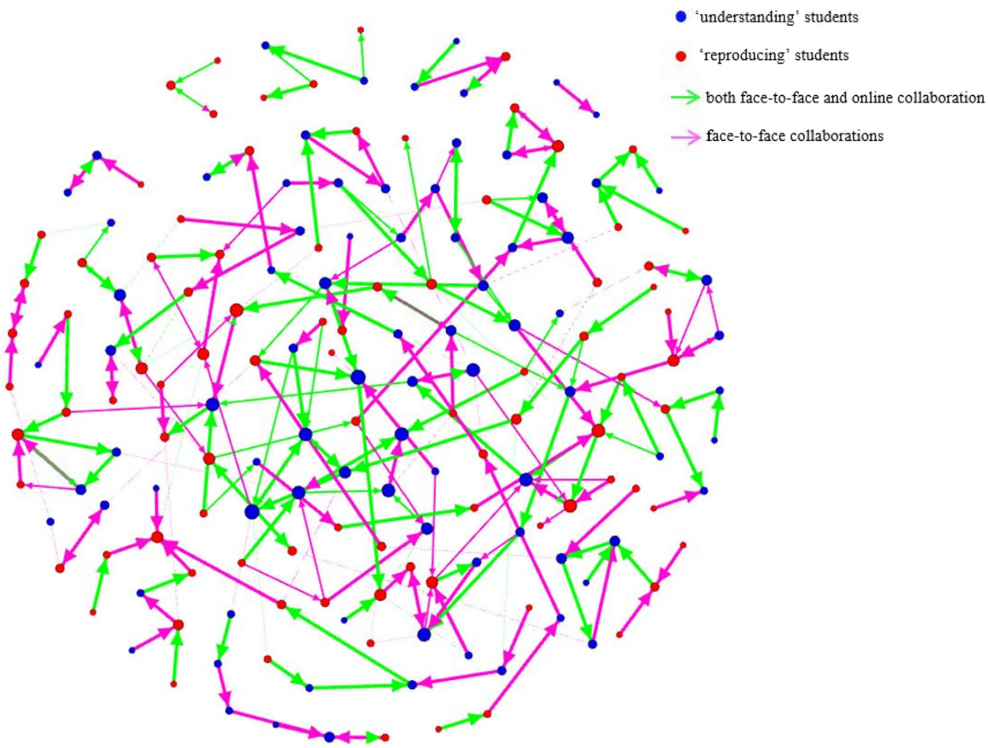

FIGURE 1 Visualization of students' collaborations by variations in learning orientations

TABLE 2 Comparison of collaborative mode

	UC		MC		RC				
Collaborative mode	*n*	%	*n*	%	*n*	%	Pairwise	*z*	*p*
face-to-face	11	18.03%	14	28%	25	39.68%	UC = MC	1.30	0.22
							UC < RC	**2.70**	**0.00**
							MC = RC	1.30	0.19
blended	50	81.97%	36	72%	38	60.32%	UC = MC	1.20	0.21
							UC > RC	**2.60**	**0.00**
							MC = RC	1.30	0.20
overall	61	100%	50	100%	63	100%	–	–	–

Abbreviations: MC, Mixed Collaborative group; RC, Reproducing Collaborative group; UC, Understanding Collaborative group.
Bold values indicates significant values.

hand, the proportion of blended collaborations in the UC group was significantly higher than that in the RC group: $z = 2.60$, $p < 0.01$. There were no significant differences between UC and MC, and between MC and RC for the proportion of blended collaborations. These results demonstrated that students in the UC groups tended to approach collaborations using different modes, hence, might be more flexible; whereas students in the RC groups tended to predominantly rely on face-to-face collaborations, which might limit the other possible opportunities to collaborate.

The results one-way ANOVAs and post-hoc analyses for comparison of the SNA centrality measures of the students amongst different collaborative groups are presented in Table 3. It shows that the students in the three collaborative groups differed significantly on degree: $F(2, 171) = 11.84$, $p < 0.01$, $\eta^2 = 0.12$; and betweenness: $F(2, 171) = 8.02$, $p < 0.01$, $\eta^2 = 0.09$. The post-hoc analyses showed that for the degree centrality, UC students collaborated most followed by RC students, who had more average collaborations than MC students. For the betweenness centrality, UC students were higher than MC students. There were no significant differences between UC and RC, and between RC and MC. These results indicate that compared with MC students, UC students were more likely to cause the disconnection of collaborations if removed, implying their important positions in the full collaborative network (Gašević et al., 2019).

3.3 | Results of the contribution of patterns of collaborations to academic achievement

The correlation analyses between SAL variables, the SNA centrality measures, and academic achievement, are presented in Table 4. The

TABLE 3 Comparison of the SNA centrality measures

SNA centrality measures	Groups	M	SD	Post-hoc	F	p	η²
Average degree centrality (average collaboration)	UC	3.46	1.62	UC > RC	**11.84**	**0.00**	**0.12**
	MC	2.18	0.96	UC > MC			
	RC	2.83	1.40	RC > MC			
Betweenness centrality (capacity to gather information based on the position in the network)	UC	0.04	0.04	UC = RC	**8.02**	**0.00**	**0.09**
	MC	0.01	0.02	UC > MC			
	RC	0.03	0.03	RC = MC			
Eccentricity (shortest distance to reach the furthest students in the network)	UC	11.43	4.10	UC = RC	2.47	0.09	0.03
	MC	12.96	3.39	UC = MC			
	RC	12.25	3.34	RC = MC			
Local clustering coefficient (tendency of students to form closely knitted groups in collaborations)	UC	0.14	0.22	UC = RC	0.37	0.70	0.01
	MC	0.10	0.28	UC = MC			
	RC	0.13	0.30	RC = MC			

Abbreviations: MC, Mixed Collaborative group; RC, Reproducing Collaborative group; UC, Understanding Collaborative group.
Bold values indicates significant values.

TABLE 4 Results of correlation analyses

Variables	CC	FC	DAL	SAL	DAT	SAT	POI	POD	DG	BT	EC	LCC
SAL variables												
FC	−0.31**	–	–	–	–	–	–	–	–	–	–	–
DAL	0.77**	−0.29**	–	–	–	–	–	–	–	–	–	–
SAL	−0.29**	0.52**	−0.20**	–	–	–	–	–	–	–	–	–
DAT	0.73**	−0.23**	0.80**	−0.15*	–	–	–	–	–	–	–	–
SAT	−0.09	0.46**	−0.02	0.68**	−0.04	–	–	–	–	–	–	–
POI	0.58**	−0.23**	0.61**	−0.13	0.64**	−0.06	–	–	–	–	–	–
POD	0.72**	−0.21**	0.64**	−0.22**	0.67**	−0.15*	0.73**	–	–	–	–	–
SNA centrality measures												
DG	0.14	0.07	0.07	−0.03	0.07	−0.05	0.06	0.19*	–	–	–	–
BT	0.07	0.05	0.07	0.01	0.07	−0.05	0.03	0.10	0.71**	–	–	–
EC	−0.06	0.12	−0.11	0.05	−0.01	0.06	0.01	0.10	0.21**	0.11	–	–
LCC	−0.03	0.08	0.04	−0.18*	−0.01	−0.09	0.08	0.05	0.14	−0.14	0.16*	–
Academic achievement												
FM	0.11	−0.17*	0.03	−0.24**	0.05	−0.16*	0.01	0.06	0.18*	0.10	0.08	−0.06

Abbreviations: BT, betweenness; CC, cohesive conceptions; DAL, deep approaches to learning; DAT, deep approaches to using online learning technologies; DG, degree; EC, eccentricity; FC, fragmented conceptions; FM, final mark; LCC, local clustering coefficient; POD, perceptions of online learning design; POI, perceptions of online interactivity; SAL, surface approaches to learning; SAT, surface approaches to using online learning technologies.
$^{*}p < 0.05$. $^{**}p < 0.01$.

correlation analyses show that the final marks were significantly and negatively correlated with fragmented conceptions ($r = -0.17$, $p < 0.05$), surface approaches to learning ($r = -0.24$, $p < 0.01$) and surface approaches to using online learning technologies ($r = -0.16$, $p < 0.05$). But the final marks were significantly and positively associated with the degree centrality ($r = 0.18$, $p < 0.05$). These variables were used to construct regression models.

The values of tolerance (fragmented conceptions = 0.71, surface approaches to learning = 0.47, surface approaches to using online learning technologies = 0.48, and degree centrality = 0.98) were all above the recommended 0.40 (Allison, 1999), meeting the requirement of no multicollinearity (Field, 2017). The value of the Durbin-Watson was 1.97, which approached to 2, hence, met the no auto-correlation assumption for regression analysis.

The results of the two regression models are presented in Table 5. In model 1, when the three SAL variables were entered as predictors, only surface approaches to learning ($\beta = -0.25$, $p < 0.05$) significantly and negatively predicted academic achievement, explaining approximately of 3% of the variance in the achievement: F (3, 170) = 2.88, $p < 0.05$, $f^2 = 0.04$. This finding suggested that

TABLE 5 Results of the hierarchical regression analyses

Predictors	B	SE B	β	t	Adjusted R^2	ΔR^2	p	f^2
Model 1					0.03*	–		0.04
FC	−0.42	1.47	−0.02	−0.28			0.78	
SAL	−3.82	1.65	−0.25	−2.31			**0.02**	
SAT	1.27	1.80	0.07	0.70			0.48	
Model 2					0.07**	0.04**		0.09
FC	−0.85	1.46	−0.05	−0.59			0.56	
SAL	−3.65	1.62	−0.24	−2.25			**0.03**	
SAT	1.48	1.77	0.08	0.84			0.40	
DG	1.45	0.54	0.20	2.69			**0.01**	

Abbreviations: DG, degree; FC, fragmented conceptions; SAL, surface approaches to learning; SAT, surface approaches to using online learning technologies.
Bold values indicates significant values.
**$p < 0.01$.

students who reported using more surface approaches to learning tended to obtain lower course marks.

The results of model 2 showed that both surface approaches to learning ($\beta = -0.24$, $p < 0.05$) and degree centrality ($\beta = 0.20$, $p < 0.05$) significantly predicted students' final marks, contributing around 7% of variance: $F(4, 169) = 4.05$, $p < 0.01$, $f^2 = 0.09$. Inclusion of degree centrality could explain an additional 4% of variance in the academic achievement, and this change in R^2 was significant ($\Delta R^2 = 0.04$, $p < 0.01$). These results indicate that the SNA centrality measure assessing the average collaborations of students could make significant and extra contribution to the academic achievement than only using surface approaches to learning as a predictor.

4 | DISCUSSION

This study identified variations in students' learning orientations in a blended engineering course. It also examined patterns of students' collaborations by variations in their learning orientations; and the contribution of patterns of collaborations to students' academic achievement. Before discussing the results, it is worthwhile noting the limitations of the study, which may affect the interpretation and generalizability of the results. The participants of the study were recruited from only one single discipline—engineering. Many more studies involving other disciplines are required for the patterns of the results to be confirmed. Moreover, because of the discipline-specific nature of imbalanced gender distribution amongst engineering students in China, only less than 10% of our participants were female students. This means that the collaborative patterns found in our study may not be representative of collaborations amongst students with more balanced male and female students. Future research should take gender balance into account when recruiting participants. Second, the data collection method is predominantly self-reporting, which needs to be triangulated with more objective observational measures and data. For instance, students' face-to-face collaborations can be observed and students' groupwork in the online discussion forum can also be traced to examine the consistency between whom students report to collaborate with and whom they actually collaborate with. Moreover, the research design is purely quantitative, which does not provide 'insiders' opinions with regard to students' collaborative learning experience. To fully understand the complexity nature of students' collaborative learning, qualitative methods, such as focused groups with students and/or semi-structured interviews with the teaching team should also be employed in the future research. Notwithstanding these limitations, the study offers some interesting insights into patterns of collaborations in blended course designs.

4.1 | Variations in Chinese students' learning orientations

Based on students' conceptions, approaches and perceptions, in blended course designs, two broad students' groupings representing two contrasting learning orientations were identified. The learning of 'understanding' group was largely oriented towards as in-depth understanding of the subject matter, and had features of holding cohesive conceptions, adopting more deep approaches to learning and using online learning technologies, and perceived the online learning was interactive with the teaching staff, and the online learning design being of higher quality. In contrast, the learning of the 'reproducing' group was mainly formulaic and mechanistic, characterized by their fragmented conceptions of learning, surface approaches, and more negative perceptions of the interactivity and design of the online learning.

It is worth noting how these results relate to past research. They are consistent with previously identified contrasting learning orientations, which only included either students' conceptions and approaches (Han & Ellis, 2019; Tsai & Tsai, 2014), or approaches and perceptions (Ellis & Bliuc, 2019; Guo et al., 2017). The results of the different academic achievement by students' learning orientations also corroborated with previous studies that 'understanding' students had significant better course marks than 'reproducing' students (Ellis & Bliuc, 2019; Han & Ellis, 2019). Furthermore, the results extend the existing research by revealing coherent patterns across conceptions, approaches, and perceptions in students' learning experience and in a relatively less researched student population—Chinese university students.

4.2 | Patterns of collaborations by variations in students' learning orientations

Three different collaborative groups (i.e. UC, MC and RC) were identified in students' learning orientations and their choices about with whom they collaborated. Of the three collaborative groups, the patterns of collaborations in the UC group exhibited the most desirable features. Students in the UC group held cohesive conceptions, adopted deep approaches, perceived positive interaction with the teaching staff, and appraised the online learning design. At the same time, they had highest average collaborations (i.e. highest degree centrality) amongst the three groups. This means that they took the opportunities to develop their collaboration and teamwork skills through learning the disciplinary contents of the course. When collaborating, a majority of students in the UC group (81.97%) also tended to move flexibly forth and back between face-to-face and online modes (i.e., collaborative mode). The also tended to remain in better positions in the collaborative networks (i.e., a higher betweenness), which can help them to gather information more effectively than the students in MC and RC groups. These results expand what we know about learner factors in students' collaborative learning in higher education (Kwon et al., 2014; Qureshi et al., 2021; Reis et al., 2018; Van den Bossche et al., 2006; Wilson & Narayan, 2016). They add new evidence about how the patterns of students' collaborations differed based on their learning orientations as measured by their conceptions, approaches, and perceptions in blended course designs.

4.3 | Contributions of collaborations to academic achievement

Previous studies have demonstrated that factors, such as students' collaborative competence (Castillo et al., 2017) and use of collaborative strategies (Stump et al., 2011), contributed to students' academic achievement. These factors, however, are not indicators, which directly reflect patterns of collaborations. This study directly examined the contribution made by SNA degree centrality measure and the results also demonstrated its significant contribution to students' academic achievement. Similar results have been reported in other studies on students' learning networks and knowledge sharing networks. For instance, Stadtfeld et al. (2019) and Tomás-Miquel et al. (2016) respectively reported that the SNA centrality measures in students' learning networks and knowledge sharing networks could explain variations in their academic learning outcomes at the level of study programmes. However, those networks were not about students' collaborative learning. By specifically focusing on students' collaborative network at the course level, our study found that students' average collaborations could make an extra contribution to their academic achievement in the course in addition to the approaches to learning, albeit explaining small amount of variance (4%) in academic achievement. Such a small amount of variance could be possibly due to how students' learning achievement were assessed in this course. The majority of assessment tasks in the course were individual task (i.e. close-book final examination, three problem solving tasks each week; and the quality of postings in the online discussion board). Only the reflection of the student-led tutorials was directly related to students' collaborative learning experience, as the tutorials were designed as group activities. This corroborated with the findings in Vargas et al. (2018) that most of SNA centrality measures of students' assignment helping networks did not correlate with the scores of the individual nature of the final exam but were significant related to the assignment scores, which allowed students to help each other to complete the assignments. Had the teacher in our study included group assessment tasks or more assessment tasks were about students' collaborative learning, the SNA centrality measures of students' patterns of collaborations might have made a larger contribution to students' academic achievement. The findings also suggest that collaboration is not only an important generic attribute for graduates to develop, but may also help improve students' academic learning outcomes, especially in courses which purposefully embed collaborative learning elements, such as the one investigated in our study.

4.4 | Implications of the study

Considering the significant contribution made by students' average collaborations to the academic achievement, the question of how to encourage students to collaborate remains a challenging task for the teaching staff. As our study shows that patterns of collaborations differ by variations in students' learning orientations, successful collaborative learning is possibly achieved by fostering a more desirable orientation to learning. As the learning orientations are jointly shaped by students' conceptions, approaches, and perceptions (Entwistle & Peterson, 2004; Lonka et al., 2004; Ramsden, 1988), teachers can assist students in developing a more desirable learning orientation in blended courses through any of these aspects. Teachers may identify students' learning orientations early on in the course, and ask 'understanding' students to explain their conceptions of learning of the subject matter and the ways they approach learning and to using online technologies, which may help 'reproducing' students to improve their conceptions and approaches. Improving students' perceptions of learning online may also help with their general orientation and can be achieved by giving prompt feedback, providing clear learning instructions and expectations, and encouraging the contacts between students and the teaching team (Garrison, 2016; Kim et al., 2011). It can also be achieved by improving the online design of the course by including meaningful online activities and by creating a clear and consistent structure that offers intuitive navigation of the course site (Dixson, 2012).

Furthermore, to improve students' orientations to learning, teachers may also consider directly modelling desirable collaborations by asking UC students to share how they collaborate. Pairing an 'understanding' student with a 'reproducing' student, or reassigning a 'reproducing' student to join a UC group, may also be a useful strategy to improve students' collaborative learning experience.

5 | CONCLUSION

Collaboration has long been a valued attribute for developing a competent graduate by teachers, universities and employers. In order to discover its contribution to students' academic achievement, we need to understand the factors, which may influence students' collaborations. This study has revealed some of the complexity involved in understanding the patterns of collaborative experience, however, more research is required into different levels of university education and in different academic disciplines so that we develop a more complete understanding of this important dimension of the university student experience of learning.

ACKNOWLEDGMENT

Open access publishing facilitated by Australian Catholic University, as part of the Wiley - Australian Catholic University agreement via the Council of Australian University Librarians.

FUNDING INFORMATION

The authors acknowledge the support by the Australian Research Council [grant number DP150104163].

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/jcal.12747.

DATA AVAILABILITY STATEMENT

The dataset 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.

ETHICS STATEMENT

This study was approved by the Human Research Ethics Committee of the authors' institutions and was carried out in accordance with the Declaration of Helsinki with written informed consent from all subjects.

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How to cite this article: Han, F., Ellis, R. A., & Guan, E. (2023). Patterns of students' collaborations by variations in their learning orientations in blended course designs: How is it associated with academic achievement? *Journal of Computer Assisted Learning*, *39*(1), 286–299. https://doi.org/10.1111/jcal.12747