# Assessing university student collaboration in newways

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**Assessing university student collaboration in new ways**

**Abstract**

This study argues for the importance of using the different evidence to assess and evaluate a key graduate skill – collaboration. To do so, it investigates the experience of 356 first-year students in a blended course design and measures their collaborative patterns. Combining research methodologies from student approaches to learning and social network analysis, the results reveal evidence of different collaborative patterns across the population sample. The investigation uncovers contrasting groupings of students with deep and surface approaches to inquiry and to online learning technologies, positive and negative conceptions of the learning environment, and relatively higher or lower academic outcomes. These are discovered to logically relate to different collaborative patterns. The most effective collaboration strategies involve collaborating only as much as tasks needed, in smaller groups, and being reciprocal by accepting and inviting peers to work together. Effective collaboration strategies also include students positioning themselves to gather information easily in their collaboration networks and to develop closely knitted collaborative groups. The results offer an evidence-base to identify different experiences of student learning and collaboration to improve program design and the attribute of collaboration and to improve the concepts underpinning policy development for quality improvement of university graduates.

**Keywords:** Assessment in new ways, collaborative patterns, student approaches to learning research, social network analysis

## Introduction

As the needs of societies become more complex and the cost of higher education rises; students, parents, governments, and employers are crystallising their expectations of what a holistic education of graduates comprises. In addition to deep disciplinary knowledge and a sound grounding in complementary areas, the transferable attributes that students can demonstrate from their university studies are of increasing interest and concern for all stakeholders (Hill, Walkington, and France 2016). These attributes include broad skills, such as critical thinking, problem solving, oral and written communication, information and digital literacy, and inventiveness (Dvorakova and Matthews 2017). At the basis of developing these skills effectively for the workplace are teamwork and collaborative skills; the ability to use technology to solve difficult problems, to share insights and analyses, to formulate solutions; and to apply the principles to new and unforeseen contexts. The generic attribute of *collaboration* is now understood as an essential part of university education. However, providing evidence of the collaborative capabilities of students is as much a problem of definition as it is an issue of its assessment and evaluation. Without an improved understanding of how to assess and evaluate collaboration, the claims of the outcomes of graduates of a university education and the processes of policy development that are related to the quality of their outcomes can be undermined. Policy formation is often impeded by imprecise or no evidence of key concepts and a lack of awareness of the details of the accompanying practice and how it should inform the structure of policy (Slavin 2002). Consequently, more precise measures of the practice of education is of benefit, not only to those involved in the classroom, but for those who seek to lead activity at the level of institutions and sectors.

To reassure all stakeholders interested in the quality of graduates and their workplace readiness, evidence-based definitions of collaboration are essential as part of a broader graduate profile and for the formulation of policy built on assured graduate outcomes.

***Definitions of collaboration as a graduate attribute***

There are diverse definitions provided for the term ‘collaboration’, such as working constructively with others (Knight and Yorke 2004); group participants sharing unique ideas and experiences (Hathorn and Ingram 2002); and “working in a group of two or more to achieve a common goal, while respecting each individual’s contribution to the whole” (Roberts 2004, 205). Collaboration should be distinguished from cooperation. While the former emphasizes the mutual engagement and the non-separable nature of the individual contributions to the task, the latter delegates a portion of the task to each individual (Kozar 2010).

While the above definitions offer a point of departure for conversations about collaboration, they do not imbue actionable knowledge (Kirchhoff, Lemos, and Dessai 2013). Definitions which are derived from practical knowledge can help to improve the application of policy to practice. They can inform educators and policy makers about, for example, what makes particular collaboration activity effective in comparison to other, seemingly similar collaborative activity on the surface, but yet fails to empower graduates in the workplace. Consequently, a key purpose of this paper is to provide a description of how to assess and evaluate different student experiences of collaboration and the accompanying measures that identify their structure and why they differ. In providing such a description and measurement, our understanding of features of different collaborative patterns will improve our abilities to foster the desirable patterns and to design course activities to produce them.

***Importance of collaboration as a graduate attribute***

Internationally, the university sector has been front and centre in national policy development and is seen as a driver for innovation, new knowledge, and capable graduates to contribute to national agendas of advancement. This is true for Australia (Chubb 2013), the United Kingdom (Clark 2014), the United States of America (Office of Innovation and Improvement 2016), as well as many other countries.

The importance of collaboration and other graduate skills as a fundamental outcome from a university education is emphasised in various ways by national bodies responsible for the quality of higher education. They are highlighted in reports on essential graduate attributes of students (e.g., Holland et al. 2013; Hill et al. 2016; Norton and Cakitaki 2016); and they are evaluated in the national frameworks of the university student experience in many countries (Indiana University Center for Postsecondary Research 2016; Neves and Hillman 2016; Whiteley et al. 2017).

Despite the effort of universities and national bodies to continually emphasise and provide evidence of the value of a university education, there is evidence of growing dissatisfaction on the part of employers with university graduates on their collaborative skills (Harder, Jackson, and Lane 2014). For instance, the percentages of the employer satisfaction on graduates' collaborative skills have consistently ranked the second lowest amongst the five graduate attributes in the national Employer Satisfaction Survey from 2016-2019 (Whiteley et al. 2020). Not only do governments and employers expect students to be able to collaborate effectively with other workplace colleagues and bodies of knowledge, but the students themselves (and their parents) expect their university education to equip them with skills to collaborate and to work in teams (Christensen, Knezek, and Tyler-Wood 2014).

***Prior research into collaboration in university education***

Given the importance of graduate skills, such as collaboration for graduates expressed by national agendas, governments, employers, and students, it is perhaps not surprising that there has been systematic research into collaboration in learning as well as how technology is used to promote collaboration in university education. The following identifies three areas of research which offer relevant background related to this study.

In the first area, over the last few decades research has investigated key aspects of effective collaboration and academic performance (Sampson and Clark 2011; Enyedy and Stevens 2014). For example, a recent meta-analysis of 225 studies found that active learning, such as collaboration-based activities, increased examination performance by approximately half a standard deviation while lecture-based pedagogies increased failure by 55% (Freeman et al. 2014). In another meta-analysis on the impact of small group collaboration on academic performance, Pai, Sears, and Maeda (2015) found evidence that small group learning could increase students' ability to transfer their learning to new contexts.

The second area of research has investigated how technology can stimulate collaboration in learning (Goodyear, Jones, and Thompson 2014). The promise of learning on-line to improve collaboration has been recognised for decades. This line of research has grown alongside the development of the Internet and the increasingly adoption of technology in education. Since then, much research has recognised the value of technology for shaping the collaboration, known as computer-supported collaborative learning (Goodyear et al. 2014). Computer-supported collaborative learning has been found to have various benefits in learning, including encouraging learning at a deeper level, promoting higher-order thinking and problem-solving, enhancing students' motivation and engagement in learning, as well as achieving better academic outcomes (Jonassen and Kwon 2001; Zhu 2012; Sung, Yang, and Lee 2017; Zheng 2017; Gokhale and Machina 2018).

In order to find out why some students are more successful in computer-supported collaborative learning, researchers have investigated factors including learners' emotion and affect (e.g., Reis et al. 2018), self-efficacy (e.g., Wilson and Narayan 2016), individual-regulation and co-regulation behaviors (e.g., Kwon, Liu, and Johnson 2014), sense of shared community (e.g., Garrison 2016), digital competence (e.g., Blayone et al. 2017), metacognition (e.g., Akyol and Garrison 2011), and satisfaction (e.g., Elia et al. 2018). Other important learner factors, such as how students go about learning (their approaches), how they perceive the learning environments in blended course designs (their perceptions), has received little systematic investigation.

The third area informing the current study is the research into student approaches to learning (Pintrich 2004), which has consistently found evidence of deep and surface approaches to learning. Deep approaches seek meaning in context, look for connections between the ideas and applications in learning, and involve strategies which are motivated by the meaningful intent of learning. Surface approaches fail to recognise the relevance of the learning and practical applications, involving formulaic strategies which typically ignore synthesis, evaluation, and recontextualisation (Biggs and Tang 2011; Prosser and Trigwell 2017). Deep and surface approaches have been found to be logically related to positive and negative perceptions of the learning environment, and relatively higher and lower levels of academic achievement. While deep approaches are typically related to positive perceptions of aspects of the environment, such as high quality teaching, appropriate workload, integrated face-to-face and online learning, and better learning outcomes, surface approaches are associated with negative perceptions and poorer achievement (Biggs and Tang 2011; Asikainen and Gijbels 2017; Vermunt and Donche 2017; Han and Ellis 2020a).

**The current study**

Building on the three areas of research discussed above, the current study adopts methodologies from student approaches to learning and social network analysis to assess and evaluate collaboration. Student approaches to learning looks for qualitatively different experiences of learning through self-report measures of elements, such as approaches to, and perceptions of learning. Social network analysis aims to identify, detect, and interpret roles of individuals within a group and patterns of relations amongst individuals using graph theory and mathematical measures (Rulke and Galaskiewicz 2000; De Nooy, Mrvar, and Batagelj 2011). The advantages of using social network analysis to investigate collaborative pattern lie in its capacity of powerful visualisations of the students and their collaborative ties to other students, and nuanced quantitative measures, which are able to reveal variations in student collaboration. The study aims to refine measures of collaboration for the purposes of improving our understanding of how to improve the evidence and claims of effective evaluation of collaboration; and to inform strategies of how to effectively integrate collaborative learning into university education. Specifically, it seeks to answer two research questions:

1) How are students' approaches to, and perceptions of, learning in a blended course design related to collaborative patterns?

2) To what extent do collaborative patterns differ as reflected by social network analysis measures?

By providing answers to the research question, the study will also have implications of these ways of assessing collaboration for evaluation policy and practice.

## Materials and methods

### *Participants*

The participants were 364 first-year undergraduates (251 females and 113 males), who were enrolled in a course on human biology. Their ages ranged from 18 to 53 ($M$ = 19.72, $SD$ = 3.55).

### *The learning context*

The course was a semester-long blended course offered in a large metropolitan Australian university. The course, which was an introduction to human anatomy and physiology, covered a wide range of topics, including cell and tissue structures, the skeletal, digestive, respiratory, circulatory, nervous, endocrine, lymphatic, urinary, and reproductive systems, and human genetics. Apart from learning disciplinary knowledge, the course was also designed to develop students' graduate attributes, such as team work and collaborative skills, creative and critical thinking abilities, competence to inquiry and evaluate information, and capabilities of following appropriate protocols to conduct research and inquiry.

The face-to-face part of the course had a two-hour face-to-face lecture per week, a three-hour laboratory session fortnightly, and a two-hour workshop every other week when there were no laboratory sessions. Students were encouraged to collaborate in the course both in and out of classes. In particular, in the laboratory classes, students were asked to form pairs or groups by taking initiatives to choose their own collaborators rather than being assigned by the teaching staff.

The online component, being integral and compulsory, required the completion of online modules, which took approximately six hours participation each week. The online modules consisted of three main parts: 1) compulsory and supplementary readings; 2) interactive activities and exercises, including drag and drop exercises, multiple choice questions, fill in tables, and open-ended questions; and 3) adaptive quizzes, which applied special algorithms to adjust level of difficulty of the items according to students' abilities as reflected by their performance in a previous item.

***Data sources and instruments***

*Data on approaches to, and perceptions of, learning*

To measure students' approaches to learning through inquiry, approaches to using online learning technologies, and perceptions of blended learning environment, a 5-point Likert-scale questionnaire was used. The questionnaire was developed using the student approaches to learning literature (e.g., Biggs, Kember, and Leung 2001), and has been used in previous research in blended learning context (Bliuc, Ellis, Goodyear, and Piggott 2010; Ellis and Bliuc 2016; Ellis, Pardo, and Han 2016; Han and Ellis 2020b), confirming its reliability and validity. It had five scales:

- The *Deep approaches to inquiry* scale (5 items; α = 0.71) describes approaches to learning through inquiry as being proactive, initiative, and independent, with deep thinking to pursue inquiry (e.g., "I often pursue independent pathways when researching something").
- The *Surface approaches to inquiry* scale (4 items; α = 0.63) describes approaches that lack reflection and independency (e.g., "Researching something for a task means only using the resources given to me by the teacher").
- The *Deep approaches to using online learning technologies* scale (5 items; α = 0.72) assesses using technologies as a way to promote understanding of the key ideas, to facilitate research, and to connect concepts in the course to real-world problems (e.g., I spend time using the learning technologies in this course to connect key ideas to real contexts").
- The *Surface approaches to using online learning technologies* scale (4 items; α = 0.66) describes using online learning technologies to a limited extent, and using them as simplistic and mechanistic ways (e.g., "I only use the learning technologies in this course to fulfil course requirements").
- The *Perceptions of the blended learning environment* scale (6 items; α = 0.88) assesses to what extent students' perceptions of face-to-face and online components are coherent and integrated (e.g., "The online activities help me to understand the lectures in my course").

*Data on students' collaboration*

An open-ended questionnaire adopting methods in social network research was used to collect information on students' collaboration. Students were asked to name up to three collaborators in the course according to the frequency of collaborations. They were asked to take into consideration both face-to-face and online collaborations when answering the question.

a) *The most frequent* __________________________

b) *The second most frequent* __________________________

c) *The third most frequent* __________________________

*Data on students' academic performance*

Students' academic performance was measured by an inquiry-based learning assessment task, which required students to carry out a scientific project and write a report on it. The project assessed students' skills of observing, recording, searching, and selecting relevant information from a variety of sources; and the report required them to summarize information, form appropriate research questions, critically evaluate and select information, and write the scientific report following standards. The task was marked on 100 point ($M$ = 67.69, $SD$ = 11.94).

**Data collection and analysis**

Data collection followed the requirements of the University ethics committee. Participation in the study was voluntary and anonymous. The data collection took place in class at the end of the semester so that the students had full experience of the course.

Data analyses were broadly carried out in two stages to answer the two research questions. In the first stage, cluster analysis and one-way ANOVAs were first performed. The cluster analysis aimed to identify sub-groups of students by maximising similarities within groups and differences between groups in terms of their learning experience. On the basis of the cluster membership, one-way ANVOAs were applied to examine the differences of students' approaches to inquiry, approaches to using online learning technologies, perceptions of the blended learning environment, and academic performance between the clusters. Using the cluster membership and students' choice of collaborations (i.e., whether to collaborate and with whom to collaborate), collaborative patterns were generated.

The second stage of analyses adopted social network analysis to visualize students' collaborative patterns and to investigate if the collaborative patterns differed. The social network analysis was performed using Gephi (Bastian, Heymann, and Jacomy 2009), which was able to provide descriptive statistics (i.e., number of students, number of collaborations, maximum number of collaborators per student, and the biggest collaborative sizes) and social network analysis centrality (i.e., degree, closeness, and betweenness) and network-level measures (i.e., network density, network clustering coefficient, and network modularity). While the centrality measures describe features and positions of nodes in the network, the network-level measures reveal the structure of the networks (Grunspan, Wiggins, and Goodreau 2014). To investigate how the collaborative patterns differed, we used *z*-tests to compare: 1) the proportion of different collaborative sizes (i.e., in pairs, in triads, and in groups of more than three); and 2) the proportion of different types of collaboration (i.e., 'being nominated only'; 'initiating only'; 'both initiating and being nominated') amongst collaborative patterns. We also directly compared centrality and network-level measures amongst collaborative patterns because all these measures were standardized, hence allowing direct comparison.

## Results

### *Results of cluster analysis and one-way ANOVAs*

[Table 1 near here]

Tables 1 presents the results of cluster analysis and one-way ANOVAs. To facilitate interpretation, all the scores were transformed into *z*-scores ($M$ = 0, $SD$ = 1) in the analyses.

The increasing value of the Squared Euclidean Distance between clusters and Dendrogram suggested a two-cluster solution: one cluster had 134 students and another cluster had 231 students. The one-way ANOVAs showed that the two clusters differed significantly on all the variables: the deep approaches to inquiry: $F$ (1, 363) = 67.80, $p < .01$, $\eta^2 = .16$; the surface approaches to inquiry: $F$ (1, 363) = 94.32, $p < .01$, $\eta^2 = .21$; the deep approaches to using online learning technologies: $F$ (1, 363) = 108.41, $p < .01$, $\eta^2 = .23$; the surface approaches to using online learning technologies: $F$ (1, 363) = 288.82, $p < .01$, $\eta^2 = .44$; the perceptions of the blended learning environment: $F$ (1, 363) = 139.50, $p < .01$, $\eta^2 = .28$; and academic performance: $F$ (1, 363) = 4.37, $p < .05$, $\eta^2 = .01$.

The *M* values in Table 1 showed that students in cluster 1 used more deep approaches to inquiry, deep approaches to using online learning technologies, were more likely to perceive face-to-face and online components being integral, and obtained higher scores on the assessment than cluster 2 students. From the patterns of their reported approaches, perceptions, and academic performance, the learning of cluster 1 students was oriented towards understanding the subject matter, hence having an ‘understanding’ learning orientation; whereas cluster 2 students learned mainly for reproducing facts, hence having a ‘reproducing’ learning orientation.

***Visualisation and descriptive statistics of the social network analysis***

Based on students’ learning orientations and their choices of collaborations as to whether to collaborate and with whom to collaborate, five different collaborative patterns (known as five networks) were generated:

(1) Understanding Alone (UA) network: formed by ‘understanding’ students who chose not collaborate.

(2) Understanding Collaborative (UC) network: formed by ‘understanding’ students who collaborated with students in the same category;

(3) Mixed Collaborative (MC) network: formed by both ‘understanding’ and ‘reproducing’ students who collaborated with students of a different learning orientation;

(4) Reproducing Collaborative (RC) network: formed by ‘reproducing’ students who collaborated with students in the same category;

(5) Reproducing Alone (RA) network: formed by ‘reproducing’ students who chose not to collaborate.

The visual representation and descriptive statistics of the five different collaborative patterns are presented in Table 2. In the five pictures depicting five networks, nodes are students represented by blue (‘understanding’ orientation) and red (‘reproducing’ orientation). Edges are student choices with regard with whom to collaborate (arrows). In Table 2, there were 61 and 88 students who did not collaborate with anyone in UA and RA networks. Among the three collaborative networks, the biggest collaborative size of RC network (6) was larger than that of MC (4) and UC (3) networks. Because students in UA and RA networks did not collaborate, the comparison described below was only concerned with UC, MC, and RC networks.

[Table 2 near here]

***Comparison of collaborative size in the three networks***

[Table 3 near here]

The number and proportion of the collaborative size amongst UC, MC, and RC and the results of *z*-tests are displayed in Table 3. *Z*-tests show that the proportion of working in pairs in UC was significantly higher than both MC ($z = 4.20$, $p < .01$) and RC ($z = 3.80$, $p < .01$), but MC and RC did not show any significant difference ($z = 0.70$, $p = .47$). The proportion of working in groups of more than 3 in UC was significantly lower than that in MC ($z = 3.30$, $p < .01$) and RC ($z = 3.90$, $p < .01$), there was no significant difference between MC and RC (*z*

= 1.20, *p* = .24). In terms of proportion of working in triads no significant difference was found amongst the three networks.

***Comparison of types of collaborator in the three networks***

[Table 4 near here]

Table 4 shows that UC had significantly lower proportion of 'being nominated only collaborators' than MC ($z = 4.10$, $p < .01$) and RC ($z = 4.40$, $p < .01$), but there was no difference between MC and RC ($z = 0.40$, $p = .68$). For 'both initiating and being nominated collaborators', paired-sample *z*-tests showed that UC had significantly higher proportion than RC ($z = 4.80$, $p < .01$) and MC ($z = 4.70$, $p < .01$), whereas MC and RC did not differ significantly ($z = 0.10$, $p = .92$). With regard to the proportion of the 'initiating only collaborators', no significant difference was found amongst the three networks.

***Comparison of standardized social network analysis measures in the three networks***

[Table 5 near here]

The standardized social network analysis measures of UC, MC, and RC are displayed in Table 5, in which rows 1-3 are centrality measures, and rows 4-6 are network-level measures. When we calculated the centrality measures, we used the undirected networks because when two students worked together, their collaboration was the same irrespective of who initiated the collaboration. On average, when collaborating in UC network (1.250), students tended to have fewer collaborations compared with MC (1.274) and RC (1.416). However, UC (0.983) had higher closeness than MC (0.845) and RC (0.865), suggesting that UC network has a structure that the students in this network used less steps to reach others compared to the structures of MC and RC networks, in which the students used more steps to reach other collaborators in their respective networks. With regard to the network-level measures, the collaborations in UC (0.900) tended to be in closely knitted groups than those in RC (0.505). Of the three collaborating networks, UC network also had a structure that enabled students in the network had the shortest average distance to reach other students (UC: 1.038, MC: 1.325, and RC: 1.330). In the context of collaboration, the shorter average path length could mean that it took fewer steps to circulate information when students collaborated in UC network. UC network also had highest value of network density amongst the three networks (UC: 0.032, MC: 0.010, and RC: 0.012). Overall, these results seemed to suggest that the features of UC network were relatively more desirable compared to those in MC and RC.

***Comparison of academic performance amongst UA, RA, and collaborating students (UC, MC, and RC)***

As the students in the three collaborative networks (UC, MC, and RC) were not mutually exclusive, we merged them into one group (collaborating students). We compared the academic performance of UA, RA, and collaborating students by conducting a one-way ANOVA and the result was significant: $F$ (2, 362) = 3.62, $p < .05$, $\eta^2 = .02$. Because of the unequal sample sizes of the three groups, we chose to use Tukey-Kramer post-hoc analyses, which showed that while UA ($M$ = 0.11, $SD$ = 0.80) and collaborating students ($M$ = 0.07, $SD$ = 0.99) did not differ in their academic performance, both students in UA and collaborating students had significantly higher marks than students in RA ($M$ = -0.25, $SD$ = 1.11).

## Discussion

This study argues for nuanced ways of assessing and evaluating collaboration in university learning in order to improve the measurement of this important graduate skill and the quality of graduates. Effective assessment of students' collaboration has long been regarded as a complex issue due to its involvement of individual accountability (i.e., the extent to which an individual of a group is accountable for the task central to the group performance) (Slavin 1980) and positive interdependence (i.e., the extent to which an individual's performance is dependent upon the performance of other members in the group) (Johnson, Misner, and Brown 1981). Despite much effort having been paid to improve assessing collaboration, current practice fails to systematically consider the use of data from the individual level and from the group in combination to assess collaboration (Strijbos 2016). The current study combined the methodologies of student approaches to learning research, which collected the individual student's approaches to learning and perceptions of the learning context; and social network analysis, which reflected the network features of different collaborative patterns derived from students' approaches, perceptions, and their choice of collaboration.

One of the main outcomes of the study is the collaborative patterns and the differences amongst these patterns. In relative terms, the most desirable pattern is the collaboration in UC network, which is formed by students who adopted approaches to inquiry and learning technologies which sought to understand the key concepts and issues in context; and reported coherent perceptions of the learning environment, indicating that they understood the relationship between the face-to-face and online contexts of their learning experience. These students also tended to have relatively higher academic performance. The desirable features of collaborations in UC network are summarized below:

- collaborations tended to be in smaller groups (mostly pairs) than the other networks; This finding seems to corroborate with Pai et al.'s (2015) meta-analysis, which reported the benefit of collaboration in smaller groups in learning.
- had a higher percentage of 'both initiating and being nominated collaborators' than the other networks. Such feature seemed to resemble the "dominant/dominant" pattern in Storch's studies (2002, 2004), which showed a higher equality of contribution from collaborators to the collaborative tasks at hand, but lower level of agreement and consensus in the process of collaborating. However, our study did not examine the issue of agreement, which could be explored by asking students to rate their level of agreement in the collaborations in future research.

- on average had shorter structural distances to travel to gather information. However, previous studies reported that in the processes of sharing and exchanging information when collaborating, students are often involved in off-topic discussions, in particular when collaborative groups are formed amongst friends (e.g., Storch 2013; Li and Zhu 2017; Le, Janssen, and Wubbels 2018). As we did not know exactly the kind of information exchanged amongst collaborators, we were unable to confirm that all the information circulated in the collaborative groups was pertinent to the study purposes.
- and the collaborations tended to be in closely knitted groups.

In contrast, the features of collaborations (or non-collaborations) in the other networks were less satisfactory. Despite the course syllabus encouraged students to collaborate both in and out of classes, and in particular, in the laboratory sessions, non-collaborating students (UA: $N = 61$, 16.8%; RA: $N = 49$, 13.5%) did not take the opportunities to develop this important graduate attribute. Even though students in UA network and those collaborating students did not differ in terms of their course marks, students UA failed to practice skills, such as sharing disciplinary knowledge, communicating effectively with team members, and working collaboratively towards a task, which are highly valued in the workplace and by employers. They also did not meet one of the course objectives, that is to develop the skills of collaboration.

In this course, we found that as much as 30.3% of students reported no frequent collaborators. Such a high percentage of non-collaborating students might be due to the non-compulsory collaborative assessment tasks in the course, which seemed not to match the course objective to foster students' collaboration. To help students develop this skill, a stronger link between assessment tasks and collaboration participation needs to be established to raise students' awareness of the importance of working with others in the course. A large proportion of mandatory collaborative activities, such as group projects, team presentations, and joint reports should be used as the assessment tasks to encourage students' collaboration and group work. The individual assessment tasks should also be catered to ask students to reflect their collaborative experiences, such as journals and reflections on collaborative experiences in the course. These adjustments are likely to help *all* students develop their abilities to collaborate and work in groups.

The RC network was formed by students who adopted approaches to inquiry and learning technologies which were formulaic and unengaged with the meaning of their learning. These students also tended to hold a fragmented perception of the online environment, thinking that it was unrelated to their learning. The RC network also had a lower proportion of 'both initiating and being nominated collaborators' than UC network. While MC network offered opportunities to students with a reproducing orientation to learn from those with an understanding orientation, their collaborations were not as desirable as UC network, such as the collaborations being more in larger groups and lower proportion of 'both initiating and being nominated collaborators', and taking more steps to have information shared with others in the network.

The current study not only confirmed the previous student approaches to learning research in the blended course design that deep approaches to face-to-face and online learning and positive perceptions of the integration of the blended learning environment tended to be desirable as they are positively related to higher academic outcomes (Ellis and Bliuc 2016; Ellis et al. 2016; Han and Ellis 2020a); it also extended beyond student approaches to learning literature and found that when students having these desirable approaches and perceptions collaborated together, their collaborations tended to be better as reflected by social network analysis measures. A recent investigation on study partnership relations reported that high achieving individuals preferred to work together (Stadtfeld et al. 2019), our findings further showed that when these more able students learned together, they were more strategic about their collaborations, resulting in better collaborations.

**Implications of the study**

Well-trained graduates are at the basis of effective government strategies for advancement and progress in society. Their ability to bring their disciplinary knowledge and graduate skills to bear on various issues in the workplace is one of the hallmarks of a successful university education.

To improve the ongoing validation of university degrees and policy formation built on the premise of quality university education, more precise measurements of graduate outcomes are essential (Van Damme 2015). Many recent reports on the quality of work-ready graduates suggest that things are not as they should be (Mourshed, Patel, and Suder 2014; Nagarajan and Edwards 2014; Phillips, Esterman, and Kenny 2015). Providing evidence of what effective and 'productive' collaboration looks like for university students, and using this to inform what constitutes better quality of learning experiences, including experience of collaboration will generate a number of benefits for universities and the stakeholders, and for policy makers who are creating frameworks on the basis of those definitions in order to ensure advancement.

For university teachers, the outcomes of this study revealed a fairly unique structure of collaborative patterns amongst first-year university students. Amongst the five networks, the UC network represent the most desirable collaboration. Courses can be designed with the foresight that similar collaborative structural patterns may exist in the class cohort. This knowledge can help with the formulation of activities so that the instructions and guidance integrated into the designs help students to experience collaboration more like those in UC network rather than UA, MC, RC or RA networks. The way teachers teach can also be usefully informed with this more precise understanding of what counts as productive collaboration.

While more studies are required to assess the robustness of the methods and the findings of this study, they also have significant implications for evaluation of graduate outcomes at the level of the national sector and for ensuing policy development by governments. In Australia for example, the national evaluation scheme of undergraduate outcomes is known as *Quality indicators for learning and teaching (QILT)* (see https://www.qilt.edu.au/) It contains a number of instruments to measure collaboration on graduation and some months after graduation. On graduation, the item assessing collaboration in the Course Experience Questionnaire is: *To what extent has your course developed your ability to work with others?* After graduation, the item assessing collaboration in the Graduate Outcomes Survey is: *To what extent do you agree or disagree that your course from your university prepared you for this job (for the following)?*

- *Working well in a team*
- *Getting on well with others in the workplace*
- *Working collaboratively with colleagues to complete tasks*
- *Understanding of different points of view*
- *Ability to interact with co-workers from different or multicultural backgrounds*

While the student responses to these questions offer some evidence of some graduate outcomes, they are not designed to reveal nuanced differences in terms of student collaborative experience. The ways of assessing collaboration adopted in this study addresses the preferred mechanism of both individual accountability and positive interdependence (Strijbos 2016), which are reflected by the approaches and perceptions adopted by individual students as well as a set of social network analysis measures at the level of network.

Only through additional evidence collected at the level of the national sector on the readiness of graduates based on their graduate attributes, the claims and processes of policy based on such nationally collected data, can be formulated to address advancement and growth in areas of society that depend on the capabilities of graduate students.

## Conclusions

Effective policy formation is best derived from evidence-based concepts (Pawson 2006; Head 2008). Despite the difficulties that may arise in assembling evidence of graduate attributes across the university sector, such as qualitatively different experiences of collaboration, such evidence is essential for those concerned about the quality of higher education and the claims about graduate attributes. To safeguard the reputation of university education, only the most-convincing evidence of outcomes should be pursued to demonstrate differences in an education from the academy.


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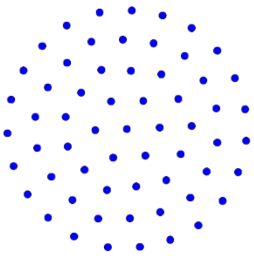
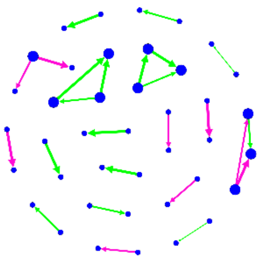
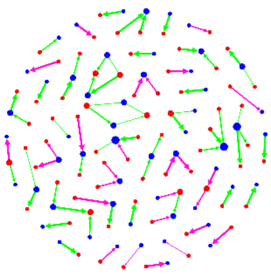
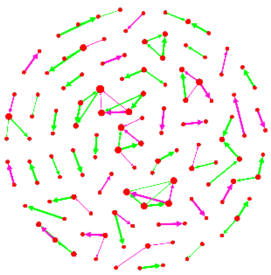
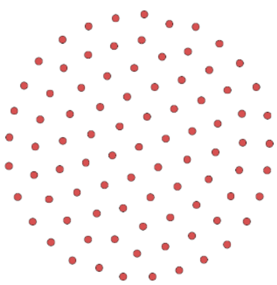
Table 1. Results of cluster analysis and one-way ANOVAs

| variables | understanding cluster ($N$ = 134) | | reproducing cluster ($N$ = 231) | | $F$ | $p$ | $\eta^2$ |
|---|---|---|---|---|---|---|---|
| | $M$ | $SD$ | $M$ | $SD$ | | | |
| DAI | 0.52 | 0.83 | -0.32 | 0.99 | 67.80 | .00 | .16 |
| SAI | -0.59 | 0.79 | 0.35 | 0.94 | 94.32 | .00 | .21 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| DAT | 0.63 | 0.80 | -0.37 | 0.93 | 108.41 | .00 | .23 |
| SAT | -0.87 | 0.65 | 0.53 | 0.82 | 288.82 | .00 | .44 |
| PBLE | 0.70 | 0.74 | -0.41 | 0.93 | 139.50 | .00 | .28 |
| AP | 0.14 | 0.78 | -0.08 | 1.11 | 4.37 | .04 | .01 |

*Note:* DAI = deep approaches to learning through inquiry, SAI = surface approaches to learning through inquiry, DAT = deep approaches to online learning technologies, SAT = surface approaches to online learning technologies, PBLE = perceptions of the integrated learning environment, and AP = academic performance.

Table 2. Visualisation and descriptive statistics of the five collaborative patterns (i

| pattern | visualisation | no. of students | no. of collaborations | maximum no. of collaborations of a student | biggest collaborative size |
|---|---|---|---|---|---|
| UA |  | 61 | – | – | – |
| UC |  | 40 | 25 | 3 | 3 |
| MC |  | 124<br>U:83<br>R:41 | 79<br>U→R:34<br>R→U:45 | 3 | 4 |
| RC |  | 120 | 85 | 4 | 6 |
| RA |  | 88 | – | – | – |

*Notes:* UA = Understanding Alone network, UC = Understanding Collaborative network, MC = Mixed Collaborative network, RC = Reproducing Collaborative network, and RA = Reproducing Alone network. Students in UC, MC, and RC are not mutually exclusive, because a student can present in multiple networks.

Table 3. Comparison of collaborative size

| collaborative size | UC No. | UC % | MC No. | MC % | RC No. | RC % | pairwise | *z* | *p* |
|---|---|---|---|---|---|---|---|---|---|
| pairs | 28 | 70% | 48 | 38.70% | 52 | 43.33% | **UC>MC** | **4.20** | **.00**** |
| | | | | | | | **UC>RC** | **3.80** | **.00**** |
| | | | | | | | MC=RC | 0.70 | .47 |
| triads | 12 | 30% | 48 | 38.70% | 33 | 27.50% | UC=MC | 1.00 | .32 |
| | | | | | | | UC=RC | 0.30 | .76 |
| | | | | | | | MC=RC | 0.70 | .50 |
| groups of more than three | 0 | 0% | 28 | 22.58% | 35 | 29.17% | **UC<MC** | **3.30** | **.00**** |
| | | | | | | | **UC<RC** | **3.90** | **.00**** |
| | | | | | | | MC=RC | 1.20 | .24 |

*Notes:* **$p < .01$, UC = Understanding Collaborative network, MC = Mixed Collaborative network, and RC = Reproducing Collaborative network.

Table 4. Comparison of types of collaborator

| types of collaborator | UC | | MC | | RC | | pairwise | *z* | *p* |
|---|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | | | |
| ‘being nominated only’ | 3 | 0.075 | 53 | 0.4274 | 55 | 0.4583 | **UC<MC** | **4.10** | **.00**** |
| | | | | | | | **UC<RC** | **4.40** | **.00**** |
| | | | | | | | MC=RC | 0.40 | .68 |
| ‘initiating only’ | 18 | 0.45 | 56 | 0.4516 | 50 | 0.4167 | UC=MC | 0.00 | .99 |
| | | | | | | | UC=RC | 0.40 | .71 |
| | | | | | | | MC=RC | 0.50 | .58 |
| ‘both initiating and being nominated’ | 19 | 0.475 | 15 | 0.121 | 15 | 0.125 | **UC>MC** | **4.80** | **.00**** |
| | | | | | | | **UC>RC** | **4.70** | **.00**** |
| | | | | | | | MC=RC | 0.10 | .92 |

*Notes:* ***p* < .01, Students in UC, MC, and RC were not mutually exclusive, thus the same student could be different types of collaborators when he/she was in different networks. UC = Understanding Collaborative network, MC = Mixed Collaborative network, and RC = Reproducing Collaborative network.

Table 5. Social network analysis measures of the three collaborative networks

| no. | social network analysis measures | UC | MC | RC |
|---|---|---|---|---|
| 1 | average degree<br>(average collaboration per student) | 1.250 | 1.274 | 1.416 |
| 2 | betweenness<br>(capacity of students to gather information) | 0.000034 | 0.000040 | 0.000048 |
| 3 | closeness<br>(total distance to reach other students) | 0.983 | 0.845 | 0.865 |
| 4 | network clustering coefficient<br>(tendency to form closely knitted groups) | 0.900 | --- | 0.505 |
| 5 | average path length<br>(average distance to reach other students) | 1.038 | 1.325 | 1.330 |
| 6 | network density<br>(the actual collaboration relative to potential collaboration) | 0.032 | 0.010 | 0.012 |

*Notes:* UC = Understanding Collaborative network, MC = Mixed Collaborative network, and RC = Reproducing Collaborative network.