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Quality in blended learning environments — Significant differences in how students approach learning collaborations

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ABSTRACT

Evaluating the quality of student experiences of learning in a blended environment requires the careful consideration of many aspects that can contribute to learning outcomes. In this study, university students in first year engineering were required to collaborate and inquire in a blended course design over a semester-long course. This study investigates their approaches to inquiry and online learning technologies as they collaborated both in class and online. The results identify sub-groups within the population sample (n > 200) which reported qualitatively different experiences of how they approached inquiry and used the online learning technologies. The results also measure aspects of their collaborations which help to explain why some students were more successful than others. The outcomes of the study have important implications for teaching and course design and the effective evaluation of blended experiences of university student learning.

1. Introduction

Education leaders and teachers concerned about the quality of education across their courses face a number of challenges when evaluating the quality of learning in blended learning environments to the quality of learning. In the current higher education environment where digital technologies are changing student expectations, stimulating innovation and reshaping teaching and learning models, clearly understanding how they contribute to qualitatively different student experiences of learning is strategically and educationally essential. The purpose of this study is to offer some explanations for why some students are more successful than others in blended contexts of collaborative learning and what this may mean for the quality agenda.

Research has shown that differing approaches to learning offer a way into understanding qualitatively different learning outcomes for students (Biggs, 2011; Entwistle, 2003; Prosser & Trigwell, 1999). Deep approaches made up of a meaningful intent and strategy to get to grips with the ideas of a course have shown to be systematically more successful than approaches to learning which skim along the surface and do not enable the students to engage through action or thought with the intended outcomes of the course (e.g., Diseth, Pallesen, Hovland, & Larsen, 2006; Ellis, Goodyear, O'Hara, & Prosser, 2007; Hazel, Prosser, & Trigwell, 2002; Lawless & Richardson, 2002; Prosser, Trigwell, Hazel, & Waterhouse, 2000). In a blended context of learning, there is still considerable debate about what constitutes meaningful intent and strategies that enable students to move back and forth between in-class and on-line environments effectively. There is even more debate about how

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these might account for why students are more successful than others. For example, some studies look for differences in the types of tools students use (e.g., Heirdsfield, Walker, Tambyah, & Beutel, 2011; Lajoie et al., 2013; Šumak, Heričko, & Pušnik, 2011), others consider the pedagogies chosen by teachers (e.g., Alonso, López, Manrique, & Viñes, 2005; Govindasamy, 2002), while other studies look to issues of motivation (e.g., Liaw, 2008; Moos & Stewart, 2013). At a national level in Australia, successful engagement in experiences of learning involving the online environment is evaluated by looking for differences in variables such as skill development, learning engagement, teaching quality, student support and learning resources (Radloff, Coates, Taylor, James, & Krause, 2012): but are these the best variables to reveal differences in the quality of engaged learning for university students?

The research gap driving this study is to identify variables that help explain qualitative differences in the students' experience of engaged learning in blended environments. The study seeks to understand why there are relative differences in success between groups of students and how these differences are partly identified in how they collaborate with each other. To do this, we draw on methodologies from relational student learning research in the first part of the study, and in the second part, we draw on methodologies from social network analysis. We use the outcomes of both approaches to look for qualitative differences in how students collaborate. We also consider the findings in a broader context of what variables may be worth systematically investigating if we are to better understand the role of the online environment in the university student experience.

1.1. *Previous research and the view of learning adopted in this study*

There are a number of areas of research which provide the background to the design of this study: Student Approaches to Learning (SAL), Social Network Analysis (SNA) and university student experiences of blended learning.

1.1.1. *Student approaches to learning research*

A relational perspective into university student learning, sometimes referred to as Student Approaches to Learning (SAL) research (Pintrich, 2004), provides evidence that qualitative differences in students' approaches to learning are closely related to differences in aspects such as perceptions of their learning environment, their departmental context, their conceptions of learning and the quality of their learning outcomes (e.g., Biggs, Kember, & Leung, 2001; Prosser & Trigwell, 1999; Ramsden, 2003). A large number of studies have identified variations of deep and surface approaches to learning and have confirmed the associations between approaches and learning outcomes in a wide variety of disciplines (e.g., Crawford, Gordon, Nicholas, & Prosser, 1994, 1998; Chan, 2014; Hay, 2007; Lindblom-Ylänne & Lonka, 1999; Lizzio, Wilson, & Simons, 2002; Trigwell, Ashwin, & Millan, 2013; Trigwell, Ellis, & Han, 2012). Student approaches to, and perception of, learning investigated in these studies are not a personal trait of that student as they may vary from course to course for each student (Entwistle, 2003; Prosser & Trigwell, 1999). Rather they are constituted in relation to the students' understanding of the learning outcomes of a course. Studies have shown that students who perceive that teaching to be of high quality, who understand the goals of the course clearly, who report cohesive conceptions of learning, also tend to approach learning more deeply and achieve more highly on academic outcome measures. In contrast, students who perceive that their workload in learning is too high, that the means of assessment is not appropriate and report fragmented conceptions of learning, tend to report surface approaches to learning and achieve relatively poorer academic outcomes (e.g., Crawford, Gordon, Nicholas, & Prosser, 1998; Lizzio et al., 2002; Wilson & Fowler, 2005). In experiences of blended learning, there are only a few studies which have found evidence that the ways students approach learning technologies may vary qualitatively: some adopt approaches to technologies and use them to broaden and deepen their understanding of subject matter they study, while others adopt a surface approach to technologies and try to restrict their use of technologies to tasks such as downloading files and collecting information (Ellis & Bliuc, 2015).

While studies such as these are very helpful in revealing how and why students approach their learning, the methodologies used do not provide any measures of the strength or relative success of collaborations amongst different groups. If we tilt the methodological lens we use to investigate student learning towards measures of collaboration, a useful area of research is SNA.

1.1.2. *Social network research into student learning*

Social network researchers have developed techniques to investigate patterns of social interactions and networks amongst students (Baldwin, Bedell, & Johnson, 1997; Gašević, Zouaq, & Jenzen, 2013). This approach draws on ideas from graph theory and uses a set of techniques to identify roles of individuals within a group and the social ties of individuals (Wasserman & Faust, 1994). SNA techniques have been increasingly applied to educational research to enable educational researchers to model, visualise, and analyse the nature and pattern of social relationships in educational settings. In this study we draw on SNA techniques to complement and extend an investigation into qualitative variation in the first year engineering student experience of learning. We use these analyses to explore qualitatively different collaborations amongst groups of students and how we might use this knowledge to improve university student learning.

The use of SNA is relatively new as a systematic approach to investigating the field of university student learning. A recent review (Biancani & McFarland, 2013), identified more than a hundred studies into education issues which used SNA. However, the majority of studies focused on topics other than student learning such as the publication productivity associations among highly ranked higher education institutions (e.g., Sheilds, 2016), social network connections of teaching discussions among faculty members (e.g., Quardokus & Henderson, 2015). SNA has been used to investigate students' friendship and learning relations (e.g., Brewe, Kramer, & Sawtelle, 2012; Rienties, Héliot, & Jindal-Snape, 2013), online learning behaviors (e.g., Rodriguez-Hidalgo, Zhu, Questier, & Alfonso, 2015), and the influence of students' network relations to their academic performance (e.g., Tomás-Miquel Expósito-Langa, & Nicolau-Julia, 2015).

Within the studies into student experience, *some* have focused on collaboration-type issues. A number of studies have argued of the benefits of peer interaction for knowledge construction (Aviv, Erlich, Ravid, & Geva, 2003; Daniel, McCalla, & Schwier, 2008; Heo, Lim, & Kim, 2010; Zhang & Zhang, 2010). Another group has focused on how the size of the social ties and the nature of the ties are important in predicting students' achievement and their engagement (Smith & Peterson, 2007; Tomás-Miquel et al., 2015).

1.1.3. University student experiences of blended learning

Prior research into university student experiences of blended learning provide some useful indications of associations amongst aspects of the experience. Studies have shown that including blended learning activities in the student experience can help to reduce student attrition, and are positively related to examination performance (López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011). Some studies argue that the designs such as in-class problem solving combined with online preparation through video assignments increase attendance and satisfaction (Stockwell, Stockwell, Cennamo, & Jiang, 2015), while other studies focus on how blended learning can enable knowledge construction and problem solving abilities (Bridges, Green, Botelho, & Tsang, 2015).

The benefits of blended learning activities for collaborative learning are captured in a number of studies. Some studies suggest that the mere inclusion of blended learning activities will improve the engagement of students (Owston, York, & Murtha, 2013) and foster positive attitudes towards collaboration and satisfaction (So & Brush, 2008), while others argue that engagement and satisfaction is related to issues such as the students' ability to control technology (Holley & Oliver, 2010). Some focus on the affordances of digital technologies, describing how the opportunities provided by interactive digital technologies for students to learn collaboratively (Gan, Menkhoff, & Smith, 2015), and how writing in wikis can promote collaboration (Wang, 2015). Few studies provide evidence for qualitative differences in how groups of students collaborate within the same class. This is one of the questions considered in this study.

In this study, the students' learning activities required them to research and investigate the core concepts of electrical circuit analysis, both online and in class through their collaborations. For this reason, the research design emphasises the inquiry-based nature of their experience as it involved significant investigative work (Aditomo, Goodyear, Bliuc, & Ellis, 2013). In setting up the study, we adopt a relational perspective on the students' experience and use the analytical techniques from both SAL and SNA studies to investigate if differences in how students approach inquiry, use the online learning technologies, collaborate and perceive the blended learning environment are related to significantly different levels of academic achievement.

2. Method

2.1. Participants and the learning context

The participants were 220 first year undergraduate engineering students enrolled in a course – Fundamentals of Electrical and Electronic Engineering – in a Faculty of Engineering at a large metropolitan Australian university. The course is a core component in a degree in electrical engineering. The main objective of the course was to familiarize students with the basic concepts of fundamental electrical circuit analysis, including topics such as circuit variables, circuit elements, simple resistive circuits and techniques for circuit analysis.

The course is a twelve-week semester-long offering, designed with a significant face-to-face component and online component. The face-to-face component was structured as a two-hour lecture, a two-hour tutorial, and a three-hour laboratory each week. The students met as one cohort for the lectures, in groups of thirty for the laboratory work and in groups of twenty for the tutorials. The online component of the course required the students to interact before and after class through an online discussion tool on the key ideas of the course, to engage with compulsory and supplementary readings in preparation for class, to research core concepts of electrical circuit design and to review the weekly lecture notes and video-recordings on key topics. The online component also provided essential information for completing assignments, such as the assessment instructions and rubrics as well as all examination information. A student wiki was used for students to raise and answer questions informally, particularly for those issues which they came across in their online research which they thought would be useful to discuss for their own clarification, or would help others in the class to be made aware of.

To engage successfully in the course, the learning activities required students to collaborate with their peers both in class when building circuits and on-line when researching and discussing the key ideas about the lectures and laboratories. The activities and resources were designed and provided so that students were able to choose how and when they collaborated in class and online.

2.2. Data sources and instruments

After receiving ethics approval from the University committee, students were voluntarily recruited and their anonymity assured. Students were invited to answer the three closed-ended questionnaires about their experience of learning through inquiry and using online learning technologies, and their perceptions of the blended learning environment of the course. They were also asked to nominate if they collaborated with fellow students, in pairs, triads or in groups of larger than three and to enable access to their marks for the course.

The questionnaires were administered towards the end of the semester so that students could reflect on the learning processes of the whole experience. Collecting data at the end of the semester also guaranteed that students had ample time to get to know their classmates and to build up a social network of collaborative learning for the course. Nine students who either did not consent to give their course marks or did not complete the course were excluded from the dataset, providing a population sample of 211 participants, representing approximately 70% of the cohort.

The students completed three closed-ended questionnaires about learning through inquiry and online learning technologies and the learning environment, and two open-ended questions about the configurations of collaboration in the course.

The first stage of analysis involved analysing student response to two questionnaires and a subscale: the 'Student Approaches to Inquiry' questionnaire, the 'Student Approaches to Online Learning Technologies' questionnaire and 'the Integrated Learning Environment' subscale. The design of the approach questionnaires was informed by previous studies into relational student learning in style and how the items were structured (e.g., Biggs et al., 2001; Tait, Entwistle, & McCune, 1998). The meaning of the approach subscales, example items and alphas are provided below:

The *Deep approach to inquiry* subscale (5 items; $\alpha = 0.67$) assesses approaches that are proactive, reflective, and involve the creation of revealing questions to promote thinking. An example item is "I often take the initiative when pursuing a line of questioning in research."

The *Surface approach to inquiry* subscale (6 items; $\alpha = 0.72$) assesses approaches to inquiry that are formulaic, automatic and conducted with little reflection. An example item is 'I do not spend much time thinking about key questions when I am researching something'.

The *Deep approach to online learning technologies* subscale (6 items; $\alpha = 0.78$) assesses approaches to technologies that use them to promote understanding by fleshing out the key ideas of the course, looking at the ideas in new ways, and how those ideas relate to real-world experiences. An example item is: "I try to use the online learning technologies in this course to achieve a more complete understanding of key concepts".

The *Surface approach to online learning technologies* subscale (4 items; $\alpha = 0.71$) assesses approaches that underutilise the technologies in learning. Approaches measured by this subscale tend to ignore the potential of the technologies to promote understanding and rather aim to reduce workload and effort in the course and use them in similar mechanistic ways. An example item is "I restrict my use of online learning technologies in this course to do as little as possible".

The *Integrated Learning Environment* subscale was developed and trialled in a number of pilot studies. The ideas for the item design came from interviews with university students across a number of disciplines and years of study (Ellis & Goodyear, 2010) and similar approaches to subscale design in related research (Ramsden, 2003). In this study, the subscale loaded significantly with 5 items in the correlation, factor and cluster analyses ($\alpha = 0.78$). The subscale assesses the students' perception of the coherence of their experience of engaging in learning tasks across class and online contexts. The items are shown in Table 1 with the key differences in the items emphasised by italics.

The second stage of investigation involved Social Network Analysis (SNA) techniques. To collect data for the SNA analyses, open-ended questions were used.

1. *In this engineering course learning activities, with whom did you collaborate;*
   a) *The most frequently* ______________________
   b) *The second most frequently* ______________________
   c) *The third most frequently* ______________________
2. *When you collaborated, did you prefer to work mainly face-to-face, mainly on-line, or both?*

When the answers provided by question 1 are fed into the SNA software, Gephi, the analysis reveals the pairs, triads and larger group connections formed by the students. For example, if students A, B and C nominate each other, then this is a triad.

Table 1
Perceptions of Integrated Learning Environment subscale.

Scales	Item description
Perceptions of integrated learning environment ($\alpha = 0.78$)	1. The *online activities* in this course help with the work we do in class. 2. I found that *engaging in activities in class and online* in this course helped my understanding. 3. The online activities help me to *understand the lectures* in my course. 4. *I see the relationship* between the classes in my course and the online activities. 5. *The ideas online* in this course related to the ideas in class.

If only two nominate each other, it is a pair. If two nominate each other and a fourth and fifth person, then the network and group structure becomes structurally more complex. Question 2 allowed us to understand student preferences of learning face-to-face or online or a mixture of both. The purpose of question 2 was to identify the students' overall preference for collaboration, as opposed to understanding how the circumstances for each collaboration might require face-to-face, online or both. Future studies may benefit from looking at how each collaborative relationship between group members relates to the mode of interaction.

To relate the students' experience of learning to their academic performance, the students' final mark for the course was used. This was made up of five elements: laboratory exercises involving building circuits (15%), marks for lecture conceptual review (5%), marks for the weekly homework which included their investigative research work online (15%), marks of the progress exams (5%), and marks of the final exam (60%). The conceptual review task, the weekly homework task, and the progress exams, were all required to be completed online using the University learning management systems (Blackboard.com for resources, Echo360.com for lecture review, Piazza.com for online discussions) outside of class. For calculation of the aggregated score, we first converted the marks of each component to its corresponding ranges of scores multiplied by the percentage it accounted for in 100, we then obtained the mean (*M*) of the five components. The range of the total mark was from 17.49 to 98.65, with a *M* of 65.56 and a standard deviation (*SD*) of 15.77. This means that the students' academic achievement is wide spread. To facilitate interpretation, the total mark was transformed into a Z-score with a *M* of 0 and a *SD* of 1.

The main high level research questions guiding the study are:

> To what extent, and what are the reasons for, qualitatively different experiences of collaborative learning in blended environments? What are the implications of this for education leaders and teachers?
>
> The main research question can be broken down into:

a) What are the elements of relatively more and less successful experiences of learning?
b) What patterns of collaboration contribute to relatively more and less successful experiences of learning?
c) What are the implications for teaching and design of the blended university courses?

2.3. Data analysis

Data analysis was in two stages. The first stage involved the SAL methodologies including correlation and factor analyses at the level of variables, and a cluster analysis to look for groups of students in the population sample with qualitatively different experiences of learning (Ellis & Goodyear, 2010; Prosser & Trigwell, 1999). Drawing on the results of the first stage, the second stage drew on SNA methodologies which investigated measures at the level of learning networks and at the level of clusters to better understand qualitatively different configurations of collaborations. Together, the outcomes of the analyses were designed to provide some evidence and reasons behind why some students were more successful than others in their approaches to learning and how they collaborated.

In the first stage of the analysis, we investigated the validity and reliability of the subscales using exploratory factor analysis at the level of the items, and then calculated Cronbach alphas. The alphas fell within an acceptable range compared to similar studies ($0.67 < \alpha < 0.78$) (Ellis & Goodyear, 2010; Prosser & Trigwell, 1999). To investigate the associations amongst the subscales, we calculated Pearson correlation co-efficients to identify significant pairwise associations, and then conducted a factor analysis to look for associations amongst groups of variables. The use of both correlation and factor analysis helps to confirm the strength of associations amongst variables and why some experiences of learning seem to be more successful than others. To identify if there were sub-groups within the population sample which reported qualitatively difference experiences, we then conducted a cluster analysis. On the basis of cluster membership, ANOVA were performed to see whether students in the clusters reported significant differences from each other in their approaches to learning, perceptions of the learning environment and academic achievement variables.

In the second stage of the analysis, we drew on techniques from SNA. In this analysis we aimed to investigate patterns of how the students collaborated in their engineering course. To calculate measures that showed students preferred configuration of collaboration, and whether they preferred to collaborate mainly face-to-face, online, or both, we drew on their cluster membership from the stage 1 and conducted a visual and component analysis using Gephi. Gephi is an open source software package for SNA and visualisation (Bastian, Heymann, & Jacomy, 2009). We used Gephi to carry out component analysis at the level of the whole learning network and each of the sub-networks; the understanding network, the reproducing network and the intergroup network. The outcomes are described in Table 5. To understand the different configurations of collaboration amongst the sub-groups identified in the population sample, we calculated the number of students in each network (nodes), the number of collaborations in each network (edges), the average collaboration per student (degree centrality), how intensely they collaborated (network density), how discernible the collaborative groups were in the networks (network modularity), and the tendency of the groups to be closely knitted collaborators (clustering co-efficient). To investigate whether the distribution of collaboration patterns across the cluster membership identified in the first stage of the analysis was significant, we conducted a *z*-test.

3. Results

The results are presented to correspond with the two stages of analysis: the correlation, factor and cluster analyses from SAL literature, and the SNA from the SNA literature.

3.1. Stage 1: results of the SAL analyses

3.1.1. Correlation analysis

Tables 2–4 summarise outcomes of the correlation, factor and cluster analyses looking for qualitative differences in the student experience of learning. The effect sizes are judged in terms of Cohen's (1992) criteria in which 0.1 is a small correlation, 0.3 is medium and 0.5 is large. Table 2 presents the Pearson correlation co-efficients.

In Table 2, the deep approaches to inquiry scale has a medium positive correlation with the deep approaches to online learning technologies scale ($r = 0.34$, $p < 0.01$) and a large positive correlation with the perceptions of integrated learning environment scale ($r = 0.45$, $p < 0.01$). The surface approaches to inquiry scale has a medium negative correlation with the surface approaches to online learning technologies scale ($r = 0.42$, $p < 0.01$). The deep approaches to online learning technologies scale has a small negative association with the surface approaches to online learning technologies scale ($r = -0.18$, $p < 0.01$), a large positive correlation with the perceptions of integrated learning environment subscale ($r = 0.52$, $p < 0.01$), and a small positive correlation with the total mark variable ($r = 0.18$, $p < 0.01$). The surface approaches to online learning technologies scale has a small negative correlation with the perceptions of integrated learning environment scale ($r = -0.22$, $p < 0.01$), and the perceptions of integrated learning environment subscale has a small positive correlation with the total mark variable ($r = 0.18$, $p < 0.01$). All other associations in Table 2, while not significant, were related in similarly consistent ways with the significant associations reported here.

3.1.2. Factor analysis

A principal component factor analysis was conducted to look for associations amongst the variables of the students' learning experience in blended learning. The purpose of the analysis was to see if the associations were consistent with the correlation analysis and to point the direction towards qualitatively different groupings of the variables that may appear when we looked for sub-groups of students within the population sample that reported similar experiences. The analysis produced a two-factor solution and the results are displayed in Table 3.

Table 3 shows that Factor 1 has substantial positive loadings on three scales of students' learning experience: the deep approaches to inquiry (0.70), the deep approaches to online learning technologies (0.85), and the perceptions of integrated learning environment (0.85). It also has moderate positive loadings on students' total marks (0.32). Factor 2 has large positive loadings on the surface approaches to inquiry (0.86) and the surface approaches to online learning technologies (0.80). The Eigen-value of Factor 1 was 1.99 and accounted for 33.16% of total variance, and the Eigen value of Factor 2 was 1.40 and explained 23.33% of variance.

3.1.3. Cluster analysis

To identify subgroups if there were any subgroups in the population sample who reported similar experiences of learning, a hierarchical cluster analysis using Ward's method was conducted (Seifert, 1995). Based on the increasing value of the squared Euclidean distance between clusters, a two-cluster solution was produced. A series of ANOVA were then performed to examine whether there were significant differences of the mean scale scores and academic achievement scores between the two clusters of students. In order to facilitate interpretation, the scale *M* scores and the achievement scores were converted to *z*-scores, and the results of ANOVA and the effect size are displayed in Table 4.

Table 4 presents statistically significant differences between two clusters of students in the population sample: the deep approaches to inquiry [$F\,(1, 209) = 46.59$, $p < 0.01$, $\eta^2 = 0.18$], the surface approaches to inquiry [$F\,(1, 209) = 6.71$, $p < 0.05$, $\eta^2 = 0.03$], the deep approaches to online learning technologies [$F\,(1, 209) = 124.99$, $p < 0.01$, $\eta^2 = 0.37$], the surface

Table 2
Pairwise associations amongst variables of the student experience of blended learning.

Variables	DAI	SAI	DAOLT	SAOLT	INTER	TM
Deep approaches to inquiry (DAI)	–					
Surface approaches to inquiry (SAI)	−0.11	–				
Deep approaches to online learning technologies (DAOLT)	0.34*	−0.02	–			
Surface approaches to online learning technologies (SAOLT)	−0.13	0.42*	−0.18*	–		
Perceptions of integrated learning environment (INTER)	0.45*	−0.06	0.52*	−0.22*	–	
Course total mark (TM)	0.05	−0.06	0.18*	−0.09	0.18*	–

Note: *$p < 0.01$; n = 211.

Table 3
Principal component factor analysis of variables in the student experience of blended learning.

Variables	Rotated factor loadings	
	1	2
Approaches		
Deep approaches to inquiry (DAI)	0.70	
Surface approaches to inquiry (SAI)		0.86
Deep approaches to online learning technologies (DAOLT)	0.80	
Surface approaches to online learning technologies (SAOLT)		0.80
Perceptions		
Perceptions of integrated learning environment (INTER)	0.85	
Academic achievement		
Course total mark (TM)	0.32	

Varimax Rotation, KMO: 0.64.
Values less than 0.30 omitted, n = 211.

Table 4
Cluster analysis of the variables in the students' experience of blended learning.

Variables	Understanding cluster (N = 130) mean (*SD*)	Reproducing cluster (N = 81) mean (*SD*)	*F*	*p*	η^2
Approaches					
Deep approaches to inquiry (DAI)	0.32 (0.78)	−0.55 (1.07)	46.59	0.00	0.18
Surface approaches to inquiry (SAI)	−0.15 (1.02)	0.20 (0.84)	6.71	0.01	0.03
Deep approaches to online learning technologies (DAOLT)	0.49 (0.76)	−0.78 (0.88)	124.99	0.00	0.37
Surface approaches to online learning technologies (SAOLT)	−0.13 (1.07)	0.19 (0.85)	5.20	0.02	0.02
Perceptions					
Perceptions of integrated learning environment (INTER)	0.56 (0.63)	−0.91 (0.81)	219.29	0.00	0.51
Academic achievement					
Course total mark (TM)	0.25 (0.90)	−0.40 (1.02)	23.54	0.00	0.10

n = 211.

approaches to online learning technologies [F (1, 209) = 5.20, p < 0.05, η^2 = 0.02], the perceptions of integrated learning environment [F (1, 209) = 219.29, p < 0.01, η^2 = 0.51], as well as the academic achievement results based on their cluster membership [F (1, 209) = 22.54, p < 0.01, η^2 = 0.10].

Table 4 shows a cluster of 130 students with a medium positive score on the deep approaches to inquiry variable (0.32), a small negative score on the surface approaches to inquiry variable (−0.15), a large positive score on the deep approaches to online learning technologies variable (0.49) and perceptions of integrated learning environment (0.56), a small negative score on the surface approaches to online learning technologies variable (−0.13), and a medium positive score on the total mark for the course (0.25). This group of students reported the blended learning experience as a way of engaging deeply with the course, they perceived how the class and online environments were integrated and performed at a relatively higher level in the total mark for the course. Cluster 1 is referred to as the ‘understanding cluster’ for the ensuing analyses in stage 2.

Table 4 also shows a cluster of 81 students with a large negative score on the deep approaches to inquiry variable (−0.55), a small positive score on the surface approaches to inquiry variable (0.20), a large negative score on the deep approaches to online learning technologies variable (−0.78) and perceptions of integrated learning environment (−0.91), a small positive score on the surface approaches to online learning technologies variable (−0.19), and a large negative score on the total mark for the course (−0.40). This group of students reported a more reproducing blended learning experience in their course, not engaging deeply in their approaches, not perceiving how the class and online environments were integrated and performing at a relatively lower level as measured by the total mark for the course. Cluster 2 is referred to as the ‘reproducing cluster’ for the ensuing analyses in stage 2.

The results of the cluster analysis provided useful evidence of qualitative variation in the blended learning experience of the students at the level of groups in the population sample, captured by the high-level descriptions of ‘understanding’ and ‘reproducing’ (Prosser & Trigwell, 1999)Broadly summarising, one cluster of 130 students, the ‘understanding cluster’ reported a relatively more successful experience as measured by their approaches to inquiry and online learning technologies in the course, their positive perceptions of how the online learning environment was integrated and the relatively better level of academic achievement (0.25). In contrast, a second cluster of students, the ‘reproducing cluster’ reported a less successful blended learning experience as measured by their approaches to inquiry and online learning technologies in the course, their negative perceptions of the integration of the online learning environment and the relatively poorer level of academic achievement (−0.40). The results of the correlation, factor and cluster analyses are considered some of the major findings of this study and were drawn on in the stage 2 analysis.

3.2. Stage 2: results of the SNA

Based on the student responses to the open-ended questions about who they preferred to work with, and whether they preferred to work mostly face-to-face, online or in both modes, a student collaboration network was developed both visually and in numerical form. Fig. 1 provides a visualisation of the patterns of interaction amongst the students.

Fig. 1 visually represents all patterns of collaboration captured in the engineering course and is made up of three networks. It includes an 'understanding network' made up of students from the understanding cluster from Table 4 (Cluster 1) who collaborate together (the black nodes connected by an edge), a 'reproducing network' made up of students from the reproducing cluster in Table 4 (Cluster 2) who collaborated together (the grey nodes connected by an edge) and the intergroup network which is made up of students from both clusters who collaborated together (the black and grey nodes connected by an edge). In the following descriptions, it is helpful to distinguish between the two clusters and three networks. There are two clusters (understanding and reproducing) and three networks (understanding, reproducing and intergroup). A key difference is, for example, that the 'understanding cluster' refers to students in both the understanding and intergroup networks.

To get a sense of the collaboration patterns, a number of network measures were investigated. These are shown in Table 5.

In Table 5, measures of understanding, reproducing and intergroup collaboration networks are summarised. Columns 1 and 2 describe the network-level measures used and columns 3–6 present the calculated measures. Rows 1–2 provide some descriptors of the networks, showing number of students and number of collaborations. Rows 3–6 provide network level measures of the collaborations in the networks. The measures have been normalised produced by Gephi, consequently notable differences between the networks are significant, such as those which have been bolded.

Table 5 shows there were 105 students in the understanding network, 63 students in the reproducing network and 125 students in the intergroup network, among which 72 are from the understanding cluster and 53 are from the reproducing cluster. In terms of their choices to work in pairs, triads or in larger groups, the collaboration configurations were formed from 101 choices amongst students from the understanding cluster, 34 choices amongst students in reproducing cluster and 131

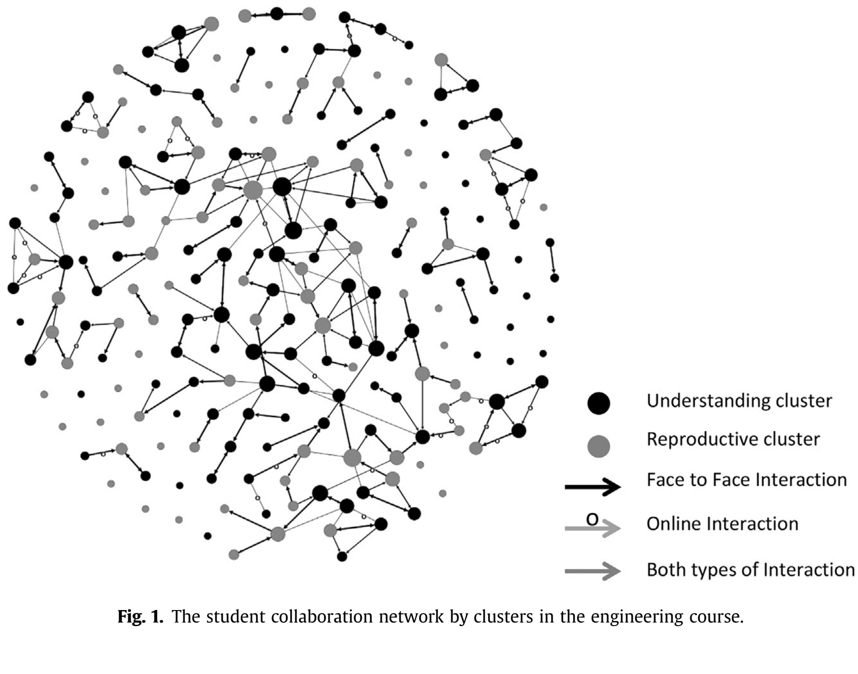

Fig. 1. The student collaboration network by clusters in the engineering course.

Table 5
Network descriptors and measures of student collaboration in the first year Engineering course.

No	Measures	Understanding network (U)	Reproducing network (R)	Intergroup network (I)	
1	No. of students (nodes)	105	63	125	72 from U 53 from R
2	No. of choices to collaborate (edges)	101	34	131	60 from R-U 71 from U-R
3	Average collaboration per student (average degree centrality)	1.39	0.825	1.68	
4	Collaboration intensity (network density)	0.013	0.013	0.014	
5	Discernibility of collaborative groups (network modularity)	0.91	0.94	0.91	
6	Tendency to form closely knitted groups (average clustering co-efficient)	0.314	0.10	–	

choices amongst students from both clusters. The directionality of choice is uninformative in the understanding and reproducing networks, since students from the same cluster make up the collaboration configurations. However the directionality in the intergroup network is of interest, with 60 students from the reproducing cluster choosing students from the understanding cluster, and 71 students from the understanding cluster choosing students from the reproducing cluster. The significance of this is explored further below.

From a learning perspective, the collaborations in the understanding network were relatively the most successful of the three networks as all students in this network performed relatively more strongly. Perhaps unsurprisingly, in comparison to the reproducing network, students in the understanding network tended to collaborate more (U = 1.39, R = 0.825) and tended to form more closely knitted groups (U = 0.314, R = 0.10). While there was a higher amount of collaboration in the intergroup network than in the other groups (I = 1.68), those collaborations do not appear to have helped the reproducing students. Some of the measures were not significantly different, such as "discernibility of collaborative groups" which measures the strength of division of the network into modules. So in this study it is not the amount of collaborations in the three networks that appears to account for the relative success, but more likely the nature of the collaborations (such as the approaches and perceptions held by the students) and how closely knitted the collaborative groupings are that contribute to qualitatively different outcomes.

Despite the learning activities requiring students to collaborate in class and online, a significant number of students worked alone. The majority of students did choose to collaborate, working in pairs, triads or larger groups. To investigate if the proportions of students collaborating in these configurations were statistically significant between the understanding and reproducing clusters, we carried out a series of two-sample *z*-tests as shown in Table 6.

Table 6 shows the frequency of the different configurations of collaboration; alone, in pairs, in triads, in groups larger than 3, with the opposite cluster. The last two columns show that the reproducing group tended to work more alone ($z = 2.6$, $p < 0.01$), tended to choose students in the understanding cluster ($z = 2.5$, $p < 0.01$) and the understanding group tended to work in larger groups than the reproducing group ($z = 3.6$, $p < 0.05$).

To investigate student preferences for collaborating face-to-face, online or both, frequencies of their choices were calculated and a series of two-sample *z*-tests were calculated. In this study, none of the frequencies were statistically significant. The frequencies are reported in Table 7.

Table 7 shows that while the number of choices differs between the two groups, the proportionalities are similar. Despite the lack of significance in this study, prior research suggests that investigating the choices made by students about how and where they collaborate will become increasingly important in the student experience, and will be worth investigating in future studies (Castle & McGuire, 2010).

4. Discussion and conclusion

The purpose of this study was to explore the student experience of blended learning in a first year university course in order to better understand why some students are more successful than others. An important goal of the study is to discover

Table 6
Comparison of distribution of collaboration patterns in understanding and reproducing clusters.

Collaboration patterns	No. of students (nodes) in the understanding cluster	Proportion	No. of students (nodes) in the reproducing cluster	Proportion	*z*-test
Alone	17	13.6%	25	27.78%	2.60**
In pairs	24	19.2%	14	15.56%	0.70
In triads	15	12%	9	10%	0.50
>3s	49	39.2%	15	16.67%	3.60**
With the other cluster	20	16%	27	30%	2.50*
Overall in each cluster	125	100%	90	100%	–

*$p < 0.05$, **$p < 0.01$.

Table 7
Student preference for mode of collaboration.

Collaboration modes	Understanding cluster collaboration choices (no. of edges)			Reproducing cluster collaboration choices (no. of edges)			*z*-test	Significant if $p < 0.05$
Network	Under-standing	Inter-group	%	Repro-ductive	Inter-group	%		
Face-to-face	79	52	76.16%	28	40	72.34%	0.70	0.49
online	12	8	11.62%	4	8	12.76%	0.30	0.70
Both face-to-face and online	10	11	12.2%	2	12	14.89%	0.60	0.54
Overall	172		100%	94		100%	–	–

evidence for teachers and education leaders to help inform decisions about teaching and course design in blended learning environments which are likely to improve the quality of student learning.

Before discussing the results in detail, it is worth noting some limitations of the study. The research site involves one university course with a population sample of 211 in undergraduate engineering. To test the robustness of the associations that revealed qualitative variation in the student experience, similar studies involving different disciplines and larger sample sizes are required to test the subject-specificity of the conclusions and overall sample size underpinning conclusions. In addition, the results are taken from a student perspective. Complementary studies adopting a teacher perspective would help to round out legitimate concerns about variables that contribute to the quality of student learning. These need to be conducted across a number of disciplines in order to account for disciplinary variation (see for example Jokinen & Mikkonen, 2013). These limitations notwithstanding, the results provide interesting and valuable implications for the design of courses and digital learning environments.

Key research questions for the study included the extent of qualitative variation in the learning experience and reasons that may explain this. The correlation and factor analyses identified significant associations amongst variables in the blended learning experience which provide some explanation of how approaches to inquiry and technologies relate to different levels of achievement. These outcomes add to the findings in previous studies by bringing to the fore the students approaches to the online learning technologies themselves. Much of the previous literature in this area does not emphasise the material aspects of the students' approaches (see for example Biggs, 2011; Entwistle et al., 2015), yet materiality in the student learning experience is an increasingly important dimension which can add to the quality of student outcomes (Fenwick, Edwards, & Sawchuk, 2015). Much more research into learning where the unit of research involves both the student and the material object used is likely to provide a fruitful course of investigation.

In this study, variation in approaches to inquiry revealed the benefit of careful reflection and analysis when formulating questions for learning and for using the technologies sensibly. Interestingly, deep approaches to inquiry were strongly related to deep approaches to online learning technologies. This may suggest that one informs the other. Similarly, surface approaches to inquiry were related to surface approaches to online learning technologies, which suggests that they also seem to inform each other. These associations offer the teacher evidence for a number of strategies to improve the student experience in blended courses in the areas of learning design (Barron & Darling-Hammond, 2008) and pedagogy (Maaβ & Artigue, 2013), which we will return to shortly.

The identification of positive and negative perceptions reported by the students also helped to identify qualitative differences. They confirm the results of some previous research (Owston et al., 2013) and extend them by looking at their associations with approaches to online learning technologies. Perceptions of an integrated environment were positively and significantly related to deep approaches and relatively better academic achievement. Likewise, perceptions of the learning environment that did not see how face-to-face and online learning were integrated were related to surface approaches and relatively poorer academic achievement. The cluster analyses gave a sense of how these associations were distributed throughout the population sample. Deep approaches, positive perceptions and relatively higher academic achievement were reported by one cluster of students ($n = 130$); and surface approaches, negative perceptions and relatively lower academic achievement were reported by a second cluster of students ($n = 81$). The identification of groups within the population sample reporting similarly different experience of learning motivated the design of the SNA methodologies.

While the SAL methodologies were useful in identifying qualitatively different blended learning experiences of the students, they are not designed to measure how or how intensely the students collaborated in their activities. The SNA drew on the SAL classification of the students from the cluster analysis in order to identify collaborative learning networks; an understanding collaboration network of students from cluster 1 ($n = 105$), a reproducing collaborative network of students from cluster 2 ($n = 63$), and an intergroup collaborative network of students from both clusters ($n = 125$).

Looking at how the collaborative networks were formed from a teaching perspective, the different patterns of collaboration reveal different outcomes. The collaborations in the understanding network were the most desirable as they are likely to have contributed to relatively better academic achievement. This may be partly due to the fact that in the understanding collaboration network, the tendency of the students to form closely knitted groups was the highest of all the networks. In this network, there was also a tendency to collaborate in larger groups and less of a tendency to work alone. In terms of the benefits for reproductive students working with understanding students, no significant measures were identified in this study. However, it may be worthwhile in future studies to design an investigation over a period of a semester or more to investigate if students in a reproductive cluster at the beginning of their enrolment improved their performance by working with students in an understanding cluster by the end of their course.

Collaborations in the other networks were not as successful and offer ideas to inform teaching strategies. It may be possible that students tended to choose partners on the basis of friendship, rather than on the basis of choosing someone who is most likely to help complete the tasks successfully (Cho, Gay, Davidson, & Ingraffea, 2007). Whether or not this was the case, students tended to work more alone in the reproducing network, tended to collaborate less and when they did collaborate, it was in groups smaller than three. The collaborations in the intergroup network also offer significant opportunity to the teacher to help the students with their learning because, although they tended to collaborate more, the perceptions and approaches held by the reproducing students in this network are likely to have held back the collaborative benefits from their efforts. These findings extend the previous research into the issues of assessing whether the groups formed in collaborations are appropriate or not (Wessner & Pfister, 2001). Assessing the understanding of approaches to inquiry and online learning technologies in blended contexts will help teachers to identify whether groups contain an appropriate mix of students and abilities.

Drawing on the results from both the SAL and SNA, the next section offers some strategies for both teachers and education leaders concerned with improving the quality of the blended learning experience and the environment in which the learning takes place.

Implications for teaching and the evaluation of blended learning.

Discerning which variables of student learning are most closely related to a quality experience of learning in a blended environment is essential if teachers are to devise evidence-based strategies for improvement. The results of this study confirm and extend previous studies (e.g., Aditomo et al., 2013; Ellis, Bliuc, & Goodyear, 2012) of the importance of recognising how impoverished approaches to inquiry and online learning technologies can impede students from fully understanding the course outcomes intended by their teacher. Clearly much more framing and scaffolding of what constitutes effective inquiry and how best to use online learning technologies would have helped the reproducing group in the population sample (Jelfs, Nathan, & Barrett, 2004). This could be achieved in future delivery of the course by designing the activities to emphasise the learning strategies most closely linked to deep approaches. It could also be achieved by identifying which students in future cohorts seem to be adopting deep approaches, and asking them to model what they do for students who are less confident.

By surveying the class early in a semester-long course, or developing some type of exercise designed to reveal student approaches to inquiry and online technologies, it would be possible to identify students who are likely to fall into an 'understanding cluster'. This information could help a teacher to more effectively manage the collaborations that students engage in, by reviewing the configurations chosen by students and intervening when the groups do not seem to include at least one student who has a relatively stronger sense of what is required when engaging in collaborations in the blended environment. By designing collaborative groups to include students with a sense of effective inquiry and how to use online learning technologies, it may also help to provide more opportunities for modelling what strategies are likely to work when they work together (Bridges et al., 2015). At the very least, the results suggest that modern pedagogies need to be more explicit about what constitutes effective learning in blended environments.

When teaching, the result of this study indicate that more time and emphasis is required in the course to help students better understand that the online environment is an essential aspect of their experience, significantly integrated in task design to help them prepare for their classwork and to reflect on it each week. Students who reported such perceptions tended to also be related to approaches which were more academically successful. For teachers, this is probably best achieved at the beginning of the course, during orientation, and then paying attention to how students are approaching the use of the online learning technologies throughout the course. The interdependency of perceptions and approaches suggests that attention given by teachers to either is likely to have a positive impact on the quality of the other (Lawless & Richardson, 2002).

When evaluating the quality of student learning in blended environments, the outcomes of this study suggest some variables which are worth paying more attention to in future studies. For example, an evaluation of the material aspects in the student experience such as online learning technologies is not just simply a matter of whether their provision is good or not, but rather how students understand their purpose for learning, how they approach their use and how they perceive their role in the learning environment in which the experience is provided. It is the differences in the quality of the approaches adopted and perceptions held by the students to aspects of their experience such as these that have helped to explain why some students are more successful than others.

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