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Multidisciplinary team working in science distance learning

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ABSTRACT

We describe findings from a study based upon a collaborative project carried out online as the end of module assessment activity of a multidisciplinary science module at the UK Open University. Our aim was to determine how well students dealt with working in a team of unfamiliar multidisciplinary scientists and to identify tools and processes that improved the team working experience. The principal source of data was in the form of reflective materials embedded in the module’s final assessment. A two-stage thematic analysis of student reflective narrative texts was performed to draw conclusions about student perceptions of the online team project. In the context of activity levels among the student teams, consistent differences in the way in which team members reflected upon their team working experience were apparent in three of the themes considered: participation, relationships and organisation. We provide a core checklist of actions that can be taken, by students and tutors, to enhance and improve the online collaborative experience.

KEYWORDS

Online team work; collaboration; project; multidisciplinary science

Introduction

Collaborative learning within online teams provides opportunities for active learning, from which new knowledge and insights arise from interactions within the team (Huang, 2002; Laal & Laal, 2012). It also provides opportunities to develop skillsets closely fitted to many modern working practices suitable for work in the global economy (Ubell, 2010; Zamecnik et al., 2021). Creating collaborative learning spaces within the context of distance learning, while seemingly suitable for developing these latter skills, presents additional challenges due to the asynchronous nature of student interactions and the lack of social and emotional cues present in face-to-face learning activities (Kauppi et al., 2020). Nevertheless, in a distance learning context, collaborative learning has been demonstrated to produce significantly better educational outcomes (Sambell et al., 2013) than independent learning (Haresnape, 2015; Means et al., 2010). In the specific context of science education, collaborative learning in groups can also replicate some of the conditions and challenges associated with working in the multidisciplinary teams that populate many laboratory facilities to which students ordinarily lack access (Stenson & Schaefer, 2021).
Collaborative learning activities are often characterised by student resentment of perceived and actual inequalities of contribution to the team work, variable degrees of engagement (both level and temporal) and dissatisfaction – disgruntlement even – with module credit associated with the activity. In their study of online collaborative learning in the context of a group project, Donelan and Kear (2018) (whose thematic analysis approach we have adapted) drew attention to some earlier work which identified perceptions of unfairness arising from dependency on the contributions of other students (Payne et al., 2006; Roberts & McInnerney, 2007; Webb, 1995). While Donelan and Kear’s data was based mainly on focus groups from student volunteers (and discussion forums with tutors), our source of data came from written student accounts forming part of their final assessment at the end of the module. The qualitative nature of this data indicates thematic analysis both as a viable approach (Bryman, 2015; Terry et al., 2017) and as a way of building on, and comparing with the Donelan and Kear study.

Our study relates to UK Open University students, who come from a wide variety of backgrounds, benefiting from the university’s ethos of open access, exemplified by an absence of any requirement for prior formal academic qualifications. The UK Open University comprises a diverse student body, many being part-time learners using a range of web-based and specialised conferencing software accessed via a variety of devices from smartphones to desktop computers. Developments in the software, particularly tools for synchronous online collaboration, and findings from an earlier study on team working activity in an online science module prompted the present work (Nicholas, 2015).

While there exists a substantial body of work pertaining to online team work (the focus of this paper), the scope of this has often been constrained in terms of both the sampling of students and nature of the disciplines involved (Cherney et al., 2018). Following Bennett (1994), we use the term ‘team’ to mean a special type of group which ‘unites the members towards mutually-held objectives.’ Many studies have focused on either graduate students or undergraduates in instructional design or education courses, and the use of such cohorts may limit the generalisability of results obtained to the wider student population. Cherney et al. (2018) highlight a relative lack of multiple disciplinary perspectives in small group research in online courses and suggest that much of the work that exists is written by, and for, education scholars. In the present work, we describe findings from a study based upon a collaborative activity carried out as the end of module assessment activity of a multidisciplinary natural science module with five discipline strands (Chemistry, Environment, Health and Life, Geology and Physics). Within each strand, students are expected to study for eight hours a week for an academic year, earning a quarter of an academic year’s credit at a level typical of the second undergraduate year of a UK university. Students from these individual strands were brought together for the final two months of the module to work on a project in multidisciplinary teams. Team communications were through online forums and online tutorial rooms. The team project was designed to replicate a multidisciplinary science team coming together to explore a particular scenario, propose and discuss investigations from their own discipline and work together to develop an agreed set of team proposals. Teams produced a report which was submitted by each member of the team as part of their final assessment, alongside reflections in which students reported their personal
experiences of the team project and the way in which their team functioned. This paper uses these reflective student responses to investigate and draw conclusions about student perceptions of the online team project.

Our aims were to understand the student perception of online group work in a multidisciplinary team focussing on investigative approaches in science, specifically to determine how well students dealt with working in a team of multidisciplinary scientists whom they did not know. Specific research questions were: (i) whether students saw the benefits of multidisciplinary team working, (ii) what students report as helping them work collaboratively and, (iii) the obstacles reported by students to multidisciplinary team working. A further aim was to understand the effectiveness of the various resources and tools provided by the module team to promote team working activity with the desire to improve team working projects in other modules in the future.

2. Methods
2.1 Module and activity details
Before the collaborative team work, the entire student cohort had spent 24 weeks studying, at 0.25 full-time-equivalent, discipline-specific topics focused on practical and investigational science that provided opportunities to develop some collaborative skills and familiarity with the online tools. At the beginning of the module, each student was assigned to a tutor group, overseen by an associate lecturer who is a specialist in the relevant discipline strand. The team work our study focuses on took part over the final 8 weeks of the module, with students being assigned to multidisciplinary teams to work on a team project.

Students were, initially, randomly allocated to teams, the only criteria being that teams were formed from roughly equal numbers from each discipline strand and all students had previously been in separate tutor groups, so had not interacted with each other on the module before. Limited adjustments were made to team memberships, to compensate for non-engagement with the module by some students, and final active team sizes ranged from 5 to 20 members. Team size, while having a mode of nine students, did include some larger teams.

Team working aids provided included guidance on team roles and prompts to help frame team activities. Online tools consisted of a forum for asynchronous communication and an online room with voice capability for synchronous meetings.

During the team project, team members were provided with a series of tasks in order to help structure their work. They received prompts via their team forum from a tutor. These prompts were targeted towards completion of particular tasks, such as assigning a team name, determining team roles, report drafting, etc. The objective of each team was to produce a series of investigative proposals for a specific scenario framed to engage all discipline strands and to encourage interdisciplinary investigations, such as a manned expedition to Mars.

In the academic year that was studied (commencing February 2013), students were part of a multidisciplinary team charged with preparing innovative proposals for practical investigations that might be carried out in support of an advanced scientific mission to recolonise a hypothetical island that had been left uninhabited for several years. Teams
were expected only to plan practical investigations – not to carry them out – though they could make some preliminary analysis of existing data. At the end of the project, teams had to produce a report outlining proposals for their investigations ready for competitive consideration. Each of the proposed investigations was to include the following:

- Investigation title (up to 10 words);
- Goal and hypothesis to be tested (30–50 words);
- Main methods or techniques to be employed (100–200 words);
- Time scale and draft schedule (50–100 words);
- Context and evidence in support of the case for selecting this investigation (250-300 words);
- Up to 3 images/diagrams, each with a concise caption.

Completion of this collaborative work by students engaged a variety of skills, notably the following:

- Communication skills, such as conveying their single-discipline specialist knowledge to non-specialists studying other subjects;
- Literacy skills (report writing);
- Critical thinking;
- Problem solving;
- Creativity, such as the exercise of core scientific skills in experimental design;
- Time management, such as meeting deadlines;
- Digital skills, notably the use of asynchronous forums and synchronous online rooms;
- Collaborative skills, such as listening to their fellow students and summarising their discussions.

As detailed below, a team’s end of project report formed part of the final assessment of individual students within that team. This assessment also included two items of reflective text written by students individually, which formed the basis of our thematic analysis. A fourth component of the final assessment comprised a critique of a different team report (from an earlier presentation) which students completed individually.

After initial team meetings, smaller discipline-specific sub-teams worked up outlines of investigations that were then discussed by the entire team, ranked into a priority list and drawn together after discussion into the joint team report, according to the structure detailed in the preceding paragraphs. The teams were guided by a project tutor who provided continuing prompts. Each annual presentation of the module had a different project and students were provided with an example of a team report from a previous module presentation to help guide their own work. As indicated above, students were also asked to critique this earlier project report as one of the tasks in their End of Module Assessment (EMA).

### 2.2 Student profile

Students studying the module were part-time distance learners on different programmes at the UK Open University; these included 47% Natural Sciences, 17% Open degree and 14% diploma/certificate. (The Open degree programme is particularly flexible, allowing
students to choose the widest possible combination of subjects consistent with degree-level rigour). The module to which our research relates was studied online, for an academic year, although some pathways included modules with residential field or laboratory work. For this study, the module presentation had an entire cohort of 604 students who were active in 68 teams. The presentation had a 25% withdrawal rate. Unless stated otherwise, our commentary and data refer to this single cohort of students following the module presentation, which commenced in February 2013.

Assessment of the multidisciplinary team project consisted of a critical review of a previous team report on an unrelated topic (to familiarise students with their own task), their team project report and two reflective pieces of work: a reflection of the team-working process, and their personal reflection on their team-working experience. Such reflections included perceptions of the benefits and drawbacks of the team working as well as what advice would be offered to others carrying out the same task.

The text of these two reflective responses, representing 55% of the total marks for the final assessment, was examined in this study to investigate students’ communication patterns, what obstacles to team work arose, what helped their team work and to determine whether students saw the benefit of team working. Reflection was elicited specifically on their perception of how their team worked (effectiveness of their team, the benefits and drawbacks of working on the project as a team) and on their personal interactions within the team which had to be supported by verifiable evidence from university-provided online communication platforms including team discussion forums, wikis and online rooms. Students were familiar with all forms of online interactive tools from their earlier activities in the module. Evidence was requested against specific prompts that provided a structure for the team project, covering introductions and familiarisation with team members, choosing a team name, assignment of team roles, availability, report writing and editing, etc. Analysis was performed on reports from students who had submitted their final reports, irrespective of their module outcome.

### 2.3 Thematic analysis of student reflective narrative texts

To identify common themes in student reflections, two approaches were taken. In the first approach, a review of a random selection of reflective accounts from 37 of the 604 students was conducted independently by two experienced tutors from the module. Emergent themes from this analysis were then independently assessed to draw up a list of core themes.

To assess students’ perceptions of team working, responses were assessed against nine themes adapted from the study of Donelan and Kear (2018) to suit the specific team project. These themes were Participation, Fairness, Feelings, Skills & Abilities, Relationships, Timings, Tools, Organisation and Task. Each theme had a series of sub-themes, for example, the participation theme had sub-themes reflecting positive aspects (active core) and more negative aspects (absences, peripheral members and late and non-starters). Sub-themes were tailored from those used by Donelan and Kear to encompass specific aspects of the team project, particularly around the tools available for collaboration (synchronous and asynchronous tools ranging from live chat to emails, wikis and forums) and the project task and support elements provided. Tutor intervention and
support was standardised across all student teams. Indeed, the only theme we did not use from the original study of Donelan and Kear was that of ‘Tutors’ as our team project did not significantly embed tutors in the teaching. Furthermore, the scope of Donelan and Kear’s study included tutors’ opinions on online group projects.

One of the original experienced tutors from the first study carried out a second phase of thematic analysis on final assessment reflective narratives from students identified as being in high and low forum-traffic teams (see, section 2.4; the actual content of forum contributions was not assessed, either in the final assessment or as part of our thematic analysis). In this case we used themes known to be important for assessed online collaborative work, informed by our initial study and by additional categories of themes identified in Donelan and Kear’s (2018) separate study of collaborative working in the UK Open University. Student reflections were scored for the presence of statements indicative of sub-themes within each of these themes. Sub-themes were classified as negative or positive in terms of their impact upon the collaborative activity. Statements were subsequently assigned a numerical score: absence = 0, single statement = 1 and strong or repeated statement = 2 to aid graphical presentation and analysis.

2.4 Analysis of team communication routes and frequency of communication

Online room session frequency and forum traffic data were analysed to determine the use of, respectively, synchronous and asynchronous communication routes by all 68 teams over the course of the team project (8 weeks). The number of new discussions and number of replies made by each student to their team forum was obtained as was the number of online room sessions per team. The student teams were categorised into low (fewer than 200 posts), medium (200–600 posts) and high (greater than 600 posts) traffic categories. Our analysis (including the thematic analysis of end-of-module reflective texts) has focused on students from low and high traffic teams.

We took two tutors who each had one low- and high-traffic team with similar numbers of active participants. These four teams were selected for a thematic analysis to explore any association with this major route of team communication. Teams selected were chosen to ensure representation of low forum activity (L-teams) (two teams: 7 members/160 posts and 9 members/182 posts) and high forum activity (H-teams) (6 members/640 posts and 9 members/766 posts). In all cases, the number of tutor discussion initiation posts was similar (5 or 6 for the low activity teams and 4 or 5 for the high activity teams), although the number of replies was higher on H-team forums (12 from each of the low activity teams; 28 and 29 from the two high activity teams). All teams met in their online rooms throughout the team-working project, and online room usage did not differ significantly between teams. The two low forum traffic teams held 6 and 3 recorded meetings in their online rooms; analogous figures for the two high forum traffic teams were 4 and 7.

2.5 Student performance in assessment

The marks attained in the four separate questions of the end of module assessment (EMA) were analysed in both low and high traffic teams. The nature of the four questions in the end of module assessment is summarised in Table 1 below:
Table 1. Summary of the content of the four questions in the end of module assessment.

<table>
<thead>
<tr>
<th>Question number</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A critical review of a previous project.</td>
</tr>
<tr>
<td>2</td>
<td>Reflection on the team, commenting on the organisation of the team and stating benefits and drawbacks of working as a team.</td>
</tr>
<tr>
<td>3</td>
<td>Team project report, all students in one team submit the same report for this question.</td>
</tr>
<tr>
<td>4</td>
<td>Personal reflection, commenting on levels of engagement, providing examples of where students acted as efficient team members.</td>
</tr>
</tbody>
</table>

3. Results

3.1 Initial thematic analysis

3.1.1 Benefits of collaborative working in multidisciplinary teams

Our initial examination of reflective accounts chosen randomly from 37 students showed that most reported benefits associated with their team project. Most noticeable was the recognition (37/37 scripts) that individual team members brought different strengths to the team project, in particular subject knowledge, writing and IT skills. One student commented:

‘The team members brought an array of different skills, ideas, suggestions and knowledge which all lended itself to the report and the team.’ Comments such as this lend support to work that shows that collaboration can be particularly beneficial to weaker students (Haresnape, 2015).

A majority (20/37) recognised that a division of labour or shared workload, and the ability to cover absences were benefits. Another student:

‘Division of roles and workload, enabling each team member to concentrate on their role, and the investigation idea they had to write up, instead of having to attempt the entire project themselves.’

A small number (5/37) commented that team working was good for motivation and found that it allowed them to play to their own strengths. There were fewer comments regarding interdisciplinarity, with some students noting the benefits of learning about other subjects and approaches to science. The following comments from two students illustrate this:

‘The scientific background of the team members was very different which allowed support and good discussion about the proposals (e.g. feasibility) from different perspectives.’

‘Looking at the problem as a team meant that there were many good ideas coming from different disciplinary backgrounds.’

3.1.2 What helped their collaborative working

Students reported that starting their team work promptly, following the prompts provided to structure the project, regular participation of team members and highlighting their availability over the project study period all helped their team work. A typical statement among student reflections relating to the benefits of starting team work promptly included the following:
‘... advice I would offer to anyone undertaking a team project is to get off to a good start. At the beginning of the team project everyone is waiting around looking for someone to make a start and guide them. The sooner you get started on the project the more time you will have at the end to make changes and maximise the quality of your report.’

On the subject of forum postings, students commonly mentioned that the use of short messages with clear subject headings and the posting of regular summaries of meetings and progress were both helpful. They reported that forum posts were useful for prompting other team members, whereas the synchronous online rooms proved most useful for ‘brainstorming’ sessions. Typical quotes were:

‘I thought it would be more beneficial to write short sentences and post them rather than one long-winded forum post that from experience can easily cause important points to be missed.’

‘I ensured all of our team contributions were summarised concisely and presented to the team or entered onto the wiki according to the schedules set, contributing to the overall efficiency of the team.’

3.1.3 Obstacles and difficulties

In common with previously published studies, most students experienced problems or difficulties in working in their teams. For example, 35 of the 37 scripts initially examined used words such as problematic, constraining, inhibiting, challenging, difficult, trying, frustrating, obstacles and concerns in the context of describing their team working experiences. These related to the constraints of communication online, having limited knowledge of other team members, time management, inequities in shared workload and the personalities of other team members.

With regard to communicating online, one example of a typical comment was:

‘I think this was one of those instances where the difficulty in communicating became apparent; it’s a lot more difficult trying to figure things out and communicate online than when working in a group who are all in the same room.’

Forum postings were noted as being problematic due to them being asynchronous, becoming unmanageable (too many threads) and allowing misunderstandings to develop. Some students reported difficulties arising from the specific roles taken by other team members and in the way in which their teams were set up and run.

3.2 Communication routes used by teams

Students were provided with online tools to facilitate collaboration. One tool was an asynchronous forum where students could post and respond to discussions by fellow team members. Students also had access to synchronous online conferencing software (an ‘online room’) with a shared whiteboard, text chat and live audio. The role of each of these communications media, in the context of the team project, is discussed below.

3.2.1 Forums

The main route for asynchronous communication between team members was through an online team forum. Across the 68 teams, 2,476 discrete forum discussions were initiated by students, prompting 26,814 replies; a total of 29,290 posts. Team forums
Figure 1. Daily total posts (students and tutors) to team project forums across all 68 teams shown for the pre-project period and Days 1–34 of the scheduled team project. Note that this is the only figure that includes contributions from tutors. Across the bottom of the figure are indicated the key stages of the project: 1 = Days 1–4 Team organisation (name, roles, familiarisation); 2 = Days 5–8 Development of initial proposals; 3 = Days 9–16 Review of initial proposals; 4 = Days 17–20 Ranking of proposals; 5 = Days 21–28 Contributions to shared team report; 6 = Assessment completion and submission deadline including individual components (including their team reflection, the subject of the present study).

were open ahead of the scheduled team project window for informal discussions, with a small amount of traffic observed (see, Figure 1). From Day 1 of the scheduled team projects starting, traffic increased for the 34 days of the projects: a mean of 938 posts/day, including relatively minor tutor contributions. There were higher numbers of daily posts nearer the assessment submission deadline on Day 34.

The number of active students in each of the teams had some influence on the forum behaviour of the team. ‘Active students’ refers to those who had contributed by the end of the project: while the initial team sizes were around 10 students, some students withdrew from the module and, occasionally, tutors would merge smaller teams together. Of the original 68 teams of students, only 10 teams were merged to form 5 teams. This was a relatively rare occurrence to enable very small teams of active students to continue to function and maintain team dynamics. Of these, 5 teams that were merged due to small numbers of active students, towards the end of the project some inactive students started to participate resulting in teams with increased numbers.

Team size did appear to have an influence over forum traffic (overall numbers of posts and posts per person), with traffic increasing with team size up to 10 members; above this, activity plateaued for total posts (Figure 2); the same trend was observed for posts per student (data not shown). We have chosen to show the team posts in Figure 2 to acknowledge the emphasis on the team unit and the fact that, within teams, students adopted different, defined (and agreed) roles. These roles included Scheduler, Time Keeper, Report Editor, Project Manager, and Critical Reviewer.
Figure 2. Relationship between team size and total individual forum activity. The mean number of forum posts (new discussions and replies by students only) across the team project is shown in relation to the number of active individuals in the team. Data for a total of 68 teams are included.

Figure 3. Range of individual team forum activity. The teams were grouped into categories according to the number of posts made to their forums.
Some teams were considerably more active on the forum than others. We illustrate this variation explicitly in Figure 3 rather than indirectly by the inclusion of (large) error bars in Figure 2. Five teams had a very high number of between 1,000 and 1,200 posts (Figure 3). Teams were selected for a more detailed thematic analysis from the ‘low’ activity (fewer than 200 posts) and the ‘high’ activity (more than 600 posts) teams.

Students were aware that they were required to provide evidence of their engagement with team working and that forum posts would form the major source of such evidence. As is common in online team working (Piezon & Ferree, 2008), a wide range of individual student forum activity was observed, ranging from highly active students who initiated new discussions and replied frequently through to individuals who posted only a few replies. See, Figure 4.

The amount of traffic on the forums varied hugely from team to team. In section 2.4 above, we note that low and high traffic teams were defined as involving fewer than 200 and more than 600 total posts, respectively. As noted in the caption for Figure 4, the data shown there (for one presentation of the module) indicates that there were 2,476 new discussions initiated and 26,814 replies from 500 of the students registered. Some students initiated many discussions and authored many replies, but others did neither.

Figure 4. Team forum posts, showing initiated discussions and replies to discussions for registered students. Data are from the single cohort of students in the presentation from February – November 2013. 2,476 new discussions elicited 26,814 replies. Each of the 500 dots represents one student. To clarify the congested lower left-hand part of the figure, 58% of students both posted less than 50 replies and initiated less than 5 discussions.
3.2.2 Online room usage

Most teams also made use of an online room for synchronous collaboration. These were either scheduled and led by the tutor, or students were able to hold ad hoc events themselves as a team. Students who could not attend live were able to watch recordings of meetings. Not all events would have been recorded, so there may have been a significant number of ad hoc events. A total of 342 online room events were recorded in the presentation starting in February 2013. The number of synchronous events varied from team to team. The mode number of recorded synchronous events was 8 (range 0–11). Little association was found between the number of events held by a team and team size or with any aspect of team forum activity, such as number of discussions. Because we have data on only the recorded online room events, a more definitive statement is not possible. However, we saw indications that the very smallest teams (5 or 6 students) and the more typical teams of 10–12 students both engaged more with the online rooms than teams larger than 12 students. Further research would be needed to establish the significance or otherwise of this.

3.3 Detailed examination of high and low communication teams and their members

3.3.1 Thematic text analysis

The main tool provided to students for team working was their dedicated online team forum. In order to explore the impact of forum activity levels on individual team members’ perceptions of team working, we performed a thematic analysis of reflective text from four different teams. Taking data from two tutors, each with a high and low activity team, we compared the combined results for the two high activity teams (10 students in total) with those of the two low activity teams (12 students in total). Each student’s reflection on the team (question 2 of the End of Module Assessment) ranged in length from 800 to 1,150 words.

One of the experienced tutors who had examined student scripts in our initial thematic analysis scored all available scripts from the four teams involved (without knowing which team members were working in which team), identifying the occurrence of nine particular themes in the student reflective commentaries as detailed in section 2, methods, above. Specifically, statements by the 22 students subject to this more detailed analysis were assigned a numerical score (see, section 2.3 above) to aid graphical presentation.

In both teams in each high and low activity category, consistent differences in the way in which team members reflected upon their team working experience were apparent in three areas: participation, relationships and organisation. The differences in these three areas are outlined below.

Participation showed the largest difference between the teams with regard to the proportion of comments related to the absence of team members (absence, late and non-starters) and to team members being peripheral, with 53% of members from the two low traffic teams commenting on these aspects, 14% with strong statements. In contrast, only 23% of members from the high traffic teams mentioned this; see, Figure 5(a).

In the context of relationships, low and high activity teams differed in their reporting of unfamiliar team members: ‘strangers’. For the low team, the awareness of strangers (difficulties forming working relationships) was reported, whereas this was absent in the high teams (Figure 5(a)). Ninety per cent of students in the high traffic teams mentioned
help and support from team members in contrast to just over 30% of students from the low activity team (Figure 5(b)). Our findings in relation to the impact of strangers and absent or peripheral team members are in accord with the recent work of Hilliard et al. (2020).

As for organisation, one sub-theme showed a difference between teams: timing; specifically, slow responses to tasks and questions. In this context, 75% of low activity team members emphasised this sub-theme compared to 40% in high traffic teams. This factor was endorsed with a margin of 58% to 20% for strong or repeated comments (Figure 5(a)).

Both low and high traffic teams made significant comments on the use of the online forum, with stronger comments coming from the latter – as might be expected from the greater use they made (by definition) of this tool; see, Figure 5(c). Both teams of students commented strongly on the use of the online room for synchronous communication. Figure 5(c) also illustrates that deadlines were important to both low and high traffic teams. As such, this provides one example of a broad alignment between the perceptions of engaged and less engaged students.

Other themes emerged from our analysis. The interdisciplinarity of the team projects was mentioned by 86% of students, though there was no clear consensus as to whether this had a positive or negative impact. 23% of students commented that the feedback from their team members helped to strengthen their proposals and 18% reflected that getting a faster start to their team working would have been beneficial.

3.3.2 Are the students’ experiences reflected in their module outcome?
The End of Module Assessment (EMA) marks from students in the high and low forum traffic teams were analysed; see, Figure 6. For question 1 of the assessment, the critical review of a previous project, there was no significant difference in marks
for the low or high traffic teams. For question 2 of the assessment, reflection on the team, there was likewise no significant difference in marks between the low or high traffic teams.

For question 3 of the assessment, the team report, there was a significant difference for the attainment of the low and high traffic teams, with high traffic teams scoring higher marks for this question. This document was the same for all members of any team, explaining the absence of whiskers in the two plots for question 3. For question 4 of the assessment, the personal reflection, students in high traffic teams scored higher marks (Figure 6).

3.4 Student perceptions of team work

In a final online survey at the end of a later presentation of the module (which commenced in February 2014) students were asked to rate their improvement in their ability to work collaboratively. This represents an additional cohort – apart from the main cohort of our study; one in which we used survey data to assess students’ perceived impact on their collaborative working ability.

As shown in Figure 7, 57% of students rated their improvement as major or profound (236 students responded). While the students surveyed were following the Health and Life strand, they were all participating in an interdisciplinary project similar to that in the
preceding presentation. The survey shown in Figure 7 is thus relevant to our present study and predated a subsequent decision, influenced by our research, to de-emphasise interdisciplinarity.

4. Discussion

4.1 Key findings

The team project at the core of the present study involves collaborative task completion, with our assessment of collaborative learning being limited to student reflections and individual performances in the End of Module Assessment. However, the act of having to collaborate does itself drive experiential learning of the actual skills and process of collaboration, the acquisition of subject knowledge being a secondary outcome. Collaboration has a particular resonance in the natural sciences, where many experimental facilities and programmes involve multidisciplinary teams. More generally, it is well recognised that practical skills are an essential part of scientific study; such skills include the design and plan of investigations and the ability to work effectively as a team member (Nicholas, 2015).

Of the themes we studied, three appear to be of particular importance in the context of science distance learning: participation, relationships and organisation (in particular, the response time of other students in the team). Instructive connections can be made concerning these themes and those of Robinson (2013). Notwithstanding the differences between our work and that of Robinson (whose data was based on unsolicited accounts of online collaboration in a 6-week qualitative psychology project), the initial themes we identified are broadly consistent. In Robinson’s work, themes were classified under the headings of autonomy, virtual others, online communication and reflection. The theme of autonomy relates well to themes of participation and fairness, which are more noticeably to the fore in the low forum traffic teams we studied (Figure 5(a)); whether this causes the

![Figure 7](image-url). Responses of 236 students to an online survey, rating their improvement in their ability to work collaboratively (personal communication with Dr Zoë Ellery).
low engagement or is a consequence of it remains a moot point. The cause or consequence dichotomy is again raised by the prominent theme identified by Robinson (2013) as ‘virtual others’, or strangers.

In contrast to the findings in other work (e.g. Jahng, 2013; Robinson, 2013; Witney & Smallbone, 2011) we found no major mentions of online tools being inhibitory to effective collaboration, at least in respect of asynchronous forum use (Figure 5(c)); this does raise the question as to whether this reflects differences in students’ study patterns arising from subsequent improvements in online forum software and greater all-round familiarity of students with social media engagement. Our module was also primarily delivered online, so familiarity was also due to the fact that students had studied a blend of online materials for all of the module to this point.

Given the context and format of the student project work in the present study, the significance of the strangers theme is likely to have been exacerbated: new student groupings being formed to drive the multidisciplinary aspect of the work. This said, we did also structure the team working to include single discipline sub-teams, thereby allowing participants ongoing access to their comfort zone. As noted in section 2.1, these smaller discipline-specific teams reported back to the entire team once they had produced an outline of part of the overall investigation. It could be that the broad multidisciplinary team experience was qualitatively different from the small sub-team working (Rienties & Héliot, 2016). We have not, however, attempted to dissociate the two in the present work.

Notwithstanding the questions raised above, our work has identified a range of benefits associated with online work, including multidisciplinary work. These include the different strengths that individuals can bring to the table as well as a practical division of labour and the covering of absences. Working in a team does motivate students, bestowing them with responsibility and providing them with opportunities to play to their own individual strengths. They can support team members less able than themselves, gain self-confidence and learn about other approaches to science. As such, the collaborative project exercise serves as an approximation to real science in the real world.

Against these benefits must be set a range of obstacles. Online communication can limit the knowledge team members have of each other due, for example, to a relative absence of nonverbal cues afforded in face-to-face interactions (Walther, 1992). It can also exacerbate more general obstacles relating to time management, inequalities in the sharing of workload, personality clashes, the setting up of teams and the assignation of roles within teams. This is where a tutor can have a key role in allocating members to teams in such a way that a critical mass of active participation is achievable.

4.2 Recommendations

Student reflections on the practices adopted during the team-working project indicate a core checklist of actions that should be inherent to the design of similar activities to enhance and improve the online collaborative experience:

- Starting team work promptly;
- Making use of project work prompts to structure activity;
- Personalising the experience through use of photographs and familiarisation activities early in the module as well as restricting teams to ‘known’ people (not strangers);
- Participating regularly;
- Communicating well;
- Being clear about availability;
- Making regular use of synchronous online rooms for real time brain-storming and discussions;
- Making use of emails to prompt students.

4.3 Limitations and future work

The principal source of data for the present study has been in the form of reflective materials embedded in the module’s assessment. This has the benefit of being informed by all active students regardless of their degree of success. It of course excludes inactive students and more information on the underlying reasons for their withdrawal, and the extent to which the prospect of online collaboration played a part in this, would be valuable. While no interview data were used in the present work, direct interviews with both active and inactive students would be a useful supplement to the reflective materials they provided, and such interviews would be free from any considerations of assessment governing their responses.

Surprisingly, issues around the fairness of assessment were not raised to any noticeable extent. This contrasts with some recent research based on detailed analysis of student focus groups (Donelan & Kear, 2018). Indeed, issues of fairness are commonplace when assessment of individual students is based in part on joint work – in this case the team report. Whether the reassuring observations in the present study result from happenstance or to the design of the team project itself would certainly be another area worthy of future study. In particular, the fact that parts of the assessment were completed on an individual basis may act to reduce feelings of unfair assessment of team work. Interestingly, the joint work component accounted for 25% of the final assessment overall, compared to 40% in the work of Donelan and Kear (2018), which they evidenced as being too high.

In the course of the module, we assigned students to teams randomly, except for a requirement to obtain a mix of the main scientific disciplines. There is evidence that this could impact upon both the effective working of such teams and the concomitant performance of and satisfaction derived by individual students, in part down to the lack of control by students of their team membership (Sadeghi & Kardan, 2015). This raises questions as to how we can develop our teaching staff to support team working projects, not least in the provision of practical and realistic guidelines.

Much of our analysis has been based on defining and comparing teams of students based on their level of participation in online asynchronous forums. The extent to which forum traffic acts as a driver of more satisfactory team work is worthy of further investigation. One would expect one consequence of such traffic to be the availability of increased practical support and help, though the fact of increased traffic might, in itself, provide a source of motivation and reassurance.
Our findings include that multidisciplinary communication posed no obstruction to effective collaboration. Whereas some student perceptions contraindicated too great an emphasis on multidisciplinary work, later changes to the module to become focused on single disciplines did not impact on headline pass rates. We do not develop these remarks here but, rather, suggest them as prompts for future study.

Outwith the formalised university settings of asynchronous forums and synchronous rooms lie the online analogues of the junior common room and college bar: many social media channels provide a lubricant for ‘true’ sociability; the ‘off-piste’ aspects of collaborative working. We need also to further investigate the degree to which high levels of posting in online forums by some students may intimidate others and deter them from participating. Forums explicitly focused on collaborative work may differ in these regard from more general forums. These questions set ongoing challenges in the context of providing verifiable evidence to inform pedagogic progress and reliable assessment.

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