STUDY HABITS IN UNDERGRADUATE MATHEMATICS: A SOCIAL NETWORK ANALYSIS

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This paper presents an exploratory social network analysis of the study behaviours of undergraduate mathematics students. Focusing on the second-year students within a large lecture class, it presents data on their self-reported percentage lecture attendance, number of hours spent studying alone and with others outside lecture time, and occasional and frequent conversations about mathematics with other students. It then presents analytical results on relationships between individuals' centrality within the network and amount of study time.

INTRODUCTION

Many factors affect students' engagement with undergraduate mathematics. Some of these factors are cognitive: we might expect students with better prior performance or logical reasoning skills to perform better in assessments (Alcock, Bailey, Inglis & Docherty, 2014). Some factors involve individual behavioural characteristics: we might expect students who are more conscientious (Alcock, Attridge, Kenny & Inglis, 2014) or who have better study skills (Credé & Kuncel, 2008) to engage more consistently and effectively with learning resources and mathematical ideas.

Some important factors, however, are not individual but social. Undergraduates do not study in isolation: their peers form an important part of the learning environment, and students are likely to share knowledge and influence one another's study habits. Mathematics educators are concerned about the role of such interactions in learning, as evidenced by research on mathematical discourse (Ryve, 2011) and by commentaries about the 'social turn' in mathematics education (Lerman, 2000) and the socio-political environment in which learning occurs (Gutiérrez, 2013). But published work in this area has been primarily theoretical (e.g. Cobb, Stephan, McClain & Gravemeijer, 2011; Morgan, 2006); where empirical studies are reported, these often involve detailed qualitative reports of short sequences of interactions in single classrooms (Ryve, 2011). Social interactions are not usually documented on a large scale or used quantitatively to predict educational outcomes.

But it is perfectly possible to study questions about social interactions at a larger scale, and *social network analysis* (SNA) provides one way to do this (Borgatti, Everett & Johnson, 2013; Carolan, 2013). The basic approach is simple: participants are asked to state with whom they interact around one or more issues, and (perhaps) how often or with what intensity they interact with those people. They might also be asked straightforward questions about their individual habits or characteristics. This information is then used to build a social network model and to investigate questions at the whole cohort level (describing features such as the density of the network or changes over time), at the dyad level (using individual characteristics to predict who interacts with whom), or at the individual level (using individual characteristics plus amount or quality of interaction to predict an outcome measure such as performance). In the study reported here, we used SNA to conduct an exploratory investigation of the interactions between students in a large undergraduate mathematics class. This paper reports early and primarily descriptive findings; at the conference we also expect to report in more detail on a broader range of analytical questions.

THEORETICAL BACKGROUND

SNA studies typically use one of two basic approaches: egocentric studies use representative sampling to select people who will report on their individual social networks; whole-cohort studies use data from every person – as far as is practical – in some well-defined group in order to construct a social network model for that group (Carolan, 2013). Studies of both types have been conducted in education. For instance, Coburn, Choi and Mata (2010) collected data from elementary school teachers involved in a mathematics reform effort, and documented a shift over time from small, homogenous, grade-level-focused networks to larger, more diverse networks influenced by a desire to interact with those with expertise; Thomas (2000) collected data on social interactions between first-year students at a liberal arts college, and found that those who were better connected were less likely to drop out.

The SNA approach is arguably of particular relevance in higher education, because the greater requirement for independent study renders student-student interactions more important than they might be for younger pupils. For instance, at the UK university in which the present study took place, mathematics students spend approximately 18 hours per week in lectures and tutorials, and lecture classes can involve over 200 students. This means that around half of the students' learning is supposed to occur during independent study time, and that most students have little individual contact with lecturers. Students' peers therefore become a natural resource for information about both mathematical ideas and practical matters; students could influence one another substantially, especially if they study together regularly.

At present we know very little about student-student interactions outside lectures, or about how mathematics students use their independent study time more broadly. Research in undergraduate mathematics education has typically focused on instructional inputs: on what the teacher does in the classroom (Ellis, Kelton & Rasmussen, 2014; Johnson, Caughman, Fredericks & Gibson, 2013), or on the design of tasks to engage students in sophisticated mathematical reasoning (Larsen, 2013; Zandieh & Rasmussen, 2010), or on students' uptake of provided learning resources (Inglis, Palipana, Trenholm & Ward, 2011). Some of this work has an important social dimension – task designers often want students to work together to reinvent mathematical ideas. But attainment in the broader sense will also likely depend upon the nature and effectiveness of independent study conducted outside the classroom.

The work reported here forms part of a wider study addressing questions about which students study together and about whether being better connected is associated with better academic performance. This paper reports early results on three questions:

1. What proportions of lectures do students attend, how much time do they dedicate to independent study, and how much of this time do they spend collaborating with other students?
2. How interconnected is the mathematical interaction network, and what is the distribution of connectedness of individual students?
3. Do better-connected students study for more hours?

METHOD

Data for this study was collected in a real analysis lecture course that was compulsory for all students in the first year of a mathematics programme and either compulsory or optional for many students in the second years of programmes combining mathematics with other subjects. The lecturer displayed partially-populated notes on a visualiser, students had paper copies, and lectures mixed traditional lecturing with short activities for students to complete in collaboration with their neighbours. All students attended the same lectures (there were no "sections"), and all were exposed to different lecturing styles in other courses. Lecture attendance was not monitored; typical attendance in the Analysis course was 160-170 out of 214 registered students.

To maximise the number of students present to take the survey – an important consideration for whole-cohort SNA studies (Borgatti, Everett & Johnson, 2013) – two steps were taken. First, data collection took place in week 9 of the 11-week term, on the day of one of three small, summative in-class tests (students who are often absent do normally attend on test days). Second, three weeks earlier, on the day of the previous test, the researchers were introduced, the plan for the study was explained, and students were shown the form they would be asked to complete and offered the opportunity to ask questions about the project.

Participants were asked to complete a two-part survey. Part 1 asked them to report their approximate percentage lecture attendance, approximate number of hours per week spent on independent study, and approximate number of those hours spent working with other students. Part 2 asked them to list other students in the class with whom they spoke about mathematics frequently (once per week or more) and occasionally (less than once per week). Asking participants about one another in this way raises ethical issues that do not arise for surveys in which participants report only on their own habits (Carolan, 2013). Thus the informed consent form attached to the survey made clear that if a student did not sign or return the form, any data provided about them by others would not be used[1].

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[1] Also, the only person to handle the original data was a lecturer not involved in teaching these students; the remaining team members worked only with the anonymised data.

To produce a relatively small dataset for this short paper, we restrict our attention to the second-year students; 77 of the 214 registered students were in this category, and 45 signed and returned their forms. These students had shared numerous lectures and tutorials in the previous year, so they form a somewhat coherent subset of the whole cohort, and they are more likely to have stable pre-existing study relationships. Data presented below come from both parts of the survey. Data from the social network part provided a total of 126 listed connections from one second year student to another[2]. These links required further processing because people have imperfect memories so it can easily be the case that one person reports an interaction that another has forgotten, or that one person reports frequent interaction where another reports only occasional interaction. In this case the researcher has a choice: work with directed links (allowing different weights to be attached to the link from A to B and that from B to A) or to assume that interactions are more likely to be forgotten than invented and to simplify by symmetrising, taking the highest level of reported link to be the accurate report (Carolan, 2013). In this report we take the second, simplifying approach.

RESULTS

In line with our research questions, we present the results in three sections: attendance and independent study time, network features and individual connectedness, and relationships between connectedness and study time.

Attendance and independent study time

Self-reported lecture attendance and independent study time varied widely. Reported lecture attendance ranged from 20% to 100%, with a median of 85% and a mean of 81%. Reported weekly hours of independent study ranged from 2 hours to 44 hours with a median of 10 hours and a mean of 13 hours. Because all students had roughly 18 hours of scheduled lecture and tutorial time, this means that the typical student claimed to study for approximately 25-28 hours per week. It is worth noting that this is less than would typically be recommended by their instructors.

Within independent study time, distribution of work alone versus work with others also varied widely. The graph in Figure 1 shows reported weekly hours studying collaboratively with others against reported total weekly hours of independent study. Naturally, students who study for more hours in total have more capacity to spend time studying with others, but there was no clear relationship beyond that: percentage of independent study time spent in collaborative study was not systematically related to total study time ($r = -.010$, $p = .516$).

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[2] Of the 49 second-year participants, 3 reported no links, 7 reported a total of 12 links to other second-year students who did not sign the consent forms (and thus were not used) and 1 listed a link to a first-year student (which is not reported here but will be considered in future analyses).

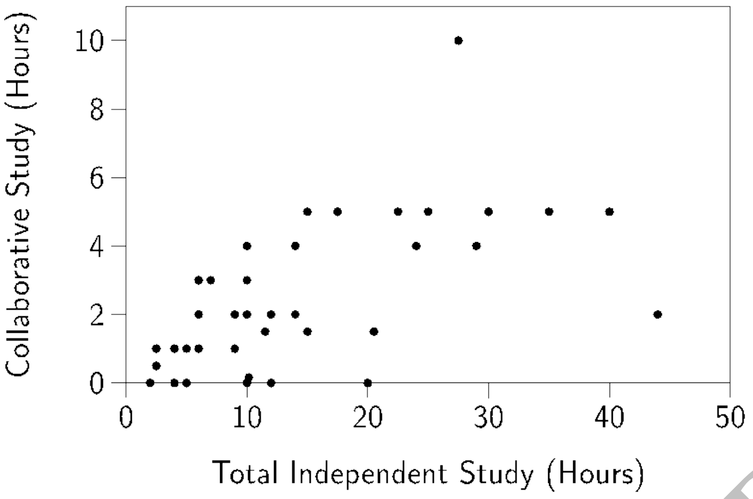

Figure 1: Hours studying collaboratively against total independent study hours.

Network features and individual connectedness

The network data was used to produce the graph in Figure 2; each node represents a student, thick lines represent reported frequent interactions and thin lines represent reported occasional interactions; isolates within this dataset are shown in the top left.

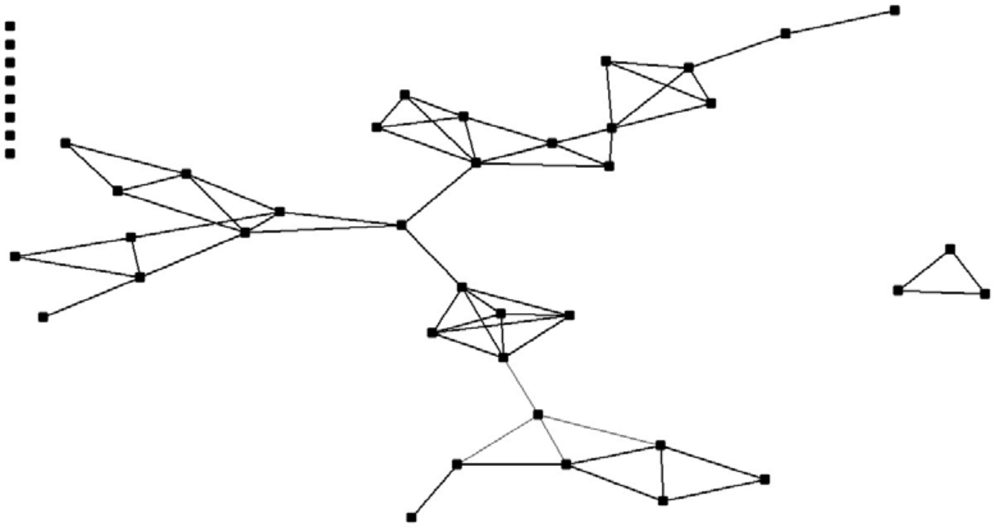

Figure 2: Students (nodes), frequent mathematical interactions (thick lines) and occasional interactions (thin lines).

One feature of this graph is that most students who participated are connected to one another, if only distantly. Another is that the nature of the connections varies widely. Some students are central in highly interconnected parts of the network, some are peripheral to these denser areas, and some study either alone or in a much smaller group[3]. This phenomenon can be captured quantitatively using various measures of

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[3] We remind the reader that these are reported links from participants only: although they provide a strong sense of variability in the network, unreported links could give a different picture and, if the paper is accepted, we will discuss this potential problem at the conference.

centrality (Carolan, 2013), the simplest of which is *degree* in the graph theory sense: the degree of a node or vertex is the number of links it has to other nodes. Table 1 displays the distribution of degrees across the 45 participants.

Degree	0	1	2	3	4	5	6	7
Number of Participants	8	3	7	9	13	3	1	1

Table 1: The number of participants with each degree (number of connections).

Connectedness and study time

The remaining question we address in this paper is whether better connected students study for more hours. It is plausible that they would: perhaps being part of regular mathematical conversations supports engagement with study. It is also plausible that they would not: people who tend to talk more might be more generally sociable and spend more time on alternative activities. Our data showed that reporting more connections is associated with more hours of collaborative work: degree is correlated with hours spent in collaborative independent study ($r = .450$, $p = .002$), meaning that those who spend more time talking about mathematics with others also study with more different people. But degree was not, in our data, linked to doing more or less independent study overall ($r = .053$, $p = .731$). The graph in Figure 3 illustrates this.

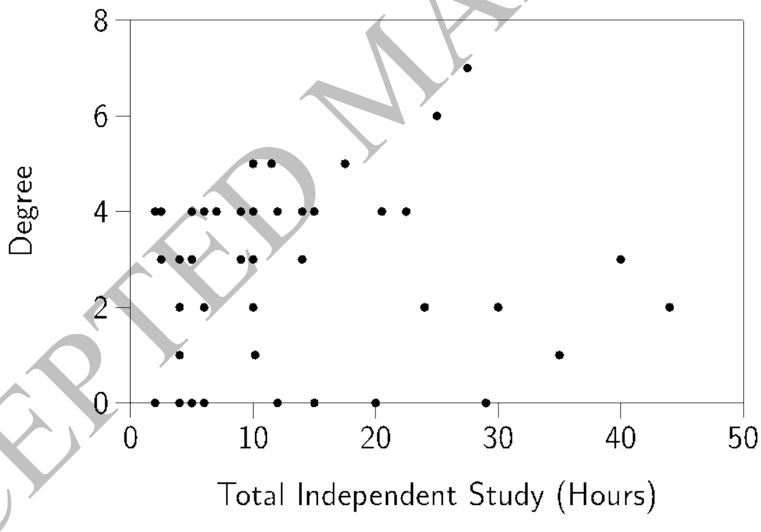

Figure 3: Degree against total independent study hours.

DISCUSSION

This paper has documented undergraduate mathematics students' self-reported independent study time and collaboration with others. This work provides a first picture of the participants' habits, but also raises many questions about the reasons for students' choices and their effects on subsequent academic attainment. We are exploring these issues and expect to report on the larger dataset at the conference.

For now, we believe that research of this nature has potential implications for study guidance, because – despite the existence of study guidebooks (e.g. Alcock, 2013) –

there is little published evidence on how mathematics students can profitably spend their independent study time. Is it better to study with other students or alone? Is it a good idea to converse frequently with a small number of others, because communication improves as people become more familiar with one another's thinking? Or is it better to have occasional conversations with many, because this provides access to a broader range of knowledge and understanding? Further, if research makes it possible to provide guidance about what works best on average, do exceptions exist? Can any student attain high levels of success by studying entirely in isolation, or is this likely only for students with particular individual characteristics or particular levels of prior attainment? A broad base of research addressing such questions would make it possible to structure student activities so as to support productive interactions, and to provide students with advice that is both evidenced and nuanced.

We also believe that research of this nature has potential for developing knowledge in mathematics education. The field has lately evolved to a state that is effectively dichotomised: researchers interested in social issues typically use qualitative methods (see e.g. Ryve, 2011); quantitative studies are routinely conducted by those with backgrounds in psychology but are comparatively rare in mathematics education journals (Alcock, Gilmore & Inglis, 2013). This no doubt occurs partly for reasons of personal interest: some mathematics educators are strongly motivated by the desire to promote productive mathematical discussions in their own classrooms (e.g. Larsen, 2013); others are strongly motivated by concerns about social justice, and are alert to inequities that might be promoted through mathematical discourse (e.g. Gutiérrez, 2013). But there is no reason why social interactions must be studied only in detail, and quantitative methods are routinely used to investigate numerous phenomena in the broader field of social studies (Neuman, 2014). We believe that diversity in methodological approaches is desirable, and that SNA might provide a focus around which researchers working primarily on social interactions and those working primarily with quantitative methods could begin productive conversations.

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