

USING A MATHEMATICAL FORUM IN A GRADUATE COURSE: THE NATURE OF RICK'S AND JOHN'S PARTICIPATION

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Our work focuses on a traditional graduate course paired with online asynchronous forum that involved engineering students. The number of students in the course was larger than expected and the forum was suggested to all students as a way to interact between students and with the teacher. We use network analysis to look for central students in the network of the interactions within the forum and then interview two of the most active students to better understand their use of this technological tool. In this paper, we present our findings with the network analysis and the feedback the students gave us to understand the reason why they use the forum.

Keywords: network analysis, online math forums, students' interaction.

INTRODUCTION AND THEORETICAL FRAMEWORK

In the last years, many universities adopt their own educational online platform, which allows instructors to share materials and provide homework, and allows students to interact with each other and with the teacher to discuss the topics of the course. Indeed, Byman, Järvelä, and Häkkinen (2005) point out that on-line discussions encourage the collaborative process to negotiate meaning and construct knowledge, which is a fundamental aspect of the learning process (Vygotsky, 1980).

According to Kontorovich (2018), we distinguish between general *online asynchronous forums* (OAFs) and *course accompanying online asynchronous forums* (CAOAFs) associated to an undergraduate courses. The main differences of a CAOAF, with respect to an OAF is that the participants are students of the course, not anonymous registered members and the online discussions are usually relevant to all students in the course (ibidem). Another difference is that in CAOAFs the lecturer of the course can participate in the discussion and, in this case, she assumes a special role. In OAFs, all participants are at the same level. The work of Perkins and Murphy (2006) concerns the categorization of participants' posts in an OAF, finding that the majority of students post to ask clarification and/or to evaluate some aspects of the discussion.

The theoretical background of our research regards the results in literature that point to the design of mathematical forums, where students acquire mathematical knowledge by construction, not only by transmission (Engelbrecht & Harding, 2005). Van de Sande (2011) describes the interactions in an OAF as a mathematical help exchange between seekers and providers, since there is a voluntary participation that is not restricted to any particular course and theme. Moreover, van de Sande (2011) distinguishes users of the forum between core and peripheral users, according to their post frequency. However, students' online interaction in math forums does not have to be confused with 'simple' interaction, such as posting and commenting: in a forum, indeed, the students participate to satisfy needs, to accomplish a desire, to negotiate identities, to learn and to discuss (Andrà, Brunetto &

Repossi, 2018). Recent research, exploiting network analysis to investigate the potential of tasks, identifies three kinds of students' behaviour in mathematical CAOAFs. These three kinds are the following: specialised students who tend to comment a lot on few selected tasks; students that comment a few on many tasks; and very active students, who comment a lot on some specific task, but who also comment on the others (Andrà *et al.*, 2018). Kontorovich (2018) argues that an online dialogue between students seems to indicate more engagement within the course material, moreover in order to seek and provide help on online forums students need to recall and reorganize the learned material. This helps not only the help-seeker but also the help-provider to better understand the topics of the course. A special focus of these researches is the intertwining of cognitive and affective aspects in students' interaction and their learning mathematics in a forum.

The aim of this work is to address the open problem, summarized by Kontorovich (2018) with the following question: *which elements bring some students answer this online call for help?* In particular, we refer to the previous problem considering the following research questions: (1) how can we identify active students? (2) Which are the reasons that push students to actively participate in a CAOAF? In order to answer these research questions, firstly it is necessary to identify the most active students, and then to investigate the reasons for their behaviour: the methodology describes the context of our research and the method of analysis.

METHODOLOGY

The sample of students we consider in this work is taken from the graduate course in Game Theory, delivered in English to the students of Computer Science and Management Engineering, at Politecnico di Milano. The course lasted 8 weeks and its schedule was 5-hours per week for theory (a full professor lectured this part) and 3-hours a week for exercises (a tutor, who has a post-doc fellowship taught this part). The number of students enrolled in the course doubled with respect to the previous years, reaching about 400 students, but the number of students who attended classes was less than 200.

At Politecnico di Milano there is an educational platform, called BeeP and hosted on the website beep.metid.polimi.it, where teachers share materials and news with the enrolled students in each course. The platform BeeP allows a lecturer to open a CAOAF in which both teachers and students can post. In the Game Theory course under our analysis, the forum was opened at the beginning of the semester to allow students to share doubts and questions among them and with the teachers. We highlight that since the beginning of the course, the tutor gave high importance to the use of the forum and prompted students to use it instead of asking her via email. The tutor was aware that an open public discussion is more helpful to students than a private one.

The data collected is the set of messages posted on the forum by students. The total number of students involved in activities on the CAOAF is 36. Considering that only 200 students were attending classes, this means that less than 20% of the students was active on the forum. The CAOAF was available for all students enrolled in the course, what about the other 80% who never posted on the forum? On one hand, in online communities there are 'lurking' users (Preece, Nonnecke & Andrews, 2004), namely students reading the post but who never write something. On the other hand, in the CAOAF we are analysing, it was not possible to track these users and distinguish them from students who never accessed the forum at all.

In the forum there are more than 200 messages, mainly written in English and organized in 53 threads. Threads, all started by students, mainly regard questions about homework and exercises, done in class by the tutor, Table 1 reports some examples. A small number (4) of threads is about theory, while some others (6) are about organizational aspects of the course. We notice that the subject of the course is very specialized, thus there are not so many online resources students can refer to, in comparison with other topics such as linear algebra and calculus. Despite the specialized content, the written communication is easier than an average mathematical course since specific symbols such as integrals, limits, graphs are not required for the content of the course. In Table 1 there is an example showing the level of complexity of the symbols used by students.

Solutions of exercises 49 and 51

Did anyone else have found different solutions of exercises 49 and 51? As for exercise 49 my solution it's swapped with respect to the one on the pdf. I obtained for the first player $(1-2/a, 0, 2/a)$ for $a>4$ and $(1/2, 0, 1/2)$ for $3<a<4$. As for exercise 51, I obtained for the first player $(2/(1+x), 1-2/(1+x))$ for $x>2$ and $(2/3, 1-2/3)$ for $x\leq 2$.

Non empty core super additive

Is it true the game is non-empty if and only if the game is super additive?
 To check if the game is empty, we just have to check if it's super additive?
 Do we also have to check $v(S) + v(T) \leq 2v(N)$?

Table 1. Examples of starting messages of threads

The tutor was an active user of the forum, usually she made only general remarks, for instance providing some external links, and directly answered the questions only when it was strictly necessary, for instance because students explicitly asked her intervention, or to reassure students that they were doing correctly (see also Swan *et al.*, 2000).

To study the interaction among students and identify different kinds of active students we build a network in the following way: each student is a node in the network and there exists a link between two students if they posted something in the same thread. The network is weighted because the more students “meet” in different threads, the stronger the link between their nodes is. The network is also undirected, because of the symmetry of the link. We underline that the tutor is not a node in our network, since we are interested only in student-student interactions.

The analysis of this network allows us to identify the students that are most central, by looking at their degree, at their weighted degree and at their betweenness (Newman, 2010). The degree of a node is the number of links of each node, in our network it represents the number of students each student discussed with in the forum. The weighted degree of a node is defined as the sum of the weights of the links of each node: this allows us to detect not only the number of students each node discussed with, but how much they posted. The betweenness of a node i is related to the concept of distance among nodes and it measures how much “longer” would be to pass from node j to node k in case node i is removed from the network. Roughly speaking it measures how much a node connects the network: removing a node with high betweenness may split the network into two or more components.

Moreover, we are interested in establishing if students are core or peripheral users, as described in van de Sande (2011). To that end, we adopt the concept of k -core from network analysis (Newman,

2010). The k -core is the set of at least k nodes such that each of them has at least degree k . We argue that active students, as identified in van de Sande (2011), are the students corresponding to the node in the maximal k -core of the network.

We integrate the quantitative analysis done with the network analysis with a qualitative analysis on the students, based on the answers to a set of questions (see Table 2), designed by the teacher to better understand the use of the forum within her course.

This set of questions allows us to distinguish students' participation in forum as help-seeker or help-provider (Kontorovich 2018), and the reasons why some students are active members of the forum. We select two students from the 5-core of the network, one of them, who is fictitiously called John, passed the exam with the maximum grade at the first attempt, whilst the other, Rick, failed the first exam.

- | |
|---|
| <p>q1. Was the online forum a useful tool? Why?</p> <p>q2. What were the main reasons that led you use the forum?</p> <p>q3. Which was mainly the goal of your messages in the forum? Why did you keep using it and participating actively?</p> <p>q4. What would you suggest to next year students about the use of the forum for this course?</p> |
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Table 2. Questions for active students in the forum

DATA ANALYSIS

The network is depicted in Figure 1, where all the 36 students who wrote at least once on the forum are shown. The dimension of the nodes is proportional to their degree: nodes with a higher degree have a larger radius. The links between nodes have different thickness, which is proportional to the weight of the link. The seven nodes in blue correspond to students who wrote only in one threads and did not receive an answer from another student; the eighteen green nodes are the peripheral students, which do not belong to the 5-core of the network. All other nodes are in the 5-core and correspond to the more active students: we highlight in red the node with degree 15 that corresponds to John and in yellow the node with degree 17 associated to Rick.

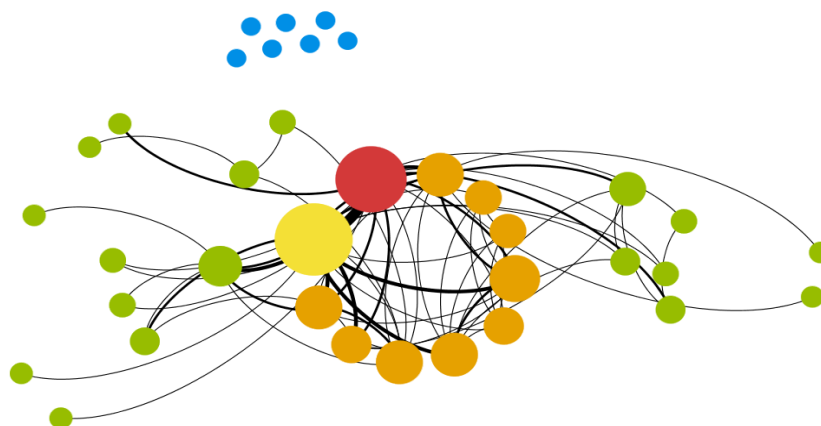


Figure 1. The network associated to students on the forum

The network analysis allows identifying the core, which is composed by 11 students. Among them Rick and John stand out since their degree and weighted degree are almost the double with respect to the average of all students in the core (see Table 3). This means that Rick and John wrote in threads interacting 36 times with 17 peers and 29 times with 15 peers, respectively. Moreover, Rick and John's betweenness is around 0.2, while the betweenness of other students in the core is in a range from 0 to 0.13. This information confirms that Rick and John are the most active users in the forum, both because they posted a lot and because they are well-connected with all the other nodes, that is they took part in many threads and engaged in online discussions with different peers.

	Degree	Weighted Degree	Betweenness
<i>Rick</i>	17	36	0.208
<i>John</i>	15	29	0.219
<i>Average of the values of the students in the 5-core</i>	8.63	13.54	0.065

Table 3. Properties of the nodes associated to Rick and John

Nevertheless, this set of properties does not provide insights about the reasons why they are active, and their attitudes towards the use of the CAOAF. To that end, we need to take under examination the other set of data composed by the answers to the questions in Table 2. In the following, we summarize their answers. We recall that John passed the exam right at the end of the course with the maximum grade, whilst Rick failed the first attempt and had to take again the exam after a couple of months. Both students were attending the first year of a graduate course in Computer Science Engineering.

First of all, John makes a general comment: he frequently uses other forum online, such as Stack overflow, for his personal and academic projects; and the platform hosting the forum under analysis is not so friendly, because threads are not well-organized and it is a bit difficult to search for other people's replies. He underlines that using a CAOAF can help all the students' community, because they frequently have the same doubts and can benefit from a general discussion on some topics. From his words, we can argue that John is expert of (CA)OAFs, and that he is aware that learning is also a social process, not only a private one.

Regarding questions q1 and q2, John says that his main goal in using this forum was to find some difficult exercises to practice, since he did not have much time to prepare the exam.

We infer that John is a motivated student, since he is looking for difficult exercises but he is also a pragmatic student since he wants to exploit his time in studying for the exam. It is well known that the management of time is one of the crucial aspects for university students to succeed in their career.

John, looking at what people asked and discussed on the forum, was a bit disappointed by his mates: he writes that there were mainly trivial questions and other students did not exploit entirely the potential of this tool. We recall that John wanted challenging tasks that his peers did not provide; this could had led him to quit the forum. However, his answer to question q3 sheds light on why John kept using it: "It was more funny to answer the questions on the forum than only doing the exercises. Answering to other students' questions usually helps me to communicate ideas and concepts in a better and more clear way". From his words, we can infer his positive attitude towards the use of the

forum and the learning process: John, by using the word ‘funny’, shows that there is an affective dimension in his approach; moreover from this answer it emerges that he is aware of the importance of communication, in terms of socio-cultural dimension, in the learning process.

Finally, answering question q4, John suggests to next year students to use the forum actively, since it can be a good place to test themselves before the exam and to find difficult and particular exercises. What is relevant in this answer is that John stresses about an active use of the forum by all users to share difficult tasks and to improve their own study. We can notice that not only affective reasons took John inside the forum, but he also evaluated cognitive ones: he is saying that learning is more effective in this way.

We now analyse Rick’s answers. First of all, he replies to question q1, saying that discussing on the forum is more helpful than a short concise answer from the tutor, since in a forum there is a more open conversation that everyone can join. We notice that Rick is aware that open discussion among peers can help the learning process, as well as John points out. Rick adds a further element: he believes that teachers provide solutions, without giving space to open discussions with students. We claim that Rick considers the tutor as an authority who delivers the knowledge and does not help the construction of that, while forums are places for trial and error, and this improves a learner’s experience.

Answering to questions q2 and q3, Rick says that he started using the forum because the tutor had said to do that if students had some doubts, and he actually had some questions. He adds that CAOAFs were not very common among other courses, in his experience as a student. He kept using it to ask and answer questions, because he noticed that it was a useful tool and many other students were participating. We note that Rick is less experienced than John with the use of (CA)OAFs; and he is a dutiful student, reinforcing the fact that tutors are authorities that should be listened to. Actually, Rick followed the instruction of the tutor, asserting that he used the forum mainly to ask doubts. Rick provided also answers to his peers’ questions when he could, becoming an active member of the community. This indicates that Rick wants to be part of the community, not only as help-seeker but also as help-provider.

Rick’s answer to question q4 is that he definitely suggests it to next year students, because it is a useful way to prepare for the exam. Rick writes that he understood many things from the online conversations, either asking or trying to provide some answers. Rick says that, in order to use the forum, he had to write clear explanations, and it was possible to do that only when he was mastering the topic, otherwise other questions and doubts were coming up. We note that Rick has something in common with John: they are both aware of the importance of communication in the learning process. However, there is a difference between the two students: John was not satisfied with the level of the discussions, he was looking for challenging exercises and deep contents; while Rick was satisfied because on the forum he found what he was looking for, namely answers to his doubts and the opportunity to discuss with his peers.

DISCUSSION AND CONCLUSIONS

This work aims at addressing the issues regarding students’ motivations behind their participation in a CAOAF, problem that has been raised by Kontorovich (2018) studying the interaction of students in the CAOAF linked to a linear algebra course. In particular, we address these two research

questions: (1) How can we identify different kinds of active students in a math forum? (2) Which are the reasons that prompt students to participate in a CAOAF actively? In order to do that, we adopt a quantitative approach using network analysis, and a qualitative approach analysing the answers to a survey.

From the network analysis we address question (1) identifying active students as the ones corresponding to the nodes in the k -core. This information is enriched by indices such as degree, weighted degree and betweenness. Many scholars, e.g. van de Sande (2011), detect core and peripheral students looking at the frequency of posts. Network analysis allows us to further enrich the characterization of active students, providing insights on the interactions among users, which would not be possible otherwise. However, there is still the issue of how to identify, in the context of a mathematical CAOAF, active students in terms of help-seekers and help-providers, since in our setting the two kinds of students are not a priori labelled as in van de Sande (2011). A more accurate design of the network could address this problem, for instance considering a directed graph, in which help-seekers could be characterized by a large number of links towards them.

Network analysis identifies the students who are the most active in terms of posting and interacting. As a pilot study, we use this information to select two of the most active students to interview in order to address question (2). From the analysis of their answers, we infer that not all active students use the forum with the same purpose. Even if John and Rick were both answering other people's questions, they were doing that for different reasons. John was looking for more deep discussions and difficult exercises to prove himself, while Rick was asking questions and answering in order to get answers for his own doubts, be part of the community and provide his own contribution to the discussion.

John is an help-provider, who seems to be a wise user, expert with online forums and who wants to find extra material with respect to what is discussed in class, his posts are in the category "assessment" (Perkins & Murphy, 2006). On the other hand, Rick is both help-seeker and help-provider, asking for clarification (ibidem): at the beginning he was motivated only by his trust in the tutor's instruction but then he found that the forum was a helpful tool and decided to use it to be part of the online discussions. Despite the different attitudes of the students, after this experience, they both are aware of the various benefits they can get by using a CAOAF. They recognize that it is helpful to share and discuss with peers the doubts, and that, to answer other students' questions, is necessary to have a more complete and deep knowledge of the topic, confirming the findings in the literature (e.g., Engelbrecht & Harding, 2005), namely mathematical knowledge is constructed and not merely acquired.

Our answer to question (2) is that some students might be looking at the forum to challenge themselves, while other students might resort the forum as a safe place for discussions among peers. Of course, a more deep analysis is needed to explore some of the aspects that are hidden behind Rick and John's answers, such as other affective dimensions, rewarding aspects, status among the community. Moreover, another interesting direction to develop this work is to interview all the 36 students who were active on the forum and use their answers to enrich the analysis. Therefore our answer has to be considered a partial one and the issue posed in Kontorovich (2018) is still open.

To conclude, we notice that the tutor plays an important role in the participation of a CAOAF, too. John and Rick's answers are particularly interesting also to address the problem of the small number of participants in the CAOAF with respect to the total numbers of students enrolled. Indeed, as John's answers suggest, the tutor may prompt students to use the forum posting more difficult exercises or specific tasks to improve online discussion. On the other hand, looking at Rick's experience, the instructors could warmly invite students to use forums, in order to make them aware of the importance of online conversations in the learning process.

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