Social Positioning and Performance in MOOCs

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ABSTRACT
Literature indicates that centrality is correlated with learners' engagement in MOOCs. This paper explores the relationship between centrality and performance in two MOOCs. We found one positive and one null correlation between centrality and grade scores at the end of the MOOCs. In both MOOCs, we found out that learners tend to communicate with learners in different performance groups. This suggests that MOOCs' discussion forum serves to facilitate information flow and help-seeking among learners.

Keywords

MOOCs; Social Positioning; Performance

1. INTRODUCTION
Massive Open Online Courses (MOOCs) have attracted over 7 million users in the past two years. In addition to offering videos and online quizzes that users can watch and take, a key feature of MOOCS is that they contain some platform for discussion among users. Indeed, discussion forums can even be considered a defining feature of a MOOC, because, without such forums, a MOOC is more like a collection of online instructional resources rather than an interactive course.

Our own preliminary data analysis of 15 MOOCs offered at the University of California, Irvine, indicates that the number of posts in MOOC discussion forums significantly predicts the number of people who complete MOOCs. Online discussion forums serve an important role in the collaborative learning process of learners [9]; however, little research explores the relationship between social positioning in the forum and the performance at the end of the course in online learning environments. To better understand learners' interaction patterns in MOOC discussions, we employed social network analysis to study the collaborative learning process in the discussions of two large MOOCs. Social network analysis is a methodology that identifies the underlying patterns of social relations of actors [11]. This paper compares the discussion forum activities of two MOOCs and examines three centrality metrics of online learners—*degree centrality, betweenness centrality, and closeness centrality*—and their relationship with learner performance.

2. RELATED WORK
Threaded discussion forums, an important component of computer assisted collaborative learning, allow learners to connect, exchange ideas, and stimulate thinking [3]. Social network analysis (SNA) is valuable for analyzing the dynamics of these discussions, as it emphasizes the structure and the relationship of actors [2]. SNA is thus a practical means for gaining insight into the relations and collaborative patterns of learners in the forum [8]. Learners' behaviors measured by social network metrics (e.g. *authority* and *hub*) in discussion forums have been identified as positively correlated with learners' engagement in MOOCs [12]. Previous research on online education indicates that network measures of *centrality* (out-degree) and *prestige* (in-degree) is strongly associated with learners' cognitive learning outcomes [10]. Research in online collaborative learning community found out that central actors tend to have higher final grades and suggested that communication and social networks should be central elements in distributed learning environments [4].

The embedded theory states that learners' embeddedness in the social networks that pervades the educational programs predicts their satisfaction and performance [1]. We hypothesize that learners' embeddeness in online learning environment is also positively correlated with their performance. Three centrality metrics, i.e.degree centrality, betweenness centrality and closeness centrality are proposed to reflect embeddness in the online learning networks.

This paper explores whether the correlation between the three centrality metrics and academic performance exists in the MOOC settings. The study mainly focused on learners who took part in the discussion forum.

3. DATASET
The project focuses on two online courses named "Intermediate Algebra" and "Fundamentals of Personal Financial Planning" delivered via the Coursera platform. The Intermediate Algebra MOOC was 10 weeks long and developed by professors from University of California, Irvine. It was open for all to enroll for free. A total 63,100 learners registered in the course, among which 43,342 learners had a record in the gradebook and 23,662 learners accessed course materials. The course consisted of lecture videos, weekly quizzes, and the final exam. The quizzes accounted for 20% of the final course grade while the final exam accounted for 80% of the final grade. Learners who obtained 65% or more of the maximum possible score were awarded with the Statement of Accomplishment, i.e. the Normal certificate. Learners who achieved 85% or more of the maximum possible score were rewarded the Statement of Accomplishment with Distinction, i.e. the Distinction certificate.

The Financial Planning MOOC was 7 weeks long and developed by a certified financial planner practitioner from University of California, Irvine. Over 110,000 learners had enrolled in the course, among which 84,234 leaners have record in the gradbook and about 55, 000 learners accessed course materials. The course evaluation consisted of weekly quizzes (30%), one peer assessment (30%) and the final exam (40%). Learners who

received a minimum of 70% on all graded assignment received the Statement of Accomplishment; those who received a minimum of 85% of all graded assignment obtained the Statement of Accomplishment with Distinction.

In the Algebra course, 2,126 learners participated in the forum during the 10 week course duration. Among them, 1,558 were identified as learners with an academic record, who can be found in the gradebook. It is unclear why a certain percentage of users who participated in the forum, but did not have a record in the gradebook. A possible explaination is that some are instructors and teaching assistants. The percentage of MOOC forum participation of the three performance groups is relatively constant, with 68% of forum participants as none-certificate earners. Table 1 shows the composition of forum participants.

Table 1 Composition of Discussion Forum Participants

Performance Group	Algebra		Financial Planning	
Distinction	311	20%	998	24%
Normal	193	12%	337	8%
None	1054	68%	2897	68%
In total	1558	100%	4232	100%

3.1 Network Descriptive

To create each network we used the following procedure. The forum consists of several sub-forums. Users can initiate a thread in a sub-forum, make posts to a thread, and make comments to a post. Each thread and post serves as a site of interaction among learners. Learners engage in a variety of actions: asking questions, seeking help, and providing assistance to fellow learners. We treat individuals as tied if they co-participate in a thread or a post. These ties represent communication among learners. Although one could create directed ties between individuals who address each other directly in the posts/comments, doing so would require extensive reading and coding of the data and tackling issues such as how to define direct communication (e.g., is implied communication sufficient, or must the alter be directly named?). Given the size of our data, such an approach is infeasible for our purposes.

The Algebra course discussion network has 1,389 nodes, as not all 1,558 individuals participated in the discussion forum have a record in the gradebook. The network has 3,540 edges. We illustrate it below in Figure 1. Nodes colored according to their performance groups. The network is dominated by a large, dense component with a periphery of low-degree actors. A few isolates and lone dyads are also present. Nodes of different performance groups appear to be intermixed throughout the main component and the rest of the graph.

Mean degree is 5.10, although mean degree varies slightly by performance group. Those in the "none" category have the lowest mean degree (4.36) while those in the "normal" performance have a mean degree of 8.249 and individuals earning "distinction" have a mean degree of 5.502.

More than twice as large as the algebra course discussion network, the financial planning course discussion network has 3,317 nodes and 5,505 edges. We depict the network in Figure 2. Like the algebra network, the financial planning network is

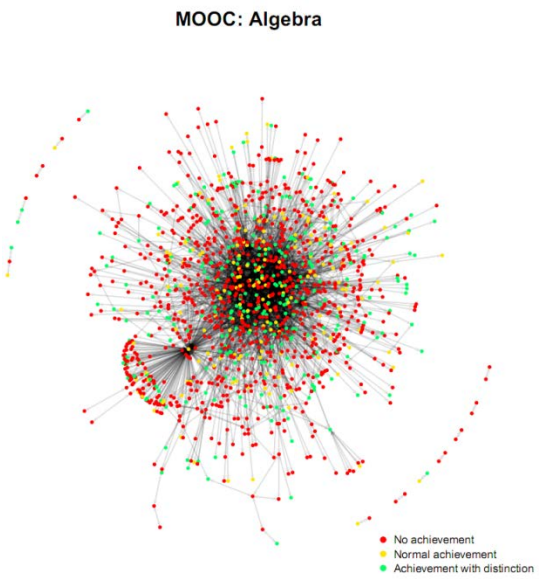

Figure 1: Algebra Network

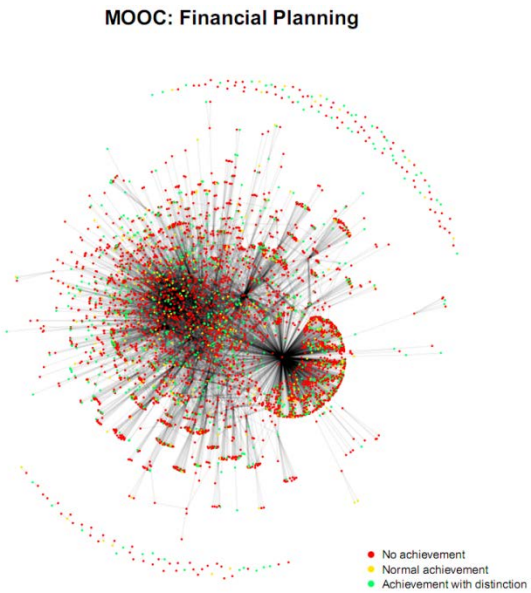

Figure 2: Financial Planning Network

dominated by a large component with a mix of isolates and smaller components. Although the financial planning discussion network is much larger than the algebra network, mean degree is lower. The average degree is 3.32. Like the algebra network, nodes with performance achievements of "normal" or "distinction" have higher degree than those in the "none" category. Those in the "none" category have an average of 2.80 ties, followed by the "normal" category with 4.15 ties, and "distinction" which has an average of 4.48 ties.

4. METHOD

Our analysis consists of analyzing the graph-level centralization and node-level centrality with permutation tests.

4.1 Centrality

Among the most common structural indices employed in the analysis of networks are centrality indices. These measures demonstrate the extent to which a node has a central position in the network [5][11]. Several measures of centrality exist and we utilize three of the most common measures in this paper: *degree*, *betweenness*, and *closeness*. One of the simplest centrality indices, *degree*, measures the total number of alters to which a node is tied. In the context of our MOOC network, this represents the number of other learners to which one is tied through participation in discussion forum threads. Those with high degree have greater levels of participation in a variety of threads that put them in contact with other learners. We also utilize *betweenness*, which measures the extent to which a node bridges other nodes by lying on a large number of shortest paths between them. Nodes with high betweenness have been described as having some degree of control over the communication of others [5] as well as greater opportunities to exert interpersonal influence over others [11]. Nodes with high betweenness in these MOOCs participate in discussions in such a way to learners across multiple forum threads. Finally, we measure *closeness*, which measures the extent to which a node has short paths to other nodes in the network. Nodes with high closeness centrality are described as being in the "middle" of the network structure [2]. Because the standard definition of closeness does not accommodate networks with multiple components, we use the Gil and Schmidt [6]approach of measuring closeness of a node as the sum of the inverse distances to all other nodes.

In addition to measuring node-level centrality, we also measure graph-level centralization. Unlike the node-level centrality indices described above, these graph-level indices produce one measure for the entire graph. These indices measure the difference between the most central node and the centrality scores for all other nodes in the network in order to provide a graph-level measure of the extent to which centrality is concentrated on a small portion of the network's nodes. We compute these centralization scores for the three aforementioned centrality measures: degree, betweenness, and closeness. These measures demonstrate the extent to which centrality is dominated by a small number of learners in the discussion network.

4.2 Permutation Test

Because we cannot guarantee the normality assumptions required by many statistical tests, we use a variety of permutation tests to assess various features of the network. While we use standard, non-parametric correlation tests, we also use non-parametric network methods. These network methods uncover structural biases by using baseline models to determine the likelihood of observing particular structural traits[2]. The results demonstrate the extent to which the network deviates from a reasonable baseline network. These tests allow us to test our hypotheses despite the statistical complexities of the network representation. We use conditional uniform graph (CUG) tests to determine whether features of our observed graph occur at levels exceeding what we would expect by chance. The CUG test conditions on a certain set of network features (typically, size, number of edges, or dyad census) and treats all graphs within that set as equally likely. It then draws at random from this set of graphs and measures whether the statistic of interest is greater, less than, or equal to the measure from our original, observed graph. To the extent that few graphs drawn from the set exceed our observed measure, the measure is higher than we expect by chance. In our analyses, we measure whether the observed levels of centralization in the discussion network are greater than what we could expect from graphs of the same size with the same number of edges.

The second non-parametric network method we employ is the matrix permutation test, often referred to as the quadratic assignment procedure or QAP test [7]. This test evaluates correlations between matrices by permuting rows and columns of the matrices, recalculating the test statistic, and measuring whether it is greater or less than the observed value. This test controls for the structure of the network and allows us to determine whether the labels (i.e., categorical attributes) of the network explain its structure. Where the correlation between the permuted graph rarely exceeds the observed test statistic, we find evidence that the observed statistic is greater than we would expect by chance. We use this technique in our MOOC network to measure whether similarity in grades between any given pair of individuals is associated with the presence of a tie between those individuals.

5. RESULTS

To determine whether observed graph-level centralization exceeds levels we would expect by chance, we use conditional uniform graph (CUG) tests conditioned on the dyad census. We hold constant the number of nodes and number of dyads (either mutual or null, given our undirected graph) when running the test. In our algebra network, degree centralization (.164), betweenness centralization (.269), and closeness centralization (.0001) all exceed chance levels, with p-values less than .01. These results are consistent with the financial planning course, where degree centralization (.354), betweenness centralization (.626), and closeness centralization (.001) were all significantly higher than baseline ($p < .01$). These results indicate that both of our observed networks have much higher levels of centralization than we would expect by chance. These networks are characterized by concentrations of centrality on a handful of nodes. While certain nodes have high levels of centrality, others lack centrality in the network.

We assess node-level centrality by relating our three centrality measures with attainment measures in the course. For each of the nodes in the network, we calculate its degree, betweenness, and closeness and measure the correlation of centrality with the final grade in the course. The correlation between the algebra course grade and degree ($r=.043$, $p=.029$), betweenness ($r=.046$, $p=.018$) are significant while closeness ($r=.028$, $p=.125$) failed to achieve significance in a non-parametric correlation test. Those with high levels of degree and betweenness centrality have higher grades in the algebra course. In the financial planning course we found no evidence of a significant correlation between course grade and degree ($r=.003$, $p=.811$), betweenness ($r=-.002$, $p=.848$), and closeness ($r=-.006$, $p=.582$). Individuals who are more central in the financial planning discussion network did not appear to have notable differences in performance compared to those with lower centrality. Although we find that both these networks have a high level of centralization, we find discrepancies between the correlation between centrality and course grade. While we find no relation between the two in the financial course, we find a weakly positive relation between centrality (except closeness) and grade in the algebra network.

Finally, we look for an association between learners' scores and their propensities to form ties with one another. We use the matrix permutation test, or QAP test, to find an association between tie formation and similar performance in the classes, where performance is measured as the overall grade or end-of-

course distinction status. To measure this association, we correlate the sociomatrix with a similarity matrix *m*, such that the *i*,*j* cell in the matrix represents the similarity in final grade between individual i and individual j. To produce this matrix we found the difference between *i*'s grade and *j*'s grade and subtracted it from 100, the maximum possible difference. The resulting scores represent similarity, where smaller scores indicate similar final grades while larger scores indicate large discrepancies between their final grades. We use the same approach to construct a distance matrix for achievement status, where learners who did not pass the class were scored as 0, while learners who passed received a 1. In the algebra course we found a significant, negative correlation between the observed sociomatrix and grade (r=-.005, p=.01) and achievement (-.007, p < .01). These results suggest that there is an association between tie formation and difference in achievement; that is, algebra learners with high achievement and high grades are *more* likely to be tied to learners with lower performance, and vice versa. In the financial planning course we found similar results: negative correlations between grade similarity (r=-.002, p=.08) and achievement status (r=-.005, p < .01). Although the relation is weak, it suggests that learners are *more* likely to form ties with learners who ended up with different achievement statuses. Learners who failed were *more* likely to communicate with learners who passed, and vice versa.

6. DISCUSSION AND CONCLUSTION

The descriptive statistic shows that the discussion forum is mainly dominated by a small percentage of learners who contributed far more than the rest of learners. This group of opinion leaders or knowledge source helps to build up and maintain the network. It also implies that the MOOCs' network is more an information network than a social network.

According to literature, a likely hypothesis would be that learners who perform well in a MOOC are more central in online discussions. However, our data demonstrated mixed results. In one MOOC (Algebra) we found a significant relationship between centrality in online discussions and student performance, while in the other MOOC (Financial Planning) we found no relationship.

It is worthwhile to consider why there might have been differences in outcomes between the two courses. Though our study was not designed to pinpoint the cause of these differences, they could be related to the differing purposes and audiences of the two MOOCs. The Algebra MOOC is more academically oriented and aims to prepare learners to succeed in higher education, whereas the Financial Planning MOOC is more geared toward assisting people in life skills. Due to the content of the Financial Planning MOOC, learners who were actively involved in the forum discussion may not have been very concerned about obtaining a certificate. Further social network analysis among a larger corpus of MOOC courses could reveal more about the relationship of course content to forum participation; we have recently obtained a corpus of data from 15 Coursera MOOCs at UCI and will conduct follow up research in this area. Additionally, moving beyond permutation tests to model-based approaches such as ERGMs could provide further insight into the properties of these networks and the relations between individual positions and outcomes.

In addition, we find in both networks a weak propensity for individuals to form ties with classmates with very different grades or attainment. This suggests that the discussion forum serves an important role in facilitating help seeking and promoting communication between the knows and the know nots.

The study also has some limitations. For example, it mainly analyzed the behavior of learners who participated in the discussion forum, which only takes up a small proportion of learners in MOOCs. In addition, we did not consider passive forum participation, such as posts or comments viewing. The future research shall include the content analysis to analyze the cognitive engagement of MOOC learners.

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