UNDERSTANDING MATHEMATICS AND SCIENCE ADVICE NETWORKS OF MIDDLE SCHOOL TEACHERS

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Abstract

We report findings from a research project designed to examine the mathematics and science advice networks of teachers who participated in professional development under the auspices of the NSF-funded Rocky Mountain-Middle School Math and Science Partnership. We provide descriptive statistics of results. Additionally, we reflect on the research process and discuss some of the practical challenges involved.

Introduction

A significant literature base discusses aspects of teacher professional networks, as there is an emerging consensus that they are an important part of school improvement [1]. Professional community among teachers is connected both to efforts to improve instruction and actual instructional improvement [2-6]. Often, this involves leadership or distributed leadership roles as a way of transmitting information among groups of teachers [7-8].

Professional development courses for teachers affect these networks. The Rocky Mountain-Middle School Math and Science Partnership (RM-MSMSP), developed at the University of Colorado Denver (UCD) and funded by a National Science Foundation Mathematics and Science Partnership (MSP) grant, offers professional development courses designed to increase teacher content knowledge. At the time of this study, over six hundred teachers had participated in courses offered through the RM-MSMSP. In addition to professional development, the RM-MSMSP focuses on contributing to the research base in middle school mathematics and science education. As part of the RM-MSMSP, we are using social networking to analyze the advice networks of participating mathematics and science teachers. That is, we investigate aspects of to whom these teachers turn for advice or information about teaching mathematics or science.

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Numerous recent studies have used social network analysis to study professional community, district policy and its connection to teachers' social networks, distributed leadership, and to evaluate MSP grants [8, 9]. Similarly, our work sought to describe the social networks of a large MSP [10, 11].

Theoretical Framework

Professional development programs seek to improve and modify aspects of teachers' practices. They do this in a variety of ways, from building content knowledge in a discipline, to challenging assumptions about and enhancing aspects of pedagogical practices. There is significant literature to support the importance of school-based professional development [12-15].

However, as teachers spend more time in their schools, they become increasingly familiar with the expectations and beliefs of others who work there, and teaching can take on a more routine quality [16]. Teacher isolation can be a common issue [17, 18]. Thus, professional development opportunities that offer participants a chance to interact with and learn from teachers outside their schools can play a central role in affecting teacher practice and school change [19-21]. In particular, these external professional development opportunities have been cited as improving teachers' classroom practice and promoting teacher leadership [22]. Thus, it stands to reason that both in-school and out-of-school professional development communities play an important role for teachers.

Successful teacher learning communities are generally characterized by a trusting atmosphere in which members have confidence in their colleagues, and in which a flow of information is created [23, 24]. These networks provide support to teachers, as well as serving as channels for information and expertise to be shared. In addition, they create an opportunity for teachers to learn from one another as well as share ideas and resources [3, 5, 25-27]. In addition to benefiting teachers, several studies have shown that the professional networks of teachers have an impact on overall school performance and student learning [28-31]. Additionally, professional networks have been found to play an integral part in successful school reform and policy implementation [3, 5, 25, 28, 32-35].

Beliefs about teaching have been shown to be highly influenced by professional networks, and teachers' attitudes have been shown to impact students [26, 31, 36-38]. Moreover, beliefs about mathematics seem to affect teachers' behavior in the classroom, including their types of questions, depth of questions, and choice of methodologies and amount of direction to provide students [39-40]. Specifically, teachers struggle to overcome their previous conceptions about how to teach mathematics [41-43]. Professional networks can aid in this.

Moreover, one study also found that the networks of literature teachers are larger than those of mathematics teachers, and that those literature teachers make more frequent contact than mathematics teachers. In the schools studied, this led to stronger literature support networks [44].

However, in general there seems to be a shortage of investigations in the literature on advice networks of mathematics and science teachers. Thus, we seek to further contribute to the research base regarding social networks and professional communities, primarily with regard to middle-level mathematics and science teachers. This study specifically addressed the following research issues:

1) Describe the social network information associated with participants in the RM-MSMSP. How does this vary across the participants in the network?
2) Do teachers who participated in a higher number of RM-MSMSP courses have stronger social networks with regard to mathematics and science education?
3) Do teachers at a given level (elementary, middle, high) have a greater propensity than others to discuss mathematics and science outside their own level?

Methods

Our study sought to capture data on the professional advice interactions of mathematics and science teachers who had participated in the RM-MSMSP, measured from the perspective of the teacher receiving advice. We proceed by providing details about the participants, and then discuss data collection and data analysis.

Participants

There are several unique challenges to social network surveys: the need for a clear network boundary, protecting confidentiality of respondents, and the need for a very high response rate [45-47]. To clearly define our network boundary, we chose to survey all of the teachers in partner districts who had participated in RM-MSMSP courses from its inception in Fall 2004 through Summer 2008. This grant was designed to meet the needs for middle school teachers in the Denver Front Range region to meet the needs of the federal No Child Left Behind legislation for teachers to be highly qualified in their discipline. Additionally, the program was designed under the assumption that teachers with higher content knowledge in their discipline would have increased student achievement [48]. Over the first two years of the project, approximately eight mathematics courses and eight science courses were developed and implemented. In subsequent years, five additional courses (two mathematics, two science, and one integrated) were developed and implemented. These were offered for 4 graduate credits and ran for either two weeks full-time (8-5 daily) or three weeks part-time (8-12 daily). These courses were generally 80% content and 20% pedagogy-focused. In addition, each course that was initially developed had a pedagogy-focused "structured follow-up" during the next academic year. Additionally, semester-long academic year versions of the courses were offered, wherein the structured follow-up pedagogy content was integrated into the mathematics and science content of the course. Teachers received stipends and reduced tuition for participation in the courses. These teachers ranged from elementary to high school teachers, with most teaching at the middle school level.

We advertised the survey via an e-mail invitation to these teachers and sent weekly e-mail reminders to participants during the approximately four weeks in which the survey was active. Of the 569 teachers invited to participate, 368 had taken mathematics courses, 300 had taken science courses, and 99 had taken both. Participants were offered a small gift card for responding to the survey and, in total, 232 teachers responded.

A summary of the teachers responding to the survey is shown in Table 1. Note that the majority of participants taught in middle schools, and the number of elementary and high school teachers was approximately the same. Also, the number of participants who were mathematics teachers was approximately the same as the number who were science teachers, and there were some participants who did not teach either subject. These tended to be special education teachers, coaches, and administrators.

Table 1
Summary of Participant Data

	Number	
Elementary school teachers	40	
Middle school teachers	105	
High school teachers	47	
Mathematics teachers	70	
Science teachers	67	
Teachers of both mathematics and science	37	
Participants teaching neither mathematics nor science	24	
	Mean	*Standard Deviation*
Years teaching	8.50	6.53
Number of mathematics classes taken*	2.43	1.68
Number of science classes taken*	2.51	1.60

**This calculation only includes teachers who had taken at least one math/science class*

Notice that teachers averaged significant teaching experience, with an average of eight and a half years.

Data Collection

Our primary means of data collection was a slight modification of the School Staff Social Network Questionnaire (SSSNQ) survey. We adapted this from the one used in Distributed Leadership Study (DLS) for Middle School Mathematics Education at Northwestern University [10]. In this survey, participants' advice networks are measured using the technique of name generators, which ask survey respondents to recall, by listing specific names, various people from whom they have sought advice or information. The survey centered on the primary question of, "During this academic year, to whom have you gone for advice and/or information about teaching mathematics and/or science?"

For each name that a respondent listed, follow-up questions asked the respondent whether they received advice or information about mathematics, science, or both, to describe the role or job description of the person named, and to characterize their interactions with the person in terms of frequency and content matter. In order to improve accuracy, respondents were also asked to provide possible alternate names (maiden names, nicknames) that their advisors might use. Finally, the survey also contained several demographic questions. Specifically, respondents were asked about the subject(s) they teach, at what levels of school(s) they have taught, and the number of years they have been teaching. The survey took between three and ten minutes to complete, depending on the number of advisors a respondent provided.

In order to minimize chances that respondents would misinterpret the questions, we followed the SSSNQ wording as closely as possible. The SSSNQ was evaluated using cognitive interviews to assess its clarity and effectiveness [49]. We also conducted a small pilot survey with teachers and made minor changes based on this feedback. Beyond that, reliability and validity were established through the DLS.

Data Analysis

Before detailed analysis on the data could be completed, significant data cleanup was necessary. Specifically, in order to obtain accurate data from the social network surveys, it is necessary that the spelling and formatting of names are consistent. Thus before beginning data analysis, it was necessary to clean up and format the data so that it could be entered into the analysis software. The majority of the data cleanup was necessary due to discrepancies in the spellings of names and the use of nicknames or maiden names. For example, one respondent may list an advisor as Bill Smith while another would list him as William Smith. Additionally, several teachers responded to the survey multiple times. In these cases, the responses were combined.

There are many measures available for analyzing social networks. We focused on out-degree due to its high level of robustness to incomplete network data and high correlation to other network measures [45, 47]. Out-degree is essentially a measure of the support network of an individual. In this case, it measures how many people a teacher turns to for advice or information about teaching mathematics and/or science based on self-report data.

To compute a more detailed measure of out-degree, we differentiated between ties seeking mathematics advice and ties seeking science advice. In addition, we computed a weighted out-degree by taking frequency of advice into consideration. That is, a tie to someone from whom a participant reported seeking more frequent advice was considered stronger than a tie to someone from whom the participant reported rarely seeking advice.

During the first round of analysis, we began by looking for correlations to assess whether there were relationships between the number of RM-MSMSP classes taken and out-degree. Additionally, we looked for correlations between out-degree and number of years teaching, as well as differences between mathematics and science advice ties.

Recall that the primary survey question asked RM-MSMSP participants to list people to whom they have turned for advice over the last school year about teaching mathematics or science. During the first stage of the analysis, we used network visualization tools to provide initial insight into the advice network. Specifically, using NetDraw, we created visual depiction of the advice network using a graphical layout known as a sociogram.

For the next part of our analysis, we investigated from whom, on average, teachers were seeking advice. We calculated the average proportion of connections from respondents of one level to advisors of another level, as well as the average proportion of connections to other RM-MSMSP participants, aggregating the data by level and subject.

Results

In all, there were 198 usable, unique responses that provided a total of 465 unique names of advisers and respondents. Due to their low numbers, the six responses that were from participants who were not teachers were not included in the statistical analysis.

Figure 1 is a sociogram depicting the advice network of our respondents. The respondents are represented as circles. Black circles represent teachers who responded to the survey, while white circles represent teachers who were named as advisors but were not surveyed or did not respond. Two teachers are connected by an arrow if one teacher sought advice from the other. The arrow points from the teacher seeking advice to the individual who gave advice. The collection of black dots at the upper left of Figure 1 denotes those respondents who reported seeking no advice or information from others regarding mathematics and/or science, and who also were not named by any other participants in the study as a source of such advice. Looking at this sociogram, we see that most teachers have only a few advice connections. It further appears that there is a lack of widespread connectedness in the network. However, this last conclusion could be limited by lack of data.

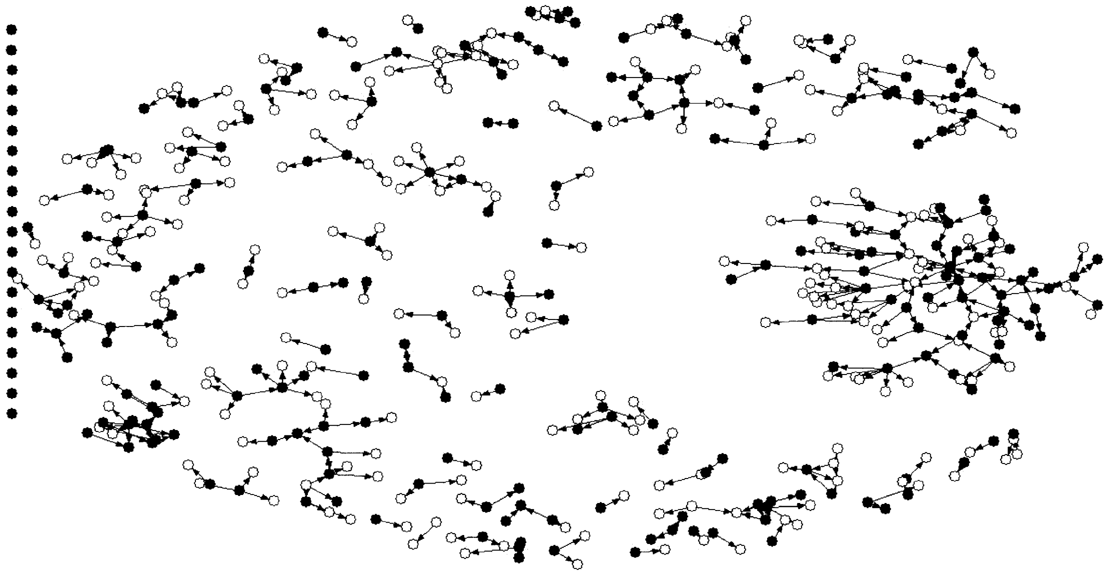

Figure 1.

Advice network of respondents.

A noticeable exception is the large group of connected teachers seen in the middle right of the sociogram. This group formed around several well-connected teachers. A sociogram isolating this group is shown in Figure 2. This group, containing ninety-nine individuals, centers on a teacher on special assignment from the Department for Learning and Achievement within a district. With an out-degree of ten, this teacher had the highest level of connectedness of all teachers surveyed. In addition, this group contains seventeen teachers with higher-than-average connectedness. This group was largely clustered by school, with these highly-connected teachers serving as links among the schools.

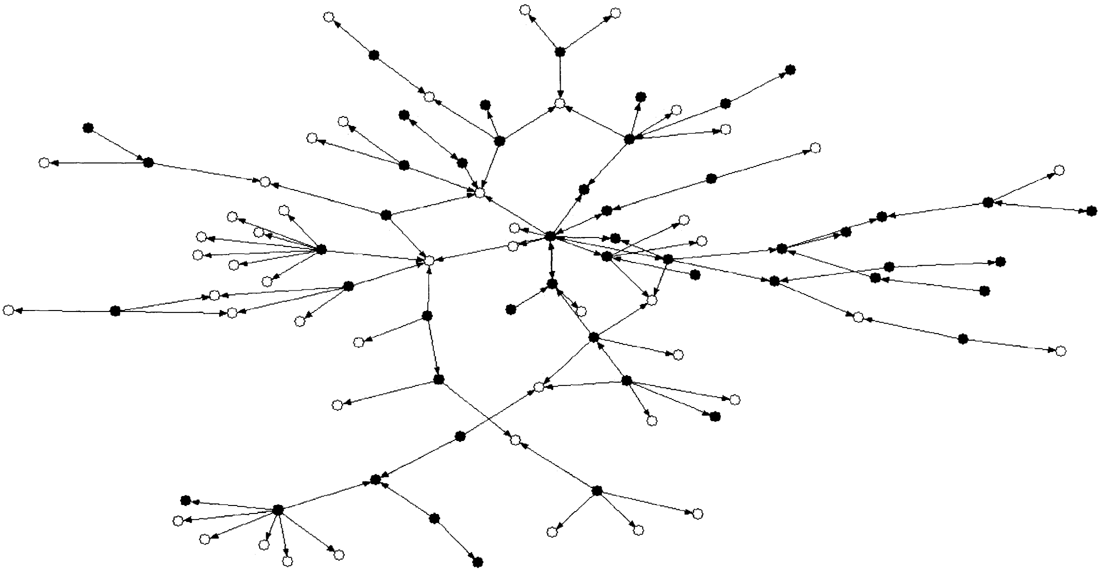

Figure 2.

Isolation of Figure 1 group formed around several well-connected teachers.

We next investigated how a teacher's level, subject, years teaching, and number of classes taken through RM-MSMSP affected the number of connections of teachers. We investigated total connections, mathematics connections, and science connections separately. There were no significant correlations found in the data. Also, there was no significant difference between data weighted by frequency of contact and non-weighted data.

Overall, the average number of advisors per respondent was 1.84. Of these connections, 0.96 were to mathematics teachers and 0.81 were to science teachers. Disaggregating the data by content area showed that teachers who taught only mathematics or only science had on average 2.0 advisors each. In contrast, teachers who taught both subjects sought less frequent advice, with the average number of advisors at 1.57, but this difference was not statistically significant. The average number of respondents did not vary significantly based on the level at which the teacher taught. For teachers who taught both subjects, the average number of advisors in each discipline was nearly the same. Overall respondents had, on average, 0.20 advisors who taught at the elementary level, 0.70 advisors who taught at the middle school level, and 0.42 who taught at the high school level. A summary of these connections is given in Table 2.

Table 2
Summary of Advisors

	Average	*Standard Deviation*
Total advisors	1.84	1.42
Mathematics advisors	0.96	1.18
Science advisors	0.81	1.15
Advisors in school	0.80	0.94
Advisors who teach elementary	0.20	0.47
Advisors who teach middle school	0.70	0.97
Advisors who teach high school	0.42	0.84

We next investigated the types of connections that teachers had. For this part of the analysis, it was necessary to remove the twenty-three respondents who reported not seeking any advice. For the remaining respondents, who reported at least one advisor, we analyzed the average proportion of connections each respondent had, aggregating the data across various characteristics.

First, we calculated the percent of advisors that teachers had at various grade levels (see Table 3). We note that each level of teacher had over half of their connections to teachers at the same level, with high school teachers having almost 70% of their advisors also at the high school level. This is consistent with what was found in Coburn, Choi, and Mata where in Year 1 of their study, 51% of their teachers' ties were actually to teachers at precisely the same grade level [1].

Table 3
Advisors by Level Taught

	Average Percent of Advisors			
	Advisors at elementary level	Advisors at middle school level	Advisors at high school level	Other advisors
Elementary teachers	55%	10%	2%	33%
Middle school teachers	4%	56%	7%	33%
High school teachers	2%	9%	69%	20%

Next, we calculated the percent of advisors that teachers had to others within their own school and to other participants in RM-MSMSP classes (see Table 4).

Table 4
Advisors

	Average Percent of Advisors			
	Advisors within teacher's school	Advisors not within teacher's school	Advisors who were RM-MSMSP participants	Advisors who were not RM-MSMSP participants
Elementary teachers	41%	59%	27%	73%
Middle school teachers	36%	64%	38%	62%
High school teachers	58%	42%	22%	78%

Discussion

This study investigated the professional advice networks of mathematics and science teachers who participated in a large mathematics and science partnership. It was grounded in the fields of social network analysis and teacher professional development.

We found evidence that there were not significant differences in the self-reported advice networks based on subject taught (mathematics or science) or level taught (elementary, middle, or high school). We found that, in the setting of this professional development program, most teachers reported a relatively small advice network. However, given the design of the professional development program, this does not seem too surprising. It does, however, suggest that this professional development (PD) model may not be ideal for the development of teacher professional networks. A small, more cohort-based model of PD may be more appropriate if strengthening teacher advice networks is the primary goal. However, this PD was designed to increase teachers' content knowledge of mathematics and science, and indicators support that it fulfilled this objective.

Our study also allows for several interesting comparisons to the Math in the Middle (M^2) Institute program. First, the average number of connections for these teachers was lower than the numbers found in the University of Nebraska at Lincoln (UNL) study of the Math in the Middle Institute Partnership. The UNL study reported the average number of advisors as 3.8, 3.5, 2.9, and 2.8, respectively, for their four cohorts of participants. This is considerably higher than the average of approximately 1.8 that we reported.

Second, for their first three cohorts, the M^2 mean number of advisors who were other M^2 participants was 1.7. In contrast, for middle school mathematics teachers who participated in our study, the mean number of connections to RM-MSMSP participants was 0.57, much lower than the M^2 participants. We posit that a reason for this difference could be the cohort model that M^2 implemented, where groups of 25-35 teachers went through the program together, taking almost all of the same coursework for twenty-six months. Since our program lacked this cohort model, teachers often would not take further coursework with each other. Also, many teachers in our program only took a few courses, whereas the M^2 teachers took approximately ten courses together. It is logical to conclude that their cohesiveness would be much stronger as a result.

Limitations

There are several limitations with this study. First, we lacked baseline information on the participants' mathematics and science advice networks. This precluded us from making any comparisons over time or drawing any causal inferences.

Second, we lacked a high response rate. Social network survey analysis requires either a high response rate or sophisticated sampling techniques. We were aiming for a high response rate. However, we did not achieve this, and we hypothesize two main reasons. First, we were attempting to survey teachers who had taken courses over a six-year time span. Many of the e-mail addresses were likely out of date, as teachers had moved schools and/or districts, or left the field. Also, many responding teachers participated in a relatively low number of courses from the RM-MSMSP. Thus, they likely did not feel the same connection to the program that teachers who took more courses felt, and were thus less likely to respond. This is in stark contrast to the Nebraska Math in the Middle Institute Partnership where teachers went through an intensive, 26-month program in cohorts of approximately thirty-five teachers and the survey was administered in person to each cohort [10]. The low response rate of approximately 35% limits our ability to use many traditional social network analysis tools. Thus, we were restricted primarily to descriptive network measures. However, given the sparseness of information in the literature on mathematics and science advice networks of teachers, we still consider this information to be of value to the field.

Suggestions for Further Study

This article raises several questions worthy of further investigation. It would be helpful to have a more complete picture of how these advice networks change over time, both within the time frame of the professional development grant and for several years afterward.

There have been a few studies of network change over time in schools, but data on network change of participants in an intensive, sustained professional development experience that is not situated in a given school or district seems limited. Another study of interest could more deeply examine the change of mathematics and/or science advice networks in schools over time.

Several other areas of study include how teacher professional development might be designed on a large scale to increase both content and pedagogical knowledge, while still developing teacher advice networks. Additionally, how can such advice networks be sustained and even further developed once the professional development opportunity ends?

Conclusion

There are many reasons to use social network analysis to study teachers' professional networks. This study examined a large advice network of mathematics and science teachers. We found that there were many commonalities between both the mathematics and science teachers, and across the different levels at which the teachers taught. While our study had significant data limitations, we feel that the research questions that it sought to address are significant and worthy of future study. We hope that our lessons learned will aid other researchers in studying the impact of large professional development programs on teacher professional networks.

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