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A Century of Leadership in Mathematics and its Teaching

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Leadership Through Professional Collaborations

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Leaders in mathematics are responsible for implementing positive change within their school districts and motivating teachers of mathematics to improve their practices. One way mathematics leaders can achieve this goal is by establishing professional collaborations. We analyzed the research and summarized the common attributes found in successful professional collaborations into a research-based framework we present as the COTEAMS framework. Using this framework, mathematics leaders can empower teachers and provide the necessary support for them to participate successfully in professional collaborations.

Keywords: professional collaborations, professional learning communities, mathematics leadership, collaboration, COTEAMS

Introduction

There is overwhelming evidence that professional collaborations in mathematics education have several benefits, including improvement in teachers' mathematics content knowledge, teaching practice, relationships with colleagues, and resulting impact on student learning (Bornemann, Haury, & Slavit, 2009; Lachance & Confrey, 2003; McClain & Schmitt, 2004). Educational researchers have sought to define and analyze the composition of effective professional collaborations within the reality of the school setting (Arbaugh, 2003; John-Steiner, Weber, & Minnis, 1998; Lachance & Confrey, 2003; Little, 2003). Commonalities in the characteristics that contribute to successful professional collaborations in education exist across many of the studies, but require an analysis of a broad body of work to extract the key ingredients for success of effective professional collaborations.

Considering the reality of the demands required of teachers of mathematics, most mathematics teachers have little time to analyze all the current educational research and extract from it what they can actually use in the classroom. It is up to mathematics leaders to examine the current research and relay that information to the mathematics teachers in their district in a way that encourages them to establish professional collaborations and supports them to ensure the success of those collaborations. In this paper, we will discuss our research of the common attributes found throughout studies of effective professional collaborations and present a research-based, actionable framework designed to serve as a guide for both mathematics leaders and teachers to establish professional collaborations within their own school setting. It is our intent to provide a framework that can serve as a bridge between the existing research and mathematics leaders.

Need for Study

The majority of the documented studies of professional collaborations among teachers of mathematics have been initiated and facilitated by an off-site researcher (Grossman, Wineburg & Woolworth, 2001). While researchers clearly gain from participation in these studies by contributing to the advancement of knowledge in their field and resulting publications, teachers also have much to gain by initiating and participating in professional collaborations. Our research uncovered four major areas where teachers benefit the most significantly from participation in a professional collaboration: improved mathematics content knowledge, improved instructional practice, improved collegial relationships, and improved student engagement in learning mathematics (Bornemann et al., 2009; Grossman et al., 2001; John-Steiner et al., 1998; Lachance & Confrey, 2003; McClain & Schmitt, 2004; Nelson, 2008).

Despite overwhelming evidence of the benefit of successful professional collaborations in the realm of mathematics education, very few teacher-initiated collaborative efforts, containing only teachers as participants and facilitators, are being made at the high school level (Grossman et al., 2001). Mathematics teachers in American high schools primarily work individually: interpreting the curriculum, planning lessons, designing assessments, and making efforts to improve one's own learning. The structure of the American high school makes it very difficult for teachers to collaborate due to such constraints as the absence

of a common planning period among colleagues during the school day (Grossman et al., 2001) and commitments such as coaching, tutoring, or sponsoring student clubs after school (Arbaugh, 2003). Professional development for high school mathematics teachers usually consists of a district in-service day and are often scattered, focused on immediate or technical issues, and "doom any attempt to sustain intellectual community" (Grossman et al., 2001). In order for mathematics leaders to motivate teachers to begin initiating and participating in professional collaborations within their own school settings, they need to be equipped with a tool that can guide them in this process. The focus of this paper is the development of this tool, a research-based, actionable framework designed for leaders of practicing mathematics teachers to establish professional collaborations in their own school setting. A thorough review of the literature is crucial to develop this framework.

Methodology

In conducting our literature review, we followed the "systematic data processing approach" presented by Levy and Ellis (2006). Their methodology for conducting an effective literature review is proposed within the context of information systems research, but the authors maintain it can be generalized to other fields. We found the systematic approach in their methodology to align well with reviewing literature in the field of mathematics education. Levy and Ellis describe their literature review methodology as comprising "three major stages: 1) inputs (literature gathering and screening), 2) processing (following Bloom's Taxonomy), and 3) outputs (writing the literature review)" (p. 181).

The first step in the systematic literature review process was to gather all attainable articles researching studies of professional collaborations, but we must first define what we mean by a professional collaboration. Certainly a group of teachers who gather to complain about a topic or even who gather for the typical administration initiated in-service day do not constitute a professional collaboration. A platform we begin from is in John-Steiner et al.'s (1998) definition of a "true collaboration":

> The principals in a true collaboration represent complementary domains of expertise. As collaborators, they not only plan, decide, and act jointly, they also think together, combining independent conceptual schemes to create original frameworks. Also, in a true collaboration, there is a commitment to shared resources, power, and talent: no individual's point of view dominates, authority for decisions and actions resides in the group, and work products reflect a blending of all participants' contributions. We recognize that collaborative groups differ in their conformance to this profile and that any single group may exhibit some of the features only episodically or only after long association. (Minnis, John-Steiner, & Weber, 1994, p. C-2 in John-Steiner et al., 1998, p. 776)

In searching the literature for professional collaborations, we found studies of the formation and value of *professional learning communities* (Bornemann et al., 2009; Nelson, 2008), *teacher communities* (Blumenfeld et al., 1994; Lachance & Confrey, 2003), *teachers' professional communities* (Nickerson & Moriarty, 2005), and *study groups* (Arbaugh, 2003), and after close inspection, consider these labels analogous to the label *professional collaborations* (Krainer, 2003). The joint thinking, acting, planning, decision-making, and commitment that John-Steiner et al. (1998) described in a "true collaboration" are the same interactions that take place in a "community." Grossman et al. (2001) discussed the ambiguous meaning of the term "community," but pointed out the "[strong] bonds of connectedness" cultivated in a community. These strong bonds of connectedness must also be fostered to have an effective professional collaboration.

The keyword professional collaborations and all analogous labels were searched in only reputable, peer-reviewed education, mathematics education, and science education journals to improve the quality of the literature review. The second step in the systematic literature review methodology was to "process, following Bloom's Taxonomy" (Levy & Ellis, 2006) the articles we found to be relevant to our objective of developing a research-based framework. Studies were used if they described a successful professional collaboration, providing evidence of its success, and if the researcher included some analysis of the case. This analysis could discuss factors that contributed to the success of the study or were found to be challenges. Studies where the professional collaboration was not successful were also used if an analysis of the factors that worked against the collaboration was presented. These challenges were valuable in determining the factors that are necessary to attain success when participating in a professional collaboration. Since our objective was to create a framework representing the common attributes found in successful professional collaborations, once the same attributes continually appeared in new articles, we felt we had exhausted our search of the literature.

Theoretical Background

Our thorough review and analysis of the literature on professional collaborations led to several common attributes that serve as vital factors for achieving success. We observed the following attributes: commitment, willingness to be open, time, essential questions, willingness to seek knowledge, motivation, and support. While some attributes were cited

more frequently than others, all were shown to contribute substantially to the success of professional collaborations through documented studies. In providing the research base for our framework, we offer a brief summary of some of these findings.

A high level of commitment on the part of participating teachers is one factor that is necessary for a successful professional collaboration. In Nelson's study (2008) of a mathematics and science teacher collaboration, she attributed some success to commitment: "Teachers also remained committed to figuring out how to collaboratively investigate and impact student learning" (p. 579). In a study conducted by Nickerson and Moriarty (2005) involving a collaboration of high school mathematics teachers from two sites, the researchers found that commitment was one aspect that influenced formation of community, observing that, "Members of the community are accountable to each other in achieving goals associated with this shared sense of purpose" (p. 115). A willingness to be open with one another and establish trust is another factor necessary for an effective professional collaboration. Nelson's research also supported this attribute:

> Teachers exhibited a great deal of trust in each other and each demonstrated a willingness to be explicit about what might be perceived as weaknesses: not understanding state standards or not holding all students accountable to high expectations, for example. As they voiced their questions and beliefs and opened their classroom practice up to scrutiny, they trusted others would not judge them. (p. 578)

The research of Blumenfeld et al. (1994) showed similar results. Their study, an analysis of a professional collaboration of five middle grade science teachers, found that while teachers were hesitant at first to take risks in front of one another, over time trust was built and eventually they viewed their group "as a community with shared investment in the endeavor" (p. 539).

In reviewing the literature, we found the most frequently cited factor crucial for an effective professional collaboration was time (Arbaugh, 2003; Bornemann et al., 2009; Lachance & Confrey, 2003). The teachers who participated in Lachance and Confrey's study (2003) reported that time was their biggest obstacle in forming professional collaborations and the study concluded, "If a mathematics faculty community is to be fostered and maintained in this setting, the time will have to be found to allow teachers to continue to build it" (p. 129). A study examining a collaboration of seven high school geometry teachers reported that three of the participants in the collaboration "would have had serious reservations about participating" (p. 155) if they had not been given release time from their classes (Arbaugh, 2003). In Goos and Bennison's (2008) study, the researchers point out the advantages of using technology to tackle this issue:

> While communities of practice are generally constituted through face-to-face interaction, technologies such as the Internet have opened up new possibilities for participation. Online discussion via email, bulletin boards, or web-based conferencing has become common in pre-service and in-service teacher education. (p. 42)

Framing the professional collaboration around a few key questions is also imperative in achieving a worthwhile experience. In one study involving a professional collaboration of seven mathematics educators, the researchers concluded that the essential questions that led their collaboration "focused our discussions and allowed us to think deeply about how teachers shape student participation and support the development of mathematical ideas" (Bochicchio et al., 2009, p. 612). Bornemann et al. (2009) found this common focus was "central to our success" (p. 551) in their collaboration. A desire to expand one's knowledge base is also a critical part of establishing and participating in a professional collaboration. In Bickel and Hattrup's (1995) study involving a collaboration of mathematics teachers and researchers, the authors reported the significance of participants' willingness "to be regularly engaged in updating one's knowledge base about learning and instruction, and to contribute to this knowledge base by capturing and sharing one's clinical knowledge" (p. 55). In order for a professional collaboration to be truly successful, all members of the group must be knowledgeable enough on the topic to actively contribute. In the Nickerson and Moriarty study (2005), the researchers stated, "In a community of learners, both mature and less mature members share responsibility for knowing, directing and structuring shared endeavors" (p. 117).

Motivation among participants is also an essential ingredient in the formation of professional collaborations. Motivation can come from extrinsic or intrinsic sources, but most studies address the intrinsic motivation necessary for a successful collaborative effort. Teachers motivated to establish professional collaborations receive fulfillment from bettering themselves and their teaching practice and enjoy the process of identifying an area that needs improvement and tackling the challenge of making that improvement. In her study of a collaboration of mathematics and science teachers, Nelson observed that the participants were "grounded in reflection, inquiry, and action directly related to teachers' work and students' learning" (2008, p. 550). The final significant attribute observed frequently in studies of professional collaborations was administrative and peer support. Nelson's research also reflected this factor, concluding that professional collaborations must be

"supported by strong leadership that is distributed across teachers and school administrators" (p. 550). In a study observing a collaboration of mathematics teachers, West and Curcio noted the necessity of administrative support in their study: "This requires coordination among the principals of the schools involved, payment for coverage of the visiting teachers' classes, and someone to attend to the logistics of the day" (2004, p. 272). The findings of our review of the current research drove the construction of our developed framework.

The COTEAMS Framework

In order for a professional collaboration to be successful and beneficial to the teachers who participate and their students who are the recipients of resulting gains, a professional collaboration must contain the following essential components:

Commitment

Teachers must commit to the project, their colleagues in the collaboration, and be willing to dedicate as much of their time and energy to the collaboration as every other member in the group. Teachers must commit to being active participants and contributors to the collaboration by creating and sharing as many materials and information with the group as all other members. Teachers should commit to an objective and deadline for their collaboration and commit to seeing it through to the end.

Openness

Teachers must be willing to be open to other teachers' opinions and philosophies and likewise be open to sharing their own. Teachers need to be open to leaving their comfort zone, such as being willing to allow their colleagues to observe them teaching or willing to share instructional materials or assessments they have designed. Teachers must be open to hearing constructive criticism about themselves from their colleagues and equally be sensitive to feelings when openly offering constructive criticism to others. If teachers are unfamiliar with any of the mathematics content being discussed, they must be open to disclosing this information to their colleagues and not fear embarrassment. If all members of the professional collaboration are open with each other, trust will be established and lead to richer collegial relationships.

Time

Posing the leading challenge for teachers, teachers must block off time in their schedules and all members of the professional collaboration must make this a priority. Teachers can seek assistance from administrators with gaining work time through requests for a common planning period with colleagues in collaboration or even substitute coverage for occasional class release time. If those options are not feasible, teachers must reduce time spent on some existing activity in order to make time for meeting with colleagues in collaboration. For example, if time is spent offering extra help to students after school on four days a week, this could be reduced to three days a week to allow for a collaboration meeting once a week. Technology should also be used as much as possible to alleviate time constraints. Teachers with overlapping schedules should correspond through e-mail and use an electronic bulletin board for discussion and posting materials.

Essential Questions

Teachers need to develop and agree upon key questions that guide the collaboration and outline the purpose of the collaborative effort. Essential questions should be specific and designed so all discussions, tasks, activities, and subsequent results from the professional collaboration project are aimed at finding the answers. Essential questions should be continuously reflected upon and guide members of the professional collaboration throughout the process.

Acquire Knowledge

Teachers must have a desire to learn new pedagogical methods and new or forgotten concepts in mathematics. If teachers involved in a professional collaboration are unfamiliar with an educational philosophy or the proposed teaching method or activity, teachers must be willing to read and do enough research to gain an adequate understanding. This also applies to any unfamiliar concepts in mathematics – teachers must be willing to work through examples and problems until they have gained a good understanding of the mathematics.

Motivation

Teachers must be motivated in order to make a professional collaboration succeed and must choose other equally motivated teachers to join them in the collaborative effort. Motivation for teachers can be extrinsic or intrinsic. Extrinsic motivation can include recognition from administration, publication of experience in a journal, or financial reward. If seeking financial reward for their efforts, teachers will need to be proactive by either requesting the administration and school board for a stipend from the district budget or applying for grant money outside of the district to support the collaborative effort. Teachers who are motivated intrinsically

will be rewarded with the improvement in their teaching practice and mathematics content knowledge, increase in their students' engagement in learning mathematics, and will overall feel their participation in the professional development is making them a better teacher.

***S**upport*

Teachers participating in a professional collaboration must have support from both administration and each other to be successful. Administrative support can include scheduling teachers with a common planning period, providing occasional class coverage to allow collaboration during the school day, or showing support through positive acknowledgement of teachers' efforts. One anecdotal example of support a middle grades teacher shared with us was when her Vice-Principal volunteered to take her and three of her colleagues' classes, totaling 100 students, to the cafeteria and teach them a lesson on study skills for two hours in order for the four teachers to hold a collaboration meeting. Teachers must also support each other in a professional collaboration and know they can rely on each other and trust each other. All members of the collaboration must consistently be professionals through verbal exchange, timely responses to e-mails, and all other correspondence.

Implications

In our research, we found most studies documenting successful professional collaborations were initiated by an off-site researcher, so there is a need for more mathematics leader-initiated collaborations and documentation of these experiences in the literature. The COTEAMS framework can assist mathematics leaders in meeting this need more efficiently. To explore the implications of the COTEAMS framework in practice, we formed a two-person professional collaboration to develop and teach a logarithms lesson in our remedial classes using the Socratic Pedagogy (Hirsch & Pfeil, 2012). We were motivated by the poor performances of many of the students in our remedial College Algebra courses and thought the lecture-based teaching style we were primarily using was one possible cause. We were interested in the Socratic Pedagogy as an alternative teaching style to ideally reach more of our remedial students. The Socratic Pedagogy "focuses on constructing questions instead of answers for the students" (Hirsch & Pfeil, 2012, p. 3) and "students construct both knowledge and understanding, instead of passively receiving knowledge" (Hirsch & Pfeil, 2012, p. 3).

We applied each of the components of the COTEAMS framework to our collaboration: commitment, openness, time, essential questions, acquire knowledge, motivation, and support with positive results. Each component of the framework served as a checklist to guide us through the process of developing and executing our plan to research the Socratic Pedagogy methodology, create a logarithms lesson implementing this methodology, and teaching the lesson in our College Algebra courses. By continually referring back to the COTEAMS framework at each step in our collaboration, we were reminded of the necessary actions we needed to take to ensure the success of our project. We followed the teaching of our Socratic logarithms lesson with a classroom discussion in our College Algebra courses "looking for anecdotal evidence of improvement in students' overall enjoyment and classroom experience while learning about logarithms" (Hirsch & Pfeil, 2012, p. 11). The feedback we received from our students was primarily positive accompanied by a handful of students who expressed a preference to the lecture-based style. Many students reported that they found the lesson more enjoyable and felt they had gained a solid understanding of logarithms. While these data were purely anecdotal, we consider our first application of the COTEAMS framework to a professional collaboration to have yielded positive results.

Concluding Remarks

The COTEAMS framework is designed to assist mathematics leaders in establishing successful professional collaborations within their school district. Each component of the framework: commitment, willingness to be open, time, essential questions, willingness to seek knowledge, motivation, and support, was found in the research to be an attribute crucial to the success of professional collaborations. Mathematics leaders can present this summary of the research findings to teachers as a starting point to engage them in a dialogue about forming professional collaborations. The COTEAMS framework is also intended to guide the mathematics leader in providing the necessary time and support for teachers to participate productively in a professional collaboration. Leaders in mathematics will find that forming successful professional collaborations will motivate their teachers to improve their mathematics content knowledge and instructional practice, advance the mathematical achievement of their students, and achieve positive change within their school district.

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