Innov High Educ (2016) 41:167–182
DOI 10.1007/s10755-015-9340-9

The Community of Practice among Mathematics and Mathematics Education Faculty Members at an Urban Minority Serving Institution in the U.S.

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Published online: 25 August 2015

Abstract Using narrative inquiry as a research method, four mathematics and mathematics education faculty members explored the integration of theoretical perspectives into their personal narratives as they developed a community of practice. Initially their focus was strictly on improving their students' mathematical knowledge. As their community of practice matured, however, their work took on a larger meaning as they contributed to the institution's strategic goal of raising the annual dollar amount of external funding and to the development

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of their personal and collective identities. This unusual level of inter-departmental collaboration has been recognized by the institution's highest administrators, who have called upon its members to develop new, collaborative partnerships with regional school districts and community colleges.

Keywords Community of practice · Mathematics education · Higher education

The explanation and description of this narrative inquiry research (Clandinin and Connelly 2000) is based on the experiences of four mathematics and mathematics education faculty members, who established a community of practice (Wenger et al. 2002; Wenger 1998) in 2010. The community initially focused on improving students' conceptual knowledge of mathematics, as it relates to teaching. One faculty member is in the education department; and the other three are in the mathematics department, all at the University of Houston-Downtown (UHD).

UHD, situated in the central business district of Houston, Texas, is considered one of the most ethnically diverse liberal arts institutions in the southwestern United States. It is a non-residential campus that serves over 14,000 students from a variety of backgrounds and is a federally designated minority serving and Hispanic serving institution. It serves many first generation college students, students who work full or part time, students who may have family obligations, and students who transfer from community colleges or other higher education institutions. Through its focus on teaching, UHD offers all students a high quality education as well as small classes and the opportunity for personal connections with faculty members.

Research Method and Theoretical Frameworks

Narrative Inquiry

We used narrative inquiry as a research method to study the experiences of these faculty members as individuals and as a collective (Clandinin and Rosiek 2007). Narrative inquiry "embraces narrative as both the method and phenomena of study" (Pinnegar and Daynes 2007, p. 5), beginning with participants' recounted experiences and interpreted with theoretical perspectives that extend the understanding of the experiences with which the inquiry began. In the course of a particular study one may focus on 1) changes in relationship between and among researcher(s) and participating subject(s), 2) a move from the use of number toward the use of narrative events as data, 3) changes in focus from general or universal toward local and specific viewpoints, and 4) acceptance of alternative epistemologies or ways of knowing (Pinnegar and Daynes 2007). These four points may not all be present in every narrative inquiry. Their inclusion and sequence of use depends on the focus and evolution of each study. The researchers explore and make sense of how participants change by focusing on explicit activities and interpersonal interactions within a study. They establish an objective stance by distancing themselves from the relationship with the research subjects by using strategies such as member checks, triangulation, and audit trails. For this particular study the researchers themselves were the participants, and they brought their own individual perspectives to the group. Over time, they crosschecked the report collaboratively to triangulate and validate the

data as they interacted and learned together. With respect to the use of words as data to support data interpretation, it is the nuances of the collaborative human experience that are of interest. These interpretations may or may not be generalizable across similar situations and are highly dependent on the particular relationships among research participants and their situation. These interpretations are usually connected to particular characteristics such as temporality, political nuances, and leadership, which may be beyond the control of participants in the study but will likely be unique to each study. The following research questions guided this narrative inquiry:

- What in participants' past experiences with mathematics motivated them to participate in this community of practice?
- How did this group of mathematics education and mathematics faculty members evolve into a mature, active community of practice?
- How has this community of practice impacted the institution's mathematics and education departments?
- How is this community of practice viewed by the upper administration?

Efforts to foster collaboration between Education and STEM (Science, Technology, Engineering, Mathematics) faculty members to improve K-12 STEM education are not unique to our institution. Programs such as the Mathematics and Science Partnership supported by the National Science Foundation for much of the 2000s and the Robert Noyce Teacher Scholarship Program, by which the authors were funded, require STEM faculty to be included. Research shows that STEM faculty benefit from engaging in work with K-12 education including gathering new ideas for teaching, learning more about student learning and educational research; and K-12 and education faculty benefit as well (Zhang et al. 2011). While many of these programs are successful in engaging all parties (Moyer-Packenham et al. 2009), little is known about the characteristics of the collaborative effort between the STEM faculty and the education faculty. With this article, the authors hope to uncover some of those qualities that support interdisciplinary collaborations—particularly between faculty members working in a mathematics department and in a department of education.

Communities of Practice

Wenger (1998) defined *community of practice* along three dimensions, namely, what it is about, how it functions, and what capability it produces over time. A key characteristic of a community of practice is that its membership is based around a shared understanding of issues that matter to its participants. Its members come together to develop practices in response to their joint negotiation about these issues, as with most professional learning communities (e.g., Foord and Haar 2008) including *critical friends* groups (e.g., Moore and Carter-Hicks 2014), which are based on reflection about mutual professional work. Critical friends groups typically use formal protocol guides to facilitate discussion. A community of practice, as described by Wenger (1998), is not defined by organizational mandate, schedule, or formal protocols, although these may be of some influence in its creation. It is the knowledge component of the issues at hand rather than the tasks of addressing the issues that are unique to a community of practice. Thus, a community of practice has an identity that is shaped by and also shapes the identities of its members as they engage in the shared practice of learning together to build shared knowledge about the issues that are important to them. This forging of identity does not

necessarily happen without conflict, but it is how the conflict is handled that further defines and sustains the community.

For this study the lead author, Sack, invited the other three members of this community of practice to participate in this joint publication, initially by writing their own personal narratives about the influences that brought them to this institution and to this particular community of practice. During this time, the members met regularly, approximately every two weeks over the course of a semester, to contribute personal perspectives about their collaborative work, to provide ongoing member checks on others' narratives, and to discuss the text as it evolved. Thus, the knowledge that evolved out of this collaboration became the data that supports the theoretical constructs of this narrative inquiry. The authors' shared interest in improving student learning across their mathematics content and methods courses for undergraduate, pre-service teacher candidates, provided the bedrock for establishing a community of practice.

Schwab's Commonplaces of Curriculum

This narrative inquiry focuses on how the participant researchers related their perspectives about teaching and learning through the lens of Schwab's (1962, 1973) *commonplaces of curriculum*. Schwab refers to the subject matter, the learners, the milieu, and the teacher as four essential "commonplaces of equal rank" (1973, p. 508), which he termed collectively the *commonplaces of curriculum*. In his understanding, these elements should be discussed with equal emphasis in any conversation about curriculum. The *subject matter*, as interpreted, should be well understood by the teacher. For example, a mathematics teacher should know what it is to be a mathematician and what it means to explain and justify one's mathematical conclusions. With respect to *learners*, the teacher should know what the learners already know, what each will find easy or difficult to learn, and what motivates or creates anxiety in each learner. The teacher should address the curriculum in ways that ensure the understanding of conceptual or cognitive components that meet the needs of each group of learners. The *milieu* represents the learning environment that impacts the affective aspects of learning. How do the learners relate to one another and to the teacher? What kind of interactive structure does the teacher favor? Beyond the classroom, how does this structure align with the learning of the curriculum content for each particular course? When working with undergraduate students, how do policy statements such as state required mathematics courses influence the milieu? How can professors support their students as they negotiate through the complications of an institutional bureaucracy and the demands of rigorous degree plans? The *teacher* commonplace refers to the instructional approaches that the teacher uses. Is the teacher flexible and ready to learn new ways of teaching? How likely is the teacher able to relate well to diverse learners, who may include, for example, non-traditional students, students from under-represented groups, or those recently graduated from urban high schools? What biases does the teacher bring to the classroom? It is the integration of the four commonplaces of curriculum that provides for successful learning for students. If any one of these commonplaces dominates or is dominated by the others, then the whole learning experience will be compromised.

Schwab (1983) also discussed the importance of membership in communities of practice. His essay describes how he sees school community participation, including teachers and administrators whose unified goals are to support all of their students. However, these ideas transfer to university settings by including administrative support in various ways, such as by encouraging inter-departmental collaboration.

Personal Beginnings

In this section, the authors' personal narratives describe key events or people that set them on pathways leading to this particular collaboration. Personal narratives of their own experiences as learners as related to Schwab's commonplaces of curriculum provide the backdrop to their ongoing work and the data for the first research question. What past experiences with mathematics motivated them to participate in this community of practice?

Nancy Leveille, Associate Professor of Mathematics Education, Department of Mathematics and Statistics

Nancy wrote,

> From my fifth grade teacher I learned to be patient with students who are not quick with answers to mathematics questions; I learned to listen to others; and I learned to wait my turn. I learned a great deal more as well. I learned to love mathematics, and that year I decided to become a mathematics teacher.

Nancy's undergraduate experiences as a major in mathematics had been challenging, given that her high school preparation was weak. She came from a very small school that did not offer pre-calculus or calculus courses to graduating seniors. She understood "what it is like to feel dumb and inadequately prepared," but it was "very caring teachers and a strong work ethic" that got her through these courses. After obtaining her B.A. degree in mathematics with minors in secondary education and natural science, she became a teacher. Her first year teaching 7th and 8th grade math, science, and reading was difficult; and she was without mentoring support. She relied on National Council of Teachers of Mathematics readings to help make her math classes interesting. After this difficult year, she decided to go to graduate school to earn her master's degree in mathematics.

Over the course of many years, Nancy had opportunities to teach in a variety of schools across the U.S. and internationally, and she developed a breadth of experience with diverse student populations and curricula. These experiences helped to develop her specialty, teaching low level students, often in remedial or "developmental mathematics" courses in community colleges and at UHD.

Timothy (Tim) Redl, Associate Professor of Mathematics and Assistant Chair for Freshman Programs, Department of Mathematics and Statistics

Tim draws his passion for teaching from several "gifted, hardworking, and dedicated teachers, who exhibited a true love for their craft." This group of teachers included his mother, an elementary teacher, who also gave him a "wealth of inspiration." He claims that mathematics did not always come easily to him, especially in college. He attributes his college success to a study group of other mathematics majors, a community of practice in its own right, during the college years when he struggled with time management issues. The group always made sure that all its members understood the course material and submitted their work on time so that all could be successful. Tim earned his M.A. and Ph.D. in Computational and Applied Mathematics at Rice University in 2004. Following a year as a post-doc lecturer at Rice and at a local community college, he joined the faculty at UHD's Department of Mathematics and Statistics in 2005.

Judith Quander, Assistant Professor of Mathematics Education, Department of Mathematics and Statistics

Judith's career as a mathematician and mathematics educator "is no accident." She was exposed to mathematics at an early age by her mathematician father, who provided substantial emotional and academic support throughout her school and undergraduate years. During an undergraduate internship she realized she was not cut out for the routine of a corporate finance career. While searching for career paths that would utilize her passion for mathematics, she found out that opportunities in mathematics education might be more rewarding and plentiful than those for graduate mathematicians. After graduating with a Masters in mathematics, she taught middle school for two years and then went on to earn a Ph.D. in mathematics education.

During her graduate school time, both in pure mathematics and later in mathematics education, Judith became acutely aware of the tensions between mathematics faculty members and mathematics education faculty members, regardless of whether they were appointed in the same mathematics department or across mathematics and education departments. However, after graduating with her Ph.D. in mathematics education, in her position as a researcher with the National Council of Teachers of Mathematics, she saw for the first time how mathematicians and mathematics educators can collaborate in "respectful and incredibly powerful ways." In 2010, Judith was appointed to the faculty of UHD as the second mathematics education professor in the Department of Mathematics and Statistics.

Jacqueline (Jackie) Sack, Associate Professor of Mathematics Education, Department of Urban Education

Jackie grew up in apartheid-era South Africa. She had outstanding high school mathematics and physical science teachers, and in college she double majored in mathematics and chemistry. Her mathematics professors and tutorial graduate assistants were extremely unapproachable, and she barely managed to pass some of those upper level mathematics courses. She earned a graduate "honours" degree in chemistry in 1975, after which she and her husband emigrated from South Africa to the United Kingdom. Five years later, they emigrated from a relatively stable but lonely life in the U.K. to Houston, Texas, in the U.S. Dissatisfied with her first career as a chemist and on the cusp of the World Wide Web becoming widely accessible, she earned a Masters in Library Science. Following two years as a technical information specialist for an engineering research company, she was offered the position of school librarian in a small independent school. A year later, the principal asked if she would teach two high school classes, Algebra and Earth Science (she had taken a full year of geology as an undergraduate). At that point her life changed, and she became a teacher.

After teaching middle and high school mathematics and some science classes for 18 years, she was hired by her district's mathematics department to write replacement curriculum modules. These became the seeds for ongoing revision over many years as a professional developer and instructional coach of mathematics teachers and later as an instructor of mathematics methods courses. During this time, she enrolled in a doctoral education program in mathematics education. In 2009, she was appointed to the UHD faculty as a mathematics education professor in the Department of Urban Education.

Each author, a member of the community of practice, had had prior experiences with mathematics that either reinforced the importance of curriculum balance or begged for the balance that would have promoted greater success. In some cases, this clear lack of balance has

influenced the way they believe mathematics should be taught, with the commonplaces of curriculum (Schwab 1973) in balance. In his personal narrative, Tim provides a quote from the mother of one of his community college algebra students:

> My daughter had the privilege of taking Math 1314 from Dr. Timothy A. Redl . . . . Dr. Redl's teaching style exemplifies both academic excellence as well as true compassion for his students. His passion for mathematics was contagious. Dr. Redl possessed an amazing ability to put students at ease, which made it easier for them to ask questions and master the material.

In making his students feel safe to ask questions, Tim could easily have adjusted the rigor level of the course to accommodate their possible lack of foundational knowledge (overemphasis on the learner commonplace at the expense of content rigor). His focus on mastery (teacher and content) while attending to making his students feel safe (learner and milieu) show that he already had the curriculum commonplaces in balance even at this early stage in his teaching career. "I truly want them to know that I am here for them and for their needs. . . . I want [them] to know that I believe in them and in their abilities and that I promise to do everything in my power to help them succeed." In 2011 Tim was awarded the prestigious UHD Excellence in Teaching Award.

Nancy's personal struggles during her undergraduate college years helped to form her teaching. The following comments address her focus on the learner and milieu commonplaces:

> I try to help students avoid experiencing feelings of utter inadequacy. I focus on creating a positive experience for each student in my classes. My purpose is to bring each one from wherever their mathematical knowledge is when they arrive in my class to what it needs to be when they finish the course.

With respect to the teacher and content commonplaces she said, "I carefully explain new material and build new concepts on a solid foundation to show students how they can overcome deficiencies in their academic preparations."

Judith comes to this story with a very different view of higher education mathematics teaching during her graduate school years. She noticed a blatant disregard for mathematics educators by pure mathematics professors. As a doctoral student, she attended a conference that brought mathematics educators and mathematicians together.

> I noticed many of the mathematicians belittling and dismissing mathematics education as a field. They discounted the notion that mathematics education was a true discipline that had a broad body of knowledge of mathematics teaching and learning as well as mathematics itself that extended beyond the typical canon of mathematics. In simpler terms, I saw a refusal to accept the possibility that mathematics educators might know more about teaching mathematics than the mathematicians in the room.

Schwab, in his series of articles on "The Practical" (1969, 1971, 1973, 1983), berated scientists (he was a research geneticist) for their focus on the content commonplace, so clearly described by Judith, at the expense of the teacher, learner, and milieu commonplaces that Tim had been so careful to nurture from his early beginnings as an instructor. Judith's experiences while working at the National Council of Teachers of Mathematics allowed her to glimpse a different perception of the relationship: "I met both mathematicians and mathematics educators who were open to each other's expertise and were willing to listen to each other in the name of making teaching and learning of mathematics better for students." From her perspective, it

appears that faculty members from both sides should be open minded to what the other has to offer, helping to bring the teacher, learner, and milieu commonplaces into balance with the content.

While Tim and Judith had experienced success in their undergraduate and graduate mathematics schooling, Jackie had a different experience. She explained as follows:

> My memory of that Mathematics II second-year course leaves me cold. How does one deal with bad instruction in a required course? I had to master the content regardless of the quality of its delivery. I sat within the first five rows of the crowded lecture theater. The professor marched to the blackboard and proceeded to write down line upon line of unintelligible mathematics. Occasionally he would stop, utter a few words of explanation, and turn back to his scripting. As a student, it was dangerous to ask questions. He only addressed those sitting in the front rows who were brave enough to ask. There was no time to ask a neighbor for help or opportunity to voice one's frustration with the situation. One simply copied every single letter and symbol that was written, fearful that something would be misrepresented. Anyhow, I would never have known.

Was Jackie's lack of success in upper level undergraduate mathematics courses due to an imbalance of the curriculum commonplaces, much as Judith had sensed in that early cross-disciplinary conference?

The 3+1 Community of Practice

This section addresses the research question of how this collaborative group of mathematics education and mathematics faculty members evolved from its beginnings into a mature, active community of practice.

Beginnings

During Jackie's first year at UHD teaching mathematics methods courses to undergraduate juniors studying to become elementary and middle grades generalist teachers, she became aware of significant gaps in their mathematical content knowledge. For example, when asked to explain why we use particular steps to operate fractions, they had two responses: "This is how we were taught," or "I have no idea, and I am unsure which rule to use." To address her own need to respond to these kinds of gaps using alternate methods to those presented in the methods textbook, Jackie began to visit classes taught by a colleague and long-time mathematics methods professor, Michael. He had taught elementary mathematics methods for many years. In 2010, they initiated conversations with Nancy, who they knew would share her perspectives on these students since she was teaching the prerequisite mathematics content courses at UHD for future teachers. In turn, she suggested they meet with Tim, who also taught some of these courses to bring a different perspective to the picture. At the same time, the Department of Mathematics and Statistics was interviewing candidates for a new mathematics education position. The new faculty member, Judith, would also teach these courses as well as college algebra, which has become a difficult, gate-keeper course for hundreds of students to pass and is a core course requirement for graduation. Judith was to begin in this position in the next academic year.

Jackie submitted a proposal to *The Texas Faculty Collaboratives: College & Career Readiness Initiative* (http://www.txfacultycollaboratives.org/mathematics) to jumpstart a formal collaboration between the two departments in order to address the issue of improving the level of mathematics performance for all of their students. . The grant was awarded and provided a small stipend for these five faculty members, 3 in the Department of Mathematics and Statistics and 2 in the Department of Urban Education, to meet weekly during the 2010 academic year.

How does one establish a culture of openness so that the initial goals of a community of practice may be realized? In her position as an eighth grade mathematics teacher, Jackie had become well aware of threats to professional learning communities, for example, by having to participate in mandated meetings for teams that had been selected by administrators with a directed purpose that might not necessarily align with individuals' personal purposes. However, she had also worked successfully with three teams of teachers in different content areas over a 10-year period, persons who taught the same group of approximately 150 students each year. In her position as mathematics department chair for five years she had experienced challenges from those who did not trust her perspectives on how they might help their students' performance in their classrooms.

How did this particular professional learning community evolve into a community of practice in which each participant felt sufficiently safe enough to share personal stories? Since Jackie and Michael had initiated the collaboration, they also met several times to work out strategies that would be perceived as non-threatening and also of mutual benefit. Together, they decided that, with group approval, over the course of several weeks each person would share mathematics activities deemed to be very engaging and successful from their own classrooms. By sharing successful practices they might add ideas to their own repertoires. Through this non-threatening interaction, the group established the trust that was key to establishing the programmatic changes and collaboration on funded projects that would ensue across both departments.

Maturation

Wenger (1998) described the stages of development through which communities of practice evolve. Initially, in the *potential* stage, "people face similar situations without the benefit of shared practice (p. 3)." By sharing mathematics activities that each member had used with some success, this community moved into the *coalescing* stage. Through the sharing of those activities they explored connections and defined the joint enterprise of helping their struggling students better conceptualize important concepts across their courses. After meeting regularly for two semesters, trust had been established; and they began to move into the *active* stage, in which members develop a collaborative practice. They were ready to engage in ways to support the teaching of mathematics in the greater Houston region through new projects on which they would work together. The now mature community of practice had begun to shape the identities of each faculty member through their desire to teach their content with a focus on balancing the four commonplaces and to improve the learning of mathematics in the region's urban high schools by developing new mathematics teachers who would engage in learner-centered instructional practices as they become teachers.

The Impact of this Community of Practice

How has this community of practice impacted the members' departments? First, we provide background information about the Urban Education department, which primarily serves undergraduate teacher candidates who seek elementary (generalist and dual language) and middle grades (generalist) teaching certificates. These students major in Interdisciplinary Studies through the education department, taking several courses within the department prior to their two semesters of school based field experiences and concurrent courses and culminating with one semester of student teaching. Students seeking secondary, content specific teaching certificates typically obtain their bachelor's degrees through the department of their major. While the elementary and middle grades certification programs typically support cohorts of approximately 200 students each semester, the secondary certification program supports fewer than 10 students each year across multiple content areas. The next section describes the funded project that has increased that number of secondary undergraduate teacher candidates.

The Noyce Scholarship and Teacher Quality Projects

In 2011, with Judith as the Principal Investigator (PI) and Nancy, Tim and Jackie as Co-PIs, UHD was awarded a 5-year National Science Foundation Noyce grant to provide scholarships to undergraduate mathematics majors who also wish to become secondary mathematics teachers. This project would bring the community of practice even closer together. At this point, the fifth original member of the community, Michael, elected to help with the project's evaluation and no longer to participate actively in the group's ongoing collaborative activities.

In order to support the Noyce scholars as they pursued their degree plans, the four faculty members, hereafter called the Noyce Team, met with them at the beginning of their program and frequently thereafter as they moved through the three field experience semesters required by the teacher education program. As the education department's arm of the Noyce scholarship project, Jackie took on the charge of finding exemplary high school mathematics teachers to serve as mentors rather than depending on seemingly random volunteer teachers in schools where she had no connections. From her previous position as an instructional coach, she had retained contact with many high school mathematics teachers across two of the largest districts in the region. Since Noyce scholars graduate with a secondary certificate that spans grades 7 through 12, the team decided to place each scholar in a middle school mathematics classroom for one of the two field experiences and in a 9th or 10th grade Algebra 1 or Geometry classroom for the other, these being the most likely positions that schools need to fill. This activity relates to the importance of integrating Schwab's (1983) commonplaces of curriculum into Noyce scholars' early classroom field experiences by carefully selecting mentors who exhibited well balanced teaching styles.

In order to have access to good middle school mathematics mentors for the Noyce scholars, Jackie and Tim collaborated as Co-PIs on a federally funded *Teacher Quality* (http://www.thecb.state.tx.us) proposal to support mathematics teachers from urban public middle schools. Beginning in the summer of 2012, approximately 25 teachers attended two summer institutes at UHD, followed by ongoing class meetings during the ensuing academic years.

In 2015, the UHD Noyce Scholarship Project boasted of its first graduates becoming full time mathematics teachers in high-needs urban schools in the region. Ongoing support was still provided through regular meetings for Noyce undergraduate scholars and graduates with

the Noyce Team. Additionally, team members visited scholars' field classrooms and graduates' classrooms to provide instructional support and coaching. These activities are not typical experiences for regular students or graduates. Thus, the Noyce team had deliberately sought to support its graduate teachers through balanced commonplace activities to promote success.

The Noyce scholarship project has impacted both the education and mathematics departments by increasing the numbers of mathematics majors who wish to pursue secondary mathematics teacher certification. The University has a very strong teaching focus. Each year a full time tenure-track or tenured faculty member is required to teach seven courses over two semesters. Generally, this teaching load has negatively impacted faculty members' capacity to apply for and support funded projects as part of their creativity endeavors. Thus, the Noyce project substantially raised the amount of funding brought into the University through departments that do not typically support this level of funding.

Co-teaching Experiences

How has this community of practice impacted the Noyce Team members' teaching practices?

While the activities described above deal with management and logistical work with students, the Noyce and Teacher Quality projects have also provided the team members opportunities to co-teach certain courses. These opportunities have reinforced the curriculum commonplace (Schwab 1983) balance for each faculty member within their own teaching practices.

Jackie and Tim co-taught all of the closed cohort summer and long semester graduate education or mathematics courses for teachers that were funded by the Teacher Quality project. They were charged with helping participant teachers become more inquiry-based in their teaching. These approaches contrast with mastery learning as typically promoted in college level mathematics content courses in that the teacher models a procedure and students try to replicate it on similar items. The inquiry-based approaches, using open-ended questions and extended wait times, were modeled extensively by Tim and Jackie during the summer institutes in alignment with balancing Schwab's commonplaces of curriculum (1983). Through co-teaching each was in a position to critique the other, in front of the participating teachers. This reinforcement of these approaches helped both instructors to become more learner-centered in their own teaching practices.

The Noyce grant provided Jackie a course release to co-teach a geometry course for high school teachers, offered by the mathematics department and taught by either Nancy or Judith. In this way students, including Noyce scholars, were provided integrated content and methods for teaching secondary level mathematics that supplemented the relatively scant secondary methods courses provided by the education department. Judith believes that her students showed above normal engagement in this inquiry-based course. Judith and Tim have collaborated on content and co-teaching of certain topics in the prerequisite mathematics courses for elementary and middle school pre-service teachers. These co-teaching experiences required respectful negotiation of each course's topics, activities, and evaluation instruments. Thus, the Noyce Team had deliberately established classroom norms at the university level in which Schwab's curriculum commonplaces were balanced. The members of the Noyce Team also continued to reach out to each other when activities in courses they were not co-teaching did not go according to plan in order to gain different perspectives on how to best reach students who struggle. This is an important characteristic of mature communities of practice, i.e., mutual trust and mutual and open respect for each other's areas of strength or weakness.

University Perceptions

We now explain how this community of practice was recognized by the University's upper administration. The UHD strategic plan (see http://www.uhd.edu/presidentsoffice/strategicplan.html) includes the goal of increasing externally funded grants across the institution to $7 million by 2015. While this was a University goal, the expectation was that the College of Science and Technology, which houses the mathematics department, would shoulder the burden of this challenge. That this community of practice alone has obtained approximately $1.3 million in federal grants since 2011, through collaboration between two departments in two colleges, is testimony to the importance of mathematics education as a field of scholarship. This accomplishment has afforded these four full time faculty members recognition through invitations to participate in particular initiatives from UHD's highest administrative level as explained in the following examples.

In the UHD mission to engage with community organizations across greater Houston, in particular with the largest public school district in the region, the administration asked Jackie to work with the team to bring a focus group of high school mathematics teachers to UHD to ascertain their needs with respect to becoming credentialed to teach dual credit (high school and college level) mathematics courses. This took place at the beginning of the Spring 2014 semester when a group of 20 teachers was welcomed personally by the University President and Provost. As a result, the mathematics department will be offering a special certificate program comprising 18 hours of graduate mathematics courses to help teachers obtain the credential. Successful teachers who need to earn a master's degree will be directed to the Master of Art in Teaching program in the education department for which they would need 18 additional credit hours. This program has resulted in an ongoing collaboration with the mathematics administration in that particular school district, which seeks to establish dual credit mathematics courses in over forty high schools in the region. Judith and Jackie have successfully earmarked both external and internal funds to support scholarships for teachers participating in this project.

While this part of the State of Texas employs the largest number of energy-related professionals in the country, downsizing due to the dramatic drop in crude oil prices is common at the time of this writing. Judith and Jackie are currently working with faculty members in the Department of Natural Sciences to secure federally funded Noyce scholarships for STEM professionals considering a career change to secondary teaching. They will help to reduce the enormous shortage of qualified and capable secondary STEM teachers in the region. The project intends to provide the 18 hours of graduate credit in mathematics or science, secondary mathematics, or science teacher certification and carefully designed professional development, with ongoing in-classroom support to fulfill the ongoing needs for highly qualified secondary STEM teachers, who will also be certified to teach dual credit courses.

Beyond their work on the Noyce scholarship project, Judith and Tim were involved in the teaching and administration of entry-level mathematics courses, such as College Algebra. In this state, every four-year institution that grants bachelor's degrees requires graduates to have at least one post-high school level mathematics course. At UHD, most freshmen take College Algebra, which is typically taught by junior tenure-track faculty, full time instructors, or part time adjunct instructors. Tim, in his position as Assistant Chair for Freshman Programs, has been charged with managing the College Algebra common course syllabus, online homework assignments, final examination review, and the common final examination. While he values

balancing Schwab's (1983) curriculum commonplaces in the courses he teaches, he felt helpless when he saw the teacher centered instructional practices employed by many of these instructors. The high failure rate was possibly a reflection of these unbalanced practices. Judith liked to teach the course, and ideally she would use learner-centered pedagogical approaches similar to what she used in her content-for-teachers courses. However, she felt constrained by the departmentalized guidelines regarding content, timeline, and curriculum. In the spring of 2014 Jackie and Judith realized the possibility of co-teaching one of her College Algebra sections in the fall of 2014. That the Provost valued this particular opportunity and was willing to cover the cost of a course release for Jackie to engage with Judith is testimony to the recognition of this community of practice afforded by the University's highest office. Furthermore, the University had set aside funds for Tim, Judith, and Jackie to establish and lead a College Algebra community of practice comprised of self-selected instructors to meet for designated professional development days prior to the beginning of the ensuing academic year. This community will be supported by their leadership team through classroom observations, co-planning, and ongoing team development activities focused on helping their College Algebra students be successful.

These activities attest to the institution's recognition of the Noyce Team, a community of practice that, in Wenger's (1998) terms, had established the joint enterprise of bringing about recognized changes in their institution. These changes included supporting students' mathematical success by learning from each other through co-teaching and through collaboratively established funded projects that would support the University's and the region's school mathematics programs.

Personal Reflections

Being a mathematics education faculty member in a mathematics department can pose interesting tensions. Judith had been teaching the typical undergraduate College Algebra course for over 15 years at various universities. She taught it as a doctoral student at a typical, four-year, residential state college, at several community colleges as an adjunct instructor, and regularly taught it at UHD. The Noyce Team, however, had provided a safe place for her to discuss and reflect on some of the concerns she had had over the course of her career. In the mathematics department, discussions about College Algebra focus mostly on pass/fail rates and making changes to the departmental final exam. Student learning and engagement is rarely discussed in these meetings. The Noyce Team not only provided Judith with a sounding board for ideas to try, it also birthed an idea to co-teach the course during one semester with Jackie so that they could work together to experiment with alternative ways of teaching the content.

Nancy, too, is a mathematics educator in the mathematics department. Before Judith came to the department, Nancy had been the lone mathematics educator. As the department moved to create space for this field of mathematics, there was much uncertainty about what it meant for mathematics education to be a part of the department. In particular, there were questions about what scholarship in mathematics education might look like—something quite foreign to many mathematicians. Through this community of practice, in particular because of the federally funded grants, mathematics education scholarship has gained credibility as a subject area in the department and at the highest administrative level. As a result members of this community of practice have been courted by other content professors to collaborate on new grant proposals. Furthermore, members of this community

of practice have been sought out by the administration to lead new projects and to join university leadership committees.

Tim reflected on his participation in the two funded projects afforded by this community of practice. He said that these projects have inspired and challenged him

> . . . to become an even better teacher (and for some courses, co-teacher) for my students, to think about teaching in new and exciting ways, and to apply inquiry-based, learner-centered teaching strategies in all of my courses – from freshman-level algebra to sophomore-level calculus to upper level operations research and decision mathematics courses, and also our teacher preparation courses for future elementary, middle, and high school teachers.

He concluded, " I am truly proud of what we have already accomplished, excited about what we are currently doing, and looking forward to what is to come."

Jackie reflected on her role as go-between for Noyce mathematics scholars, who must negotiate between expectations of both the mathematics and education departments. She has helped clear up misunderstandings as they try to make sense of education course requirements and also to integrate them into her middle grades mathematics methods courses. She commented, "I am particularly excited when my Noyce scholars use my course resources in their field-based classrooms and report how well these are received by those students. I hope they will keep these experiences close by when they become teachers of record themselves." She also reflected on her co-teaching experiences . She has had to be mindful that she is not always the instructor-of-record and must stand back to allow her colleague co-teacher to make key decisions. She commented, "It has been wonderful to be allowed to re-structure particular lessons to help concept development build from somewhat intuitive introductory problems that then progress to the symbolic abstractions and to move about and see how students deal with these connections." At this mature stage of their work the members of this community of practice had established a level of mutual trust that raised their collaborative engagement when any one member brought curriculum questions to the table.

All four faculty members have had opportunities to disseminate aspects of their Noyce work, which arose from the collaborative activities of the community of practice, to colleagues within their departments and within international, national and regional mathematics and education conference presentations. Some of these presentations have included Noyce scholars (Leveille et al. 2014, 2015; Quander and Sack 2014; Redl et al. 2013; Sack 2014).

Conclusion

The members of this community of practice have gained the respect of mathematicians in the mathematics department and of the University's administration through the curricular advances they have implemented and through their ability to bring in federal funds to a much greater extent than this institution has historically been awarded. These programs have provided them opportunities to develop and co-teach a range of courses, while integrating Schwab's (1983) curriculum commonplaces about what should be taught, how it should be taught to each particular group of students, and how to evaluate students' progress – an ongoing discussion built upon trust.

Upper administration, i.e., the Provost, has also influenced this community's work through invitations to particular university level working groups. In this context, he serves as a part-time contributor to and member of this community. For example, he called on this community to bring together school district mathematics administrators and high school teachers in order to help focus University resources and create particular courses to support the teachers. This work will directly impact the University's strategic plan to increase graduate course enrollment and also to develop meaningful community partnerships.

As this community of practice continues to evolve and as the faculty members involved become more seasoned, they will have to contend with external tensions. For example, while Jackie, Nancy and Judith were all assistant professors when the community of practice began, Nancy has received tenure, Jackie has submitted her tenure portfolio and will become an Associate professor in the 2015-2016 academic year, which is when Judith will be applying for tenure. Tim is now in his second year as Assistant Department Chair. In a small university like UHD, promising young faculty members are often asked to take a more active role in the leadership of the University by serving on university-wide communities or taking on administrative positions such as department chairs or college level deans. The tendency might be for these community members to become focused on those priorities set forth by the administration as opposed to those that come out of the community itself. As Wenger (1998, 2002) pointed out, for such a community of practice to sustain itself, its members need to find ways to balance their community of practice work with that demanded by the institution as a whole.

This community of practice, through deliberate attention to Schwab's commonplaces, has shown how they have worked collaboratively to produce high quality teaching experiences for their students and meaningful research with funded projects over a five-year period of time. They intend to extend and share details of these experiences through additional opportunities in the short and long term future.

Acknowledgment The preparation of this article was supported in part by the National Science Foundation under Grant No. 1136222. The authors wish to thank Michael Connell for his thoughtful feedback during the writing process.

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