1-1-2016

10. Building Effective Quantitative and Math Faculty Development

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1 Introduction

Faculty development — in the form of elective programs to encourage effective teaching — can transform a campus from within, and quantitative and math support centers (QMaSCs) are well positioned to lead such programs. In order to have the most positive influence, these programs must be responsive to specific campus needs, sustain partnerships across organizational boundaries, and, over time, be assessed regularly for continuous improvement.

Support for student learning and student success is central to the mission statement of any QMaSC, and the staff of such support centers is likely to spend the majority of their time working directly with students. These students, however, may often report that it is not only the content of their course with which they struggle, but the student's preferred learning style and needs may not align with the style of instruction and level of support provided within their course. Students' experiences with math teachers have tremendous power to shape their attitudes toward mathematics in profound and persistent ways. Unfortunately, these experiences may affect students negatively as well as positively. The effectiveness of teaching styles has been shown to be a factor in the development of math anxiety, which hampers student learning and fosters innumeracy at all levels of education [1].

Suggested Citation: Matthew Salomone, Kathryn Bjorge (2016), "Building Effective Quantitative and Math Faculty Development", http://dx.doi.org/10.5038/9780977674435.ch10 in G. Coulombe, M. O'Neill, M. Schuckers (Eds.) *A Handbook for Directors of Quantitative and Mathematical Support Centers*, Neck Quill Press, http://scholarcommons.usf.edu/qmasc_handbook.

This material is based upon work supported, in part, by the National Science Foundation under Grant DUE-1255945. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation

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Support centers can facilitate the use of more effective methods and manners of instruction in the classroom not only by providing a positive environment for tutoring *and* supplemental instruction, but more indirectly, through investing in both student and faculty excellence. Through faculty collaboration and provision of professional development opportunities, support centers can see their investment multiply, as each instructor they reach may in turn reach dozens more students. Centers that participate in faculty development may also find benefits from being better integrated into their campus community and culture, because they provide valuable service to both the student affairs and academic affairs divisions of their institution.

As with effective teaching approaches for students, faculty development programs can vary in their effectiveness. At best, faculty development programs can be transformative for both faculty members and their students, succeeding by both drawing upon and reinforcing positive faculty culture and institutional values [2]. Strong faculty development programs, like strong curricula, are outcome-driven and research-based. They have their own cycle of assessment and are valuable parts of their participants' self-assessment and professional growth processes. They seek partnerships, both horizontally across academic departments and vertically across instructional class, supporting senior and junior faculty, part-time lecturers, graduate teaching assistants, and undergraduate tutors and mentors. Faculty development programs foster a culture of continuous improvement among their participants and use campus-wide events to issue challenges and celebrate achievements.

Above all, though it may take many different forms, successful faculty development is intentional, even scientific. It proceeds from needs to hypotheses, experiments, conclusions, and reflection. It happens most effectively within a community of faculty, staff, and students, in which to "build the commonalities and connections so essential to our education and our society" [3, p. 92]

2 What is Faculty Development?

Faculty members hold multifaceted jobs, and so the term "faculty development" suffers from a multiplicity of definitions [4]. Most commonly, "faculty development" refers to programs that focus on the role of faculty as teachers. These programs provide support for faculty designing course syllabi and assignments, evaluating their students' learning, improving their classroom management and practice, and improving their students' experience. Other faculty development programming focuses on the role of faculty as scholars, providing support for their scholarly writing, grant writing, and administration activities. "Teacher-scholar" programs that target the intersection of these two primary faculty roles can be particularly effective; for example, encouraging faculty to bring their scholarly interests into the classroom provides for both more authentic teaching and more inclusive scholarship. Finally, faculty development programming may also focus on supporting the individual's personal professional development, wellness, and leadership, all of which can help to transform faculty's service roles on campus from onerous to effective. The particular focus of faculty

development in an institution is driven largely by institutional culture and associated contexts, such as those that emerge during a needs assessment.

Whatever faculty development is, however, it is crucial to understand what it is not. Faculty development is formative, not summative: it is an elective process of a faculty member's personal professional growth. It is not a job requirement or a part of the evaluative process by which promotion and tenure is granted. As such, faculty development programs are typically not coordinated by those faculty or administrators with direct supervision over the participants. Instead, it is initiated and supported by campus teaching and learning centers who maintain participants' confidentiality [5]. Teaching and learning center staff, replete with expertise in good teaching practice, are invaluable partners in the establishment of teaching-focused faculty development programs, on which this article shall focus.

In addition to the organizational and pedagogical support provided by a teaching and learning center, a strong faculty development program requires an active facilitator to coordinate its efforts. The QMaSC director could be well positioned to facilitate such a program, particularly if he or she is also well connected with the faculty that would participate. Because support centers occupy a unique position between student affairs and academic affairs, this affords the QMaSC access to both the unvarnished perspective of struggling students and the faculty who work with these students on a daily basis.

The kinds of events and programs that faculty development offers to its participants can also vary. Offering public presentations or colloquia on teaching practices is a natural first step. Just as with students, however, faculty members learn best through active engagement with facilitators and with one another. Faculty development programs that offer targeted skill or subject workshops, intensive teaching institutes, mentorship programs and open classrooms, and teaching consultations have been shown to be most effective in both supporting good teaching and improving faculty culture [6].

Due to its elective nature, faculty development programs sometimes find it necessary to incentivize participation either in a tangible fashion with stipends, teaching release, internal grants, or professional memberships, or in a less tangible fashion by helping participants to showcase the results of their participation in their academic portfolios. Whether or not these external incentives exist, a faculty development program's success and sustainability depends on its ability to draw on the felt significance of both its participants and its institution. Locating this significance — defining an answer to "what's in it for me?" for both the faculty that participate and the administrators that support faculty development — is the crucial job of a needs assessment.

3 Why Faculty Development? Defining a Scope and Assessing Needs

How will a quantitative or mathematical faculty development program benefit faculty, students, and the institution? Establishing specific rationales for programs will serve both to recruit the right coordinators and participants and justify its continued existence to administrators who support it. Moreover, effective academic development is academic in approach, grounded in research, and driven by data [7]. Motivation for better teaching, and for the role of a support center in helping to bring it about, can come from both the perspectives of the academic affairs and the student affairs divisions of the institution. These motivations can inform both initial and ongoing assessments of campus needs, and progress toward meeting them.

What Counts? Supporting Students' Academic and Social Development

As with everything a QMaSC does, the ultimate goal of any faculty development program is to improve the experience of students at the institution. Fortunately (and unfortunately), students' college lives are sufficiently multi-faceted that their experience may be affected in a wide variety of ways. Effective faculty development, then, is focused so as to do the most good for the most students.

Among the most obvious targets for faculty development are the academic lives of students. Outwardly, these manifest as course grades and GPA, persistence and graduation rates, and post-graduate and workforce placements. Inwardly, these are reflected in students' acquisition of particular skills and development in higher-order thinking. These are the aspects of students' college lives with which faculty members are most intimately familiar, and with which their superiors — from department chairs to deans and provosts — are primarily concerned. Even so, they make up only one piece of the student success puzzle.

Students are most likely to succeed academically when their environment is conducive to success, and this environment includes not only the academic milieu but also the social. How engaged they are in their education, their level of access to supportive educational experiences, their integration into the campus community, and their one-on-one connections with faculty members all correlate positively with students' academic achievement. Student affairs divisions are primarily concerned with these aspects of students' lives, and since they are the aspects with which faculty are least familiar, student affairs professionals are a valuable resource in faculty development.

A truly student-centered approach to faculty development addresses each phase of, and each transition within, students' college experience, from input factors (what are students' backgrounds and educational goals?) to environmental factors (how and how well are they meeting those goals while in college?) to output factors (where do students go when they leave?). Measuring student outcomes against these goals, and the mission of the institution, is essential [8] and seminars that acquaint faculty with their students' and institution's particular goals have been shown to maximize

faculty involvement in development [9].

Case Study: "Streams" Retention Enhancement[10] (Bridgewater State University, 2012)	
Identified Need:	Students leaving their math/science majors due to high rates of attrition in introductory courses
Key Metric:	Failure rates in introductory courses, initially 30-35%
Initiative:	Structured learning assistance (SLA), assigning a dedicated peer tutor to each introductory course section and creating required small-group tutorial sessions
Faculty Development:	Train faculty to design tutorial activities integrated with lecture material and to expect students to make the most use of their peer assistant
Support Center Role:	Recruit, hire, train, and oversee peer SLA assistants
Result:	Failure rates in supported courses decreased to 15-25%

Student success can be challenged most during transitions into, within, and out of college. Transition points such as students' declaration of major, enrollment in their first college math course, their first failing exam grade or course grade, and their beginning upper-level coursework, represent crucial moments in which a students' situation, self, support, and strategy are all tested [11]. QMaSCs provide an important network of peers, faculty, and resources that can provide more, and deeper, points of contact for struggling students. Moreover, faculty development is a valuable tool for reinforcing these contacts, creating shared purpose and message, and giving faculty strategies to help their students cope with difficult transitions.

Effective faculty development, then, must not miss either the academic or the student-support perspective, and the institutions with the most successful students actively attend to both aspects of their students' college experience [12]. Collaboration that includes both faculty and student affairs staff affords the best opportunity for holistic, student-centered programming enriching both students' academic and social lives.

What Can We Accomplish? Mission- and Needs-Driven Faculty Development

Effective (and sustainable) faculty development is reflective of its institution's mission, and responsive to its campus' needs. Formulating both long- and short-term goals and intended outcomes for a program will help demonstrate its effectiveness, and justify its continued existence. In this, a quantitative and math support center – of all campus units! – must be driven by data. The choice of one or two key measures of student success to address through faculty development, and track over time, is vital to a focused and impactful program.

Measures of student success come in many forms, and most institutions already collect a wide variety of them. Academic measures, which are typically collected by institutional research departments, may include the success rates of students in particular courses; persistence, retention, and graduation rates; outcome- or exam-specific assessments; or academic portfolios. Such data are often used in departmental program evaluations, and department chairs and deans are responsive to them. Due to their visibility among faculty, these are often the first measures of student success which faculty development seeks to target.

Students' social support factors, while less obvious to measure, are no less important to their success, as discussed above. There are several widely-used instruments to measure these factors, already in place on many campuses. On the input side, the CIRP Freshman Survey is a valuable tool for acquainting a campus with its incoming students' backgrounds, expectations, and behaviors [13]. The environment can be measured using instruments such as the Inventory for Student Engagement and Success (ISES) and the National Survey of Student Engagement (NSSE). These assess, respectively, the conditions present for student success on a campus and the extent to which students engage and thrive in those conditions [14, 15]. Output measures, such as exit surveys and graduating senior focus groups give students the ability to look back upon their whole college experience and provide feedback on the experiences they found most significant to their success.

The particular metrics chosen to assess a campus' needs and gauge the impact of a faculty development program will also have the effect of defining its future participants. For example, a program whose goal is to reduce the failure rate in a particular calculus course is likely to invite participation from faculty who teach pre-calculus and calculus courses, while a program whose goal is to strengthen the numeracy content of the liberal-arts curriculum as a whole is likely to invite participation from faculty across departments. Each choice comes with a unique set of opportunities and challenges.

Development Programs for Mathematics Instructors

Programs focused specifically on mathematics courses often have the luxury of taking their participants' content knowledge as given, which enables participants to focus on the pedagogy of syllabus and assignment design, classroom practice, and student mentorship and support. The Mathematical Association of America regularly shares articles on best practices in teaching undergraduate mathematics and activities for faculty development [16]. The MAA also coordinates a special interest group around research in undergraduate mathematics education. The Math Teachers Circle model, in which in-service teachers gather regularly for problem-solving and enrichment activities, may also be useful in engaging college math faculty in developing classroom strategies [17].

Faculty development focused on achievement and retention of underrepresented students in mathematics courses have been shown to be successful in improving these students' outcomes [18]. Inclusive teaching methods, such as the incorporation of active and project-based learning, feature

heavily in these programs and are especially effective in increasing the engagement and performance of diverse populations of students.

Development Programs Across Disciplines ("QuAC")

Programs aimed more broadly at strengthening quantitative reasoning in liberal-arts core curriculum courses will need to engage all faculty who teach those courses, thereby establishing a "conspiracy" across disciplines [19]. Both the MAA and the Association of American Colleges & Universities [20] have developed educational standards for cross-curricular quantitative reasoning. Likewise, the National Numeracy Network [21] strongly supports numeracy-oriented faculty development through their organization's journal *Numeracy*. "Quantity Across the Curriculum" (QuAC) programs have begun to do for the basic skill of numeracy what similar Writing Across the Curriculum (WAC) programs have succeeded in doing for student writing in the postsecondary curriculum. In fact, QuAC programs have found success emulating and partnering with established WAC programs to reach broader segments of their institutions [22].

Numeracy-oriented faculty development across disciplines entails a unique set of challenges. Faculty in disciplines that are not traditionally quantitative often do not know how to incorporate numeracy content in their teaching. Moreover, some such faculty struggle with their own math anxiety in a similar way as pre-service elementary educators do [23], and in the U.S., even highly educated adults struggle with numeracy skills [24]. Assisting faculty in locating "sophisticated reasoning using elementary mathematics" in their discipline [25] is important to place numeracy into the context of their teaching, in order that they can connect their students with those contexts in turn.

After the institutional needs and objectives of a faculty development program have been identified and made public, and a group of participants have come forward, the work of building a learning community begins.

4 What's It Look Like? Learning and Partnerships

Because they are detached from formal evaluative processes, faculty development programs often forgo hierarchical organization and thrive in small, decentralized groups. Where the need for these programs is less urgent, teaching circles, book clubs, "brown bag" lunch groups, and seminar series, may be sufficient to carry on the work. Where specific, urgent needs, and a timeline in which to meet them, exist, these informal structures may not be insufficient. In cases that call for more intensive, focused work, faculty learning communities (FLCs) have been shown to be effective platforms for achieving program goals.

Faculty Learning Communities

Faculty learning communities are focused versions of "communities of practice," groups of practitioners bound together by shared expertise, interest, and purpose [26]. In an FLC, a relatively

small group of 4–10 faculty, instructors, and/or staff engage in an active, often year-long, collaboration. Frequent activities, workshops, and seminars are held, designed to accomplish a well-defined teaching and learning development goal. Participants in an FLC "determine both their individual and collective outcomes and ways they would achieve them" [27] and may share the responsibility of facilitating the group [28]. The establishment, facilitation, and assessment of FLCs have been extensively documented [29]. Due to their size, FLCs make smaller the daunting task of launching a new faculty development initiative and can foster close interpersonal relationships between their participants on campuses of any size. Over time, FLCs can develop into networks of support across campus that foster not only faculty and student learning, but organizational learning and progress.

There is also evidence to support the inclusion of undergraduate students, and especially undergraduate tutors, as participants in a faculty learning community. Not only does this enfranchise students in the "co-creation" of teaching approaches and course design, which is of particular value to students who plan on careers in education, but the collaboration often uncovers new insights and encourages shared responsibility for learning [30, 31].

Integrating Tutor Training and Faculty Development

One innovative approach to faculty development is to offer workshops that bring together tutors and instructors. QMaSCs with well-established programs for tutor training may find it useful to build faculty development atop their training program. The goals of tutor training programs — for instance, to increase student engagement in learning activities and help students to develop positive study habits — are goals both tutors and instructors can help to address in complementary ways [32].

"Vertically-integrated" programs for improving both teaching and tutoring are in some ways analogous to corresponding vertically-integrated programs for undergraduate, graduate, and postdoctoral research, such as the National Science Foundation's Vertical Integration in Graduate Research and Education (VIGRE) program, and the benefits of shared expertise and cross-difference dialogue are similar.

Case Study: "Beyond the Formula" Combined Tutor/Faculty Workshop [33]	
Objective:	Give faculty and tutors tools to encourage students' quantitative reasoning using non-algebraic problem solving techniques
Format:	Half-day workshop, using a combination of presentations and small-group inquiry activities; each group included both tutors and faculty
Attendance:	8 faculty/staff members; 20 undergraduate tutors

5 Is It Working? Assessment for Continuous Improvement

Faculty development programs can require substantial investments of institutional funding and faculty time to sustain. Thoughtful assessment of the program not only illustrates its value to administrators, it also highlights its own strengths and weaknesses to its facilitators and participants.

But what, and whom, should be assessed? The foremost answer to this question is linked to the needs identified when the program is established (see Section 2, above). If the mandate for a faculty development program comes from deficiency in a key metric, such as a calculus course pass rate, assessment can and should begin with this metric. However, one data point rarely paints a complete picture of the impact of a faculty development program, especially if it reflects its impact only on students. The program's impact on its faculty participants is equally deserving of measurement.

The domains of assessment for faculty learning communities [29] are applicable to other faculty development models as well. A program may assess the development of its faculty participants to demonstrate the program's reach, the efficacy of its individual program components to demonstrate its efficiency, and student learning in participants' courses to demonstrate its impact. Of these, only student learning may be assessed purely via institutional metrics. The first two must be assessed by the program itself, or by the teaching and learning center to which it reports.

Insofar as faculty development resembles other organizational training programs, its impact on participants and the effectiveness of its individual components may be evaluated on four levels [34].

1. **Reaction:** How well did participants enjoy their experience?
2. **Learning:** To what extent did participants acquire knowledge and skills?
3. **Behavior:** Did participants use this knowledge and skill to change their practice?
4. **Results:** Did participants' experiences lead to a tangible outcome?

These four levels need not be assessed with equal frequency. Participants' reaction and learning may be assessed at each workshop, institute, or event through brief exit surveys. These quick evaluations provide immediate feedback to facilitators that can help guide future programming on an ongoing basis. Assessments of participants' behavior and results are likely to be infrequent — biannual or annual — and more circumspect. For example, a key behavioral assessment tool for a teaching institute or learning community is the collection of its participants' pre- and post-workshop syllabi or the exhibition of novel assignments or pedagogical experiences they implemented as a result of their participation. Assessments of results may be tied to institutional metrics, but may also include student work or works of faculty scholarship.

Thorough assessment can also provide a faculty development program with its own best publicity. Not only is an effective program likely to secure continued funding from administrators, it is also likely to attract wider and more energetic participation from faculty.

6 Conclusions

QMaSCs are uniquely positioned on campus to facilitate dialogue and establish partnerships that lead to more effective teaching in quantitative and mathematics courses. Faculty development programs that assess and address specific departmental, student, or campus needs; sustain partnerships in focused learning communities that bring together participants from across boundaries of department and instructional class (including students); and engage in ongoing assessment have considerable influence in improving the experiences, effectiveness, and overall success of both students and faculty in the educational process [11].

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8 Acknowledgements

The authors wish to acknowledge Roben Torosyan and Ann Brunjes for their energetic support of faculty development across the curriculum at Bridgewater State University; Stacey Sheriff, now director of Colby College's Writing Program, for her partnership in launching and co-facilitating the Quantity Across the Curriculum faculty development initiative at BSU; and Grace Coulombe and the QMaSC team for putting together this valuable project.

9 Appendix

The following are materials used in the two faculty development case studies of this article: a faculty program to encourage high-impact educational practices in the sciences, and a combined faculty and student program to develop strategies for communication through formula.

"STREAMS" course development program [10, 35] (Bridgewater State University, 2012.)

Student Retention Enhancement Across Mathematics and Science (STREAMS) was a series of programs supported by the National Science Foundation's Science Talent Expansion Program (NSF-STEP). The primary goal of STREAMS was to increase the number of students graduating with a math or science degree.

STREAMS supported redesigning both curriculum and pedagogy in introductory courses with high attrition rates. As part of this effort, the faculty who coordinate and teach these courses received course development grants and attended a faculty development event. In its call for grant applications, STREAMS listed its expectations that grant recipients:

1. Introduce new course elements and commit to the implementation of these elements for several years,

2. Define or clarify course learning objectives,

3. Develop and implement an assessment plan for learning objectives,
4. Share their approach with faculty colleagues at a STREAMS workshop, and
5. Present their work at a campus-wide symposium.

In the application and in subsequent faculty development workshops, grant recipients were engaged in discussion around the following questions:

1. Describe the aspects of your current course that you believe are least conducive to student learning / achieving learning outcomes.
2. Describe the pedagogical changes you believe will best address those weaknesses.
3. What literature exists that is relevant to the changes you propose?
4. How will you know whether the changes are working? What is your assessment plan?

"Beyond the Formula" faculty/student quantitative reasoning workshop [33, 36]

As part of an interdisciplinary quantitative reasoning faculty development program, the workshop entitled "Beyond the Formula" was offered to both faculty and peer tutors. The workshop's objective was to develop techniques for conveying quantitative concepts and reasoning without relying upon formulas. The workshop was offered first as a half-day event; it was abbreviated to two hours when repeated in a subsequent semester.

The program for the half-day event included both presentations and interactive, inquiry-based discussions in mixed groups of faculty and tutors:

1. Discussion: The Trouble With Formula
   Objective: To challenge participants' assumptions about whether students are more successful reasoning within an applied context, or using a formula, using a study [37].
2. Presentation: Meaning and Context: Reclaiming Formula
   Objective: To introduce participants to their "expert blind spot" and connect formal (exact, algebraic) with informal (approximate, numerical) modes of reasoning.
3. Discussion: Telling Formula Stories in the Classroom
   Objective: To engage participants in developing a narrative around selected formulas to explain their "meaning."
4. Discussion: Peer Assisted Learning (PAL) in Formula-Rich Courses
   Objective: To invite student participants to reflect on their own tutoring practice, summarize takeaways from the workshops, and develop individual statements of teaching philosophy.

For all discussions, participants were provided with worksheets of prompts with space to write their responses. Handouts and resources from this and a variety of other quantitative reasoning faculty development workshops have been made available online [36].