Fishbowl Discussions: Promoting Collaboration Between Mathematics and Partner Disciplines

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https://doi.org/10.25891/1z36-ks38

Abstract

A National Consortium for Synergistic Undergraduate Mathematics via Multi-institutional Interdisciplinary Teaching Partnerships project (SUMMIT-P) is a collaboration of institutions focused on revising first- and second-year mathematics courses with the help of partner disciplines with prerequisite mathematics courses. This paper describes the fishbowl discussion technique used by the consortium members to encourage interdisciplinary conversation. Vignettes describing the results of conversations that occurred at several consortium member institutions are provided by the co-authors.

Keywords

Curriculum Foundations report, SUMMIT-P, interdisciplinary collaboration, fishbowl discussions

Many disciplines use mathematics, but rarely do faculty from mathematics and other disciplines engage in meaningful conversation about how the subject is taught and used in the undergraduate curriculum. Faculty from other, nonmathematical disciplines can be important partners in developing a more robust mathematics curriculum. A National Consortium for Synergistic Undergraduate Mathematics via Multi-institutional Interdisciplinary Teaching Partnerships (SUMMIT-P), a project funded by the National Science Foundation (NSF), is a nationally distributed group of institutions focused on revising first- and second-year mathematics courses in collaboration with partner disciplines with prerequisite mathematics courses. Such revisions and interdisciplinary partnerships allow faculty to encourage broader and more successful participation in science, technology, engineering, and mathematics (STEM) learning, especially as it relates to learning in undergraduate mathematics courses. The goal of these partnerships is to build stronger support for partner disciplines and to encourage critical thinking skills in all fields while empowering sustained growth in the STEM workforce.

The nine original institutions of SUMMIT-P are Augsburg University, Ferris State University, LaGuardia Community College, Lee University, Norfolk State University, Oregon State University, Saint Louis University, San Diego State University, and Virginia Commonwealth University. As of January 2020, three additional institutions, Embry-Riddle University, Humboldt State University, and University of Tennessee-Knoxville have joined SUMMIT-P. Conducted across disciplines at each institution, SUMMIT-P meetings build on the strength of collaboration between a variety of partner disciplines, including nursing, economics, business, biology, chemistry, engineering, physics, and social work. Participants from partner disciplines work with mathematics faculty to discuss appropriate measures for updating mathematics curricula to make them more relevant to students majoring in the partner disciplines.

This paper will describe the partner-discipline conversations, known as fishbowls, which have been conducted by several institutions as part of the SUMMIT-P project. These conversations were modeled on the basic methodology established at the inaugural SUMMIT-P meeting in 2016. After describing the background and methodology used in developing these conversations, we will present illustrative vignettes to summarize the experience of using the fishbowl discussion technique at six of the partner institutions. These discussions have generated a viable roadmap for developing expanded mathematics curricula based on the wish lists created through the partner-discipline conversations.

Background

The National Science and Technology Council (NSTC) report stresses the importance of STEM in helping the United States develop a competitive economy (National Science Council, 2018). STEM knowledge is a critical component for an innovative workforce. In fact, employers place a premium on employees conversant in mathematical skills. An analysis of résumés and salary reports by the jobs and recruiting firm Glassdoor (Berry, 2018) finds that the best-paying jobs are those that require mathematical knowledge and skills. However, according to the President's Council of Advisors on Science and Technology (PCAST), fewer than 40% of students who plan to major in a STEM field actually complete programs and graduate with a STEM degree (PCAST, 2012). PCAST reports that it is necessary to increase the retention of STEM majors to reach the goal of producing one million more college STEM majors by the next decade in order for the United States to maintain its excellence in science and technology (PCAST, 2012).

Attracting and retaining students in STEM programs has proven challenging. In fact, there are many reasons students abandon STEM majors. Students express that they find STEM courses uninspiring and uninteresting; some indicate that the mathematics required in these courses can be difficult, leading them to give up on their programs and pursue a different major. To reverse this situation, the PCAST report recommends improving STEM teaching methods through the use of evidence-based approaches to engage students in “active learning,” which could lead to an increase in the number of students in STEM majors; Braun et al. (2017) provide recent examples of active learning techniques. However, many teachers are unfamiliar with these approaches or lack experience in teaching using such methods (PCAST, 2012).

Work on understanding and addressing these issues was conducted in the early 2000s. The Mathematical Association of America (MAA), through the Curriculum Foundations (CF) project, conducted a series of national workshops to facilitate discussions with non-mathematics faculty from November 1999 through February 2001. In these workshops, participants from 17 disciplines provided their insights on the mathematics curriculum in order to help create meaningful and relevant content for students majoring in their disciplines. Later workshops including five additional disciplines were held between 2005 and 2007. The combined results of these workshops were summarized in two reports that offered recommendations for departments interested in updating college mathematics courses (Ganter & Barker, 2004; Ganter & Haver, 2011). The CF reports’ findings revealed that faculty in disciplines that include mathematics seek to emphasize conceptual understanding and problem-solving skills in their introductory mathematics courses. At the same time, the connection between mathematics and the students’ chosen field is often not made clear from the outset, leading to confusion and frustration. For this reason, the reports concluded that mathematicians and partner-discipline faculty should work together on curriculum development to demonstrate to students the essential connection between mathematics and their discipline. The CF recommendations emphasize creating successful experiences for students by making mathematics content relevant to students’ lives and future studies.

The SUMMIT-P consortium has worked to amend the mathematics curriculum of the participating institutions based on the CF recommendations. These changes have been implemented in ways that support improved STEM learning. In addition, the interdisciplinary collaboration within each member institution and across the SUMMIT-P member institutions creates a network that supports transformative institutional change. This network of institutions can share challenges, successes, and ideas to further promote interdisciplinary partnerships within other institutions. This can lead to improved teaching and learning in undergraduate mathematics courses and ultimately to improved STEM learning for all students.

Development of the SUMMIT-P Fishbowls

All nine institutions of SUMMIT-P participated in structured conversations, called fishbowl discussions or simply fishbowls. The fishbowls employ a discussion technique (Priles, 1993) that allows for rich interaction between groups, where one group (the partner-discipline faculty) responds to questions while the other, silent group (mathematics faculty) observes the discussion. In this way, the dynamics of discussions are focused on a partner discipline’s needs and allow for honest conversation by and between the non-mathematics faculty.

While the original CF fishbowl discussions of 1999 – 2001 were held by the Mathematical Association of America (MAA) across the country at various academic institutions, the SUMMIT-P discussions were conducted at each of the participating SUMMIT-P institutions. The ground rules established for the discussions incorporated recommendations in the CF project reports (Ganter & Barker, 2004; Ganter & Haver, 2011). The context of discussions varied however, as each SUMMIT-P institution was unique in terms of student population, size of institution, culture, partner disciplines participants, and curriculum (Beisiegel & Dorée, 2020). In each case, the SUMMIT-P project institution revisited CF report recommendations and considered whether, and to what degree, they remained applicable within their own institution, and modified them accordingly. A set of discipline-specific "wish lists" was generated collaboratively from these fishbowl conversations, where the participants sought to capture what they felt were important mathematical concepts that should be included in their revised curricula. The creation of these lists constitutes an important element in the success of SUMMIT-P's work, as the wish lists could be implemented by each institution and each discipline to map both the mathematics and partner discipline course learning objectives. We describe these institution-specific fishbowl discussions in the vignettes below.

Fishbowl Structure

The first project-wide SUMMIT-P meeting in 2016 gathered all project participants from the nine institutions, including principal investigators (PIs), co-PIs, evaluators, and a project management team (administrators of the NSF grant) representing a variety of disciplines.

To prepare for the inaugural fishbowl, all SUMMIT-P members read the CF report that was relevant to their discipline and reviewed the original recommendations in that report. In addition, questions to be used in the fishbowl were provided to participants ahead of time (see Table 1). The fishbowl participants were first asked if the recommendations from the original CF report still rang true and if there were any points missed by the recommendations or learning skills omitted from the original summary CF reports. The other questions were arranged in four categories: understanding and content, technology, instructional interconnections, and instructional techniques. Table 2 provides a list of the participants and the roles necessary for a fishbowl discussion. Since there were over thirty SUMMIT-P project participants, two fishbowl discussions occurred simultaneously, one with faculty from the physical and natural sciences and engineering and one with faculty from the social sciences, business, nursing, accounting.

The fishbowl facilitators had an important role in guiding the conversation. The discussions in the initial SUMMIT-P fishbowls were led by two non-mathematics SUMMIT-P participants (engineering and economics) who posed questions, directed discussion, and monitored the time. Significantly, facilitators were chosen from a discipline other than mathematics to ensure that faculty from the partner disciplines would feel comfortable answering questions about the mathematics skills needed for their own disciplines. At the same time, it was deemed important for the partner disciplines to be aware of and acknowledge mathematics faculty members' opinions. For this reason, mathematics faculty were expected to observe the conversations and serve as a resource if there were any questions. After about 20 minutes, the discussion was opened up to the mathematics faculty observing the fishbowl.

The participants of the two initial SUMMIT-P fishbowls then participated in fishbowl discussions at their respective institutions as part of their institutional SUMMIT-P projects. In this way, the activity at the SUMMIT-P meeting proved to be a beneficial modeling exercise for learning and experiencing the process firsthand.

Table 1
Fishbowl Activity Questions

General
1. As you read the CF report, do the recommendations still ring true?
2. Do you believe there are topics unique to your discipline that are not reflected in the summary report?

Understanding and Content
1. What conceptual mathematical principles must students master in the first two years?
2. What mathematical problem-solving skills must students master in the first two years?
3. What broad mathematical topics must students master in the first two years?
4. What priorities exist between these topics?
5. What is the desired balance between theoretical understanding and computational skill? How is this balance achieved?
6. What are the mathematical needs of different student populations and how can they be fulfilled?

Technology
1. How does technology affect what mathematics should be learned in the first two years?
2. What mathematical technology skills should students master in the first two years?
3. What different mathematical technology skills are required of different student populations?

Instructional Interconnections
1. What instructional methodologies relative to teaching mathematical concepts in your discipline would you like to be made aware of?

Instructional Techniques
1. What kinds of mathematical technologies do you use in your discipline?
2. What mathematical technologies should students develop?

Vignettes

The vignettes presented here provide summaries of fishbowl discussions conducted from 2016 – 2017 at six SUMMIT-P institutions: Augsburg University, LaGuardia Community College, Lee University, Norfolk State University, Oregon State University, and Virginia Commonwealth University. The authors describe the experience of using the fishbowl discussion technique, including the preparations for, participation in, and outcomes derived from the conversations that took place on their respective campuses. As these vignettes show, even though the basic methodology was modeled at the 2016 SUMMIT-P meeting, each institution customized the technique to suit their institutional profile and specific programmatic goals and needs.

According to the rules laid out in the initial SUMMIT-P meeting, depending on the size of the group and the number of disciplines involved in the discussion, an institution could choose to run a fishbowl with any number of partner disciplines. For example, Oregon State University ran a fishbowl with faculty from biology while Lee University facilitated a fishbowl discussion with chemistry and biology. Augsburg University held seven separate fishbowls (a separate fishbowl for each discipline).

In the vignettes that follow, Rhonda Fitzgerald from Norfolk State University and Joan Kunz from Augsburg University explain the process of conducting fishbowls at their universities. Tao Chen from LaGuardia Community College and John Hearn from Lee University describe the table mapping exercises by which they connect the wish lists to course learning objectives. Lori Kayes from Oregon State University provides a vignette describing the dialogue between biology and mathematics. Rebecca Segal and Afroditi Vennie Filippas describe how information and wish lists were obtained at Virginia Commonwealth University.

Table 2
Fishbowl Participants and Their Roles

The discussion technique used to create conversation and share ideas is called a fishbowl. One group (usually 5 – 8 people) sit in a circle or at a table, conversing in full view of another group of listeners (also 5 – 8 people).

Participants	Roles
Mathematics Faculty	Observers who serve as a resource if questions arise about mathematics curriculum
Partner-Discipline Faculty	Discussants who answer questions posed by the facilitator
Facilitator	Participant from a non-mathematics discipline who poses questions, directs discussion, provides a summary or recap after each question, and keeps time
Note Taker	Participant assigned to take notes and record comments of discussants and any new questions posed

Augsburg University

Augsburg University is a small private university located in Minneapolis with a diverse student population. The Augsburg SUMMIT-P team includes three faculty members from the mathematics department, one faculty member from chemistry, and one from economics. The goal defined by the Augsburg SUMMIT-P team was to revise three calculus courses (Calculus I, II, and III) to align with the CF recommendations.

The team organized multiple fishbowl conversations about calculus between the SUMMIT-P team and various partner-discipline departments: biology, chemistry, economics, mathematics education, environmental studies, and physics. They followed the traditional fishbowl format with minor adjustments. Members of the SUMMIT-P team made arrangements for the meetings and asked the partner discipline departments to consider several questions before arriving for the fishbowl event. There was one fishbowl conversation for each discipline for a total of seven fishbowls. The questions posed included the following:

- How does the faculty use calculus in their major?
- How does the current calculus delivery and sequence serve their major?
- How does the current calculus delivery and sequence not serve their major?

The fishbowl meetings were held in person with the partner discipline departments and a non-mathematics facilitator from economics (also a participant in the SUMMIT-P project) leading the discussion. The rest of the Augsburg SUMMIT-P team sat outside the inner table, took notes, and ensured they did not interrupt the flow of the conversation.

Each conversation usually started by having the partner discipline faculty describe which courses in their major use calculus and how it is used in each course. The conversation then segued into what is currently working and what is not working within the present calculus sequence. After 20-30 minutes of discussion among the partner discipline participants, the mathematics faculty were brought into the conversation. This provided a format for the Augsburg SUMMIT-P team to evaluate the strengths and weaknesses of the current system from multiple perspectives and use this information to decide what changes should be made to the calculus courses.

The main challenge in these discussions was to avoid pitfalls such as disparaging some students' apparent inability to perform basic functions of mathematics or algebra; the facilitator helped keep the discussion on track to prevent this from happening. Surprisingly, the most common source of errors was determined to be deficient skills in algebra as opposed to calculus; it was therefore determined that partner disciplines should ensure student competence in this area by employing sufficient "drill" homework that builds mastery in this algebra.

Another challenge revealed through the conversations was the divergent use of vocabulary; according to the participants, partner disciplines often use language that differs from that used in mathematics to describe a skill or concept. As one participant stated, "We still need to figure out how to help our students 'translate' between the two languages."

After the fishbowl was completed, the Augsburg SUMMIT-P team created wish lists for each partner discipline based on the conversations. These lists were then compared for commonalities. From there, the team worked on revising the calculus topics sequence to address the concerns raised in the discussions and wish lists. One key outcome of the fishbowl discussions provided significant impact to chemistry students who need multivariable calculus and partial derivatives but not some of the other topics covered by the calculus curriculum. By rearranging topics in Calculus I, II, and III, the Augsburg SUMMIT-P team provided a direct pathway from Calculus I to Calculus III. These students are thus able to succeed in Calculus III with a prerequisite of Calculus I. The Augsburg team plans to observe student performance by reviewing course evaluations and monitoring grades in both Calculus III and in the partner-discipline courses (especially physical chemistry) that use multivariable calculus.

LaGuardia Community College

LaGuardia Community College (LAGCC) is part of the City University of New York university system, which serves a diverse population (43% Hispanic, 21% Black) of 50,000 students. Many students are first-generation college students and come from low-income families. The goal of the LAGCC SUMMIT-P project was to improve students' quantitative and digital reasoning by revising College Algebra to include applications from business and the social sciences. Each semester, more than 40 sections of College Algebra are offered. College Algebra serves to assess students' inquiry and problem-solving competencies. Student responses to surveys about College Algebra found that they have negative attitudes towards the course since they do not recognize its usefulness. In addition, instructors of economics courses teach mathematics skills in their courses because of their students' diverse mathematics proficiency. In order to address this disparity, the LaGuardia team consisting of two mathematics faculty and two economics faculty are contextualizing College Algebra with economics by soliciting mathematical needs from economics faculty, exchanging and implementing mathematics resources in economics courses, piloting a course pair of College Algebra and Microeconomics, developing mathematics projects contextualizing economics, and implementing these projects in multiple sections of College Algebra.

In order to obtain authentic insights into the mathematical needs of economics courses, the LAGCC SUMMIT-P team held a face-to-face fishbowl discussion session between mathematics and economics faculty. The two CF reports were distributed among economics faculty with particular attention on the economics chapter from the report *Partner Discipline Recommendations of Introductory College Mathematics and the Implication for College Algebra* (Ganter & Barker, 2004).

The fishbowl exercise, led by an economics faculty member, began with a discussion about the reports, and all agreed that most of the mathematics needs summarized in the report also applied to their courses, specifically the following concepts from the CF reports:

- Basic arithmetic and algebra skills—equations and algebra, effects of changing parameters in linear equations;
- Calculating the area of relatively simple geometric figures;
- Generating and interpreting graphs for linear and exponential data: calculating and interpreting the slope of a line and the slope at a point on a non-linear graph, calculating rates of change;
- Two linear simultaneous equations;
- Total/average/marginal concepts;
- Compound interest.

The economics faculty indicated that additional mathematical concepts are needed for LaGuardia students in economics courses. These additional concepts include: absolute value inequalities, rational functions, and trigonometric functions.

The fishbowl discussion helped the LaGuardia mathematics faculty understand the mathematics needs of the economics courses offered at the school. One challenge with the discussion was in communicating across the two disciplines. Economics faculty presented materials in a different manner than mathematics faculty. As a result, the discussion sometimes turned into an impromptu lecture, allowing faculty from the two disciplines to understand the differing notation and concepts. Similar to the conclusions from the original CF report, the discussion revealed that mathematics is widely applied across the economics curriculum at different levels.

After the discussion, economics faculty were invited to summarize the needed mathematical topics and to provide some related economics examples in detail. In order to truly understand the application of mathematics in economics courses, a mathematics faculty member visited economics courses to observe how mathematics is applied in these courses and to witness the challenge students face when they apply mathematics in these courses. Moreover, faculty from economics and mathematics matched the syllabi of two courses, College Algebra and Microeconomics, to develop a detailed mapping of concepts and to create a timeline so that students are mathematically ready for all economics topics that will be taught. Table 3 provides a mapping of concepts between College Algebra and Introductory Microeconomics.

Table 3
LAGCC: Mapping Curriculum between College Algebra and Introductory Microeconomics

Topics in College Algebra	Topics in Introductory Microeconomics
linear equations	equations of demand and supply curves
system of linear equations	market equilibrium
difference quotient	marginal value (marginal cost, marginal revenue, marginal product, marginal utility); elasticity
operations of polynomials	cost function, production function in polynomial functions
quadratic functions	cost and revenue functions
rational functions	cost function, production function in rational function
inverse functions	converting demand/supply functions where the price depends on the quantity demanded/supplied
exponential functions	compound interest; growth in macroeconomic variables such as GDP, price level, and others; exponential consumer utility function
exponential equations	consumer preferences
logarithmic functions	compound interest; growth in macroeconomic variables such as GDP and price level; logarithmic production function; logarithmic consumer utility function
logarithmic equations	consumer preferences; production decision

The LAGCC SUMMIT-P fishbowl showed that some quantitative skills are essential, for example, in economics courses, understanding tables of data and creating and interpreting graphs. From the experience of economics instructors, students who lacked these skills tended to perform poorly in economics courses. Therefore, the exchange of ideas across these two disciplines was felt to be vital to understanding the mathematical needs supporting the subjects in these courses.

Lee University

Partner-discipline faculty from chemistry (John Hearn), psychology (Brian Poole), and education (Jason Robinson) worked with mathematics faculty (led by Caroline Maher-Boulis) to revise Algebra for Calculus, College Algebra, Concepts of Mathematics, and Statistics. Each of the partner disciplines conducted separate fishbowls, and we present here the results from discussions between science (chemistry and biology) and mathematics faculty regarding Algebra for Calculus. This course was selected because it is a foundational course for much of the chemistry and biology curriculum. The fishbowl was jointly facilitated by John Hearn and Caroline Maher-Boulis.

Prior to the fishbowl exercise, the CF recommendations were presented to chemistry and biology faculty by a SUMMIT-P team member and they were asked which recommendations they would give highest priority. The Lee University team then deviated slightly from the traditional format during the actual fishbowl exercise. Partner-discipline faculty were given the current Algebra for Calculus syllabus as well as relevant information from the CF reports. These documents were used to keep the conversation focused and relevant.

As part of the fishbowl exercise, partner-discipline faculty discussed the CF recommendations and generated a wish list based on those recommendations. In addition to the algorithmic skills of algebra (e.g., solving for x), partner-discipline faculty wanted students to have a solid understanding of the characteristics of functions and relations and their similarities and differences. The CF recommendations were particularly relevant in regards to two statements: (1) students majoring in biology need to understand the meaning and use of variables, parameters, functions, and relations, and (2) students majoring in chemistry need to be able to follow and apply algebraic arguments in order to understand the relationships between mathematical expressions, to adapt these expressions to particular applications, and to see that most specific mathematical expressions can be recovered from a few fundamental relationships in a few steps (Barker & Ganter, 2004).

Partner-discipline faculty drafted a wish list consisting of nine statements. For students to have a "good understanding" about functions and relations, they should:

1. Be able to generate mathematical expressions from fundamental relationships or through logical deduction,
2. Be able to work with equations without the letters "x" and "y,"
3. Know the difference between dependent and independent variables,
4. Be able to regroup variables and constants to simplify expressions,
5. Be able to manipulate and quantitatively explain rational relations,
6. Understand numeric, algebraic, and graphical relations and their interrelationships,
7. Be able to move beyond language to conceptual thought,
8. Be able to interpret graphs, and
9. Be able to manipulate equations with confidence.

Since the recommendations would be implemented at Lee University, the team was able to take the fishbowl exercise a step further and conduct a syllabus review. After the faculty discussed the CF recommendations and drafted a wish list, they reviewed the current Algebra for Calculus syllabus. The mathematics faculty member answered questions about the course with the goal of mapping the wish list items to the general course objectives and topics (see Table 4). The wish list items were not mapped to the specific behavioral objectives (e.g., solve quadratic equations of one variable) that are used as the primary measurable outcomes of the course. Instead, each wish list item noted above was mapped to one or more learning objectives or course topics (see Table 4). Such mapping provided the necessary feedback for determining whether the curriculum needed to be modified in any way. The mathematics faculty concluded that all of the wish list items were addressed somewhere in the Algebra for Calculus course.

Table 4
Wish List Items Mapped to Algebra for Calculus Learning Objectives and Topics

	Wish List Item								
General Learning Objective	1	2	3	4	5	6	7	8	9
Acquaint the student with the processes for determining the correct algebraic model from a given set of data.	X								
Acquaint the student with the processes for determining a locus or graph for a given algebraic equation or function.								X	
Acquaint the student with the processes of using algebraic models to solve everyday types of problems.	X	X					X		X
Course Topic									
Algebraic equations and inequalities									
Functions and graphs			X			X		X	
Polynomial functions: zeros and graphs						X		X	
Rational functions					X				X
Exponential and logarithmic functions									X
Systems of equations and inequalities				X					X

One of the course topics not listed in Table 4 is “equations in one variable.” This topic caused some confusion among partner-discipline faculty because the word *variable* in science has the precise meaning of something that can change. When an algebra textbook says, “an equation in one *variable*,” a scientist may say, “an equation with one *unknown*.” As the conversation progressed, the partner-discipline faculty asked whether such a topic was needed, since equations with two variables become equations with one unknown when the value of one of the variables is specified. This change would allow more time to be devoted to more advanced algebraic concepts, such as exponential and logarithmic functions. At the conclusion of the fishbowl activity, the algebra faculty member decided to remove that topic (equations with one variable) from the course curriculum.

Following the fishbowl exercise, partner-discipline faculty drafted several problem sets involving applications of algebra in biology, health science, and chemistry. These problem sets were intended to serve as a resource for algebra instructors. The instructor could show students how they may be asked to apply the algebra content in later discipline-specific courses. In addition to generating direct input into the algebra course, the fishbowl discussions revealed areas where partner-discipline faculty could improve their courses by helping to bridge the gap between mathematics and science. These outcomes, however, were not systematically documented.

The Lee University fishbowl led to the following two results. First, while Algebra for Calculus already addressed all the topics outlined in the wish list items drafted by partner discipline faculty, the time devoted to these topics was revised so that logarithmic and exponential functions could be covered near the end of the course. Second, partner-discipline faculty garnered a better understanding of the language differences between mathematics and science courses. This awareness can improve mathematics education while also advancing science education.

Oregon State University

At Oregon State University (OSU), the SUMMIT-P discipline partners are biology and chemistry. Only the biology partnership will be discussed here. The biology faculty involved directly with the project are two senior instructors who teach either a very large enrollment (~1000 students per term) introductory biology course for life science majors or a large enrollment (~200 students per term) upper division human anatomy and physiology course. The mathematics faculty member is a tenured associate professor in mathematics education. The OSU team is working on discipline integration into Differential Calculus courses. Differential Calculus was chosen for a number of reasons: 1) Calculus (Differential and Integral) is required for biology majors, and 2) there has been a lot of focus on improving college algebra courses using adaptive online and active in-class learning that is concurrent with the SUMMIT-P project, and the OSU SUMMIT-P team wanted to avoid conflicting projects. The modified fishbowl activity was facilitated by the SUMMIT-P biology co-PIs.

The biology co-PIs engaged the entire biology department in a modified fishbowl activity to determine if their faculty's mathematics topics for biology wish list was similar to the CF recommendations. Prior to the fishbowl activity, the OSU SUMMIT-P biology team compiled a list via email of critical mathematics skills that faculty wanted students to be prepared to use in their biology classes. Using the wish list, the OSU SUMMIT-P team led a faculty meeting where faculty 1) determined if the wish list was complete, 2) indicated the mathematics skill levels they expected students have before and during the specific biology courses that individual faculty were responsible for teaching, and 3) indicated whether biology faculty used the mathematics skills in their biology courses. In this way, the fishbowl was modified to meet the needs and the availability constraints of biology and mathematics faculty.

A number of biology faculty also contributed ideas via email; the OSU SUMMIT-P team utilized this feedback to spur conversation during the faculty meeting. At the faculty meeting, the OSU team asked biology faculty to work in small groups to review the wish list and answer questions by filling out an evaluation. Biology faculty were very interested in talking about the uses of and need for mathematics in their biology classes. A noted benefit was that faculty engaged in conversations about curricula, something they rarely do. Focusing on the necessary mathematics concepts made the conversation feel less threatening to biology faculty than a conversation about biology topics. Some of the challenges in implementing the fishbowl technique included finding ways to include biology faculty who do not teach biology majors in the conversations and reaching faculty in different units who teach core biology courses. Additionally, the biology faculty largely found the OSU students lacking in generalized mathematical skills (i.e., proportions, fractions and probabilities) that are not taught at the collegiate level.

In general, the wish list created by the OSU biology faculty contained topics at lower mathematics levels than the concepts and skills outlined in the CF report. The OSU biology faculty also largely desired that students have strong sense of quantitative literacy (Steen, 2004). They also desired that all students and instructors use clear methods to incorporate symbols in activities and assignments that represent and model biological phenomena. Additionally, the OSU team found that very few biology faculty members actually use mathematics (except for statistics) in their biology courses. The lack of mathematical utilization appears to be somewhat sub-discipline specific; for example, the ecology and genetics focused courses were much more likely to utilize mathematics in their biology courses than physiology or organismal focused courses.

The OSU SUMMIT-P team used the adapted fishbowl protocol described above to have additional conversations about the mathematics concepts and skills they should be focusing on in the project to help identify courses in the biology curriculum that require the use of mathematics and places in the biology curriculum where they might engage biology faculty in implementing more mathematics. The OSU team recently used the adapted fishbowl protocol to encourage curricular conversations around teaching mathematics and, more broadly, the importance of mathematics in the OSU biology curriculum. Additionally, they have used the adapted fishbowl protocol to gather feedback on the quantitative aspects of the biology curriculum. The team's next steps include talking to OSU biology students about their experiences with mathematics in their biology courses. They would also like to get students to share any biology-related experiences that take place in their mathematics courses to see if they can identify any patterns and to help faculty discuss mathematics skills and concepts in a similar manner in both disciplines.

This experience taught the OSU team that the fishbowl can be useful for disciplines even without engaging the mathematics faculty in the process and that biology faculty really enjoyed discussing mathematics topics in their curricula. The OSU SUMMIT-P team were able to leverage the faculty meeting to get broad participation from faculty within a variety of sub-disciplines in biology and also engage the majority of the biology faculty. By linking the fishbowl back to the biology major curriculum and the required quantitative literacy, the OSU team was able to get buy-in from the department chair to use faculty meeting time.

The team gathered information in two ways: first through an online survey to develop an initial list of topics and then during the faculty meeting. During the meeting, worksheets were distributed with the categories and topics that had been gleaned and summarized from the online survey. Faculty completed the worksheets in small groups. The worksheets were collected after the fishbowl activity and compiled and synthesized into a final wish list.

One of the lessons learned from implementing the adapted fishbowl protocol is the need to prepare a list of mathematics concepts ahead of time. Additionally, having biology sub-disciplines (e.g., physiology, ecology, and genetics) work together so that each sub-discipline had a voice in the process and could share their specific mathematics desires was important. The OSU SUMMIT-P team was pleasantly surprised by how much the faculty thought about and cared about the mathematics skills required in their major programs. These curricular conversations around mathematics and biology continued in subsequent meetings and resulted in modifications in the biology major to expand the types of quantitative courses offered in the major.

Norfolk State University

Norfolk State University (NSU) is a public, historically black university (HBCU) in Virginia serving 5,100 undergraduates. The goal of the NSU SUMMIT-P team is to broaden the participation of African-Americans in the STEM workforce. Mathematics and engineering faculty are partnering to redesign Calculus I and II because these two courses are identified as roadblocks for students interested in majoring in science.

In May 2017, the mathematics and engineering faculty at NSU joined together for an end-of-year, half-day faculty retreat to discuss how to best serve the engineering majors at the university. To initiate the dialogue, the faculty participated in a fishbowl activity, a first of its kind at NSU. Faculty from both departments have had similar discussions; however, never had the majority of faculty from both departments been in the same room at the same time for a discussion like this. Prior to the retreat, the faculty were emailed the CF report on electrical engineering from *Voices of the Partner Disciplines* (Ganter & Barker, 2004). Printed copies were also available at the retreat.

The fishbowl activity was new to the faculty in that the engineering faculty were able to have a discussion about what they felt was important to them without having input from the mathematics faculty. The discussion was led by engineering professor Dr. D. Geddis, former SUMMIT-P co-PI, who had a list of questions through which to navigate. The second half of the morning involved working groups in discussion and producing recommendations for engineering application problems to be included in a newly designed section of Calculus I to be taken only by engineering majors.

As the conversation in the fishbowl kicked off between the engineering faculty, many of the statements were not surprising, and they aligned with the CF report. As the mathematics faculty looked on, several things became clear. First, there were a few items that engineering faculty mentioned as important that mathematics faculty may overlook or not emphasize. Second, mathematics faculty realized that there were misconceptions among engineering faculty about when certain topics were covered in the mathematics curriculum. Engineering faculty mentioned several topics that they deemed important which were not covered in the actual required mathematics courses; this opened the eyes of many mathematics faculty. At the end of the discussion, the mathematics faculty were able to suggest elective courses that would help support the engineering students.

In the end, all participants of the fishbowl discussion agreed that the CF recommendations still hold true but that there was much work to be done. Mathematics and engineering faculty need to work together to make sure that courses are aligned to better support students. The engineering faculty developed a wish list that contained the items they felt to be important. For their part, the mathematics faculty reviewed the list and discussed ways to implement the wish list items, agreeing that such conversations should be held more often. It is everyone’s responsibility to ensure that courses are aligned and to give students the tools they need to be successful.

Virginia Commonwealth University

At Virginia Commonwealth University (VCU), the main focus of the grant effort has been to strengthen student ability to transfer mathematics knowledge about differential equations to the engineering courses that build on differential equations. VCU is a large, urban research university serving 22,000 undergraduates. Approximately 7,000 students per year take mathematics and almost 80% of these students are STEM majors. Thus, better aligning mathematics courses to STEM disciplines can improve STEM learning. The VCU College of Engineering offers eight different undergraduate degree programs, and all but one requires differential equations. Because the faculty is so diverse and large, it would be challenging (read: impossible) to get input from all of the programs at once in a single fishbowl activity. In the CF projects (Ganter & Barker, 2004; Ganter & Haver, 2011), each engineering discipline offered their own report; thus, to prevent VCU mathematics faculty from having to facilitate seven different fishbowl activities, VCU took a multilevel approach to gathering information.

Similar to OSU, VCU used a modified fishbowl approach, beginning with a survey to gather information from as many faculty members as possible, using an online form. This form contained a list of all the major topics typically contained in an introductory differential equations course. The survey was sent to all the engineering faculty, who were asked to rate the importance of each topic to the courses they teach. The ratings were compiled and circulated to the mathematics faculty in preparation for their actual fishbowl meeting.

At the official fishbowl, VCU had representatives from four engineering programs as well as mathematics faculty who were current or recent instructors of differential equations. Armed with the list of the highest ranked topics, as well as the discussion questions from the CF report, VCU held a fishbowl style meeting with the engineering faculty. Some back and forth conversation did take place, but there was also significant listening on the part of the mathematics faculty.

Following the fishbowl meeting, a survey was circulated through the engineering faculty to request engineering application problems that incorporate differential equations concepts and skills. The mathematics faculty also met separately to determine the final list of topics to be covered in the course. The current syllabus is a pared-down version of that list and is a direct result of the fishbowl. Having heard that the laundry list of methods that the course used to cover is not useful for students, this survey offered a clear direction for the mathematics faculty to pursue as a way to better serve the engineering faculty.

VCU mathematics faculty took a multilevel approach to gathering information from colleagues in engineering. They conducted an online survey of all faculty to gather as much input as possible and to prime the faculty for thinking about mathematics topics. This approach worked well for this large institution, which meant that the VCU SUMMIT-P team collected broader input than would be possible with face-to-face meetings. Interested engineering faculty were then invited to participate in the fishbowl. The mathematics faculty primarily listened to the input from the engineering faculty. The VCU mathematics faculty were surprised to learn that streamlining the course content would serve engineering students better, and this information led to syllabus revisions.

Fishbowl Technique in Practice

As can be seen from the vignettes shared above, the fishbowl discussion technique used in the initial meeting and the subsequent SUMMIT-P fishbowls conducted at each member institution offered informative results and, not surprisingly, participants agreed with the CF project's original recommendations. The participants generally agreed that mathematics and non-mathematics disciplines regularly use different vocabulary to describe the same mathematical concepts. There was also agreement that the fishbowl discussions helped faculty to see and think beyond their own disciplinary silos and encouraged better communication across disciplines. Since only non-mathematics faculty participated in the fishbowl discussions, reflecting and responding to questions, partner-discipline participants felt more at ease and engaged in sharing their experiences and perspectives. In addition, mathematics faculty found it helpful to look at partner-discipline curriculum broadly to identify which mathematical concepts were used and where in the curriculum those concepts were introduced (for example, concepts introduced in upper-level courses versus introductory courses).

Conclusion

The fishbowl discussion technique provides a framework for discussion across disciplines. As seen in the vignettes, the original fishbowl technique was modified specifically for each institution. In order to move from a national model to an institutional model, these vignettes create the foundation for an institutional fishbowl framework or protocol that contains five steps:

1. Craft survey questions using the CF report with reference to the specific topics covered in the mathematics course or courses under study or slated for revision; distribute this survey to partner disciplines
2. Analyze survey responses to create a new, common starting point for the fishbowl discussion, which is shared with the partner-discipline fishbowl participants prior to the fishbowl.
3. Hold the fishbowl meeting following a structure similar to the original fishbowl, making sure the right participants are included in the fishbowl discussion.
4. Create partner-discipline wish lists and a syllabus map in which the topics identified in the survey and fishbowl are actually mapped onto the syllabus of the course slated for revision.
5. Compile and create exercises and examples with partner discipline input that utilize the mathematical concepts identified in the fishbowl exercises. Shared materials can be used in the classroom. In this way, collaborations among partner disciplines and mathematics can lead to substantive changes in the classroom curriculum to benefit student learning.

For institutions interested in conducting their own fishbowl discussions and implementing CF recommendations, it is important to obtain buy-in from partner disciplines who will fully participate. Some colleges and universities have a history of collaboration across their campuses while others do not. Emphasizing the need for reform in the content and pedagogy of mathematics courses and highlighting the potential increase in retention of students in STEM majors and improved student learning is therefore a great motivator for participation. Communication is critical: sharing and disseminating information to partners and keeping them in the loop further encourages partner disciplines to buy-into the project. Finally, it is important to have a person or group of people who advocate and champion for collaboration among partner disciplines and mathematics in order to sustain the conversations. The customized fishbowl technique fosters productive collaboration on course development and has proven to be instrumental in the success of the SUMMIT-P project.

Acknowledgment

This paper was developed in part through the project *Collaborative Research: A National Consortium for Synergistic Undergraduate Mathematics via Multi-institutional Interdisciplinary Teaching Partnerships* (SUMMIT-P, www.summit-p.com) with support from the National Science Foundation, EHR/IUSE Lead Awards 1625771, 1822451, 1942808. The opinions expressed here are those solely of the authors and do not reflect the opinions of the funding agency.

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