Title:

The Impact of Future Faculty Professional Development in Teaching on STEM Undergraduate Education: A Case Study about the *Delta Program in Research, Teaching and Learning* at the University of Wisconsin-Madison

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Vignette:

The Delta Program brought together an intergenerational, interdisciplinary team that consisted of a Computer Science graduate student, a post-doc, who is now an assistant professor at a major research university, and an assistant professor in Civil and Environmental Engineering. Through a course about creating instructional materials, the Program provided them with the capacity to accomplish the design of an interactive web tutorial to improve students' problem solving abilities.

As a result of their experience in the classroom, this team found that undergraduate students were having trouble translating word problems into the conceptual framework of disciplinary models, and then manipulating equations to solve the problems. The web tutorial that this team designed guided students through step-by-step solutions of problems, and then required them to solve similar practice problems on their own.

The team analyzed student solutions of a sample problem across two semesters to compare student performance both without and with the learning module. To do this, they classified the types of mistakes students made in their answers into categories. Setting up and solving equations, initially observed as one of the worst areas in student performance *before* use of the tutorial, saw the most improvement among the six types of student solutions analyzed. From their data, these researchers concluded that the web tutorial approach was effective in reducing students' misunderstandings about solving this type of problem. The data also indicated additional areas where students needed support, which gave the team clearer insight into the next round of revisions.

The story of this intergenerational, interdisciplinary graduate student, post-doc and faculty team provides some insight into the broad value of Future Faculty Professional Development (FFPD) programs. *First, these programs can have profound benefits for future faculty by providing them with the training that they need to (a) be better prepared for entering the job market, and (b) for their roles once in a new position. Second, FFPD also have an enormous potential to improve undergraduate education at both the training institution (e.g. by way of implemented projects as well as through Teaching Assistants (TAs) who are more fully trained), and the undergraduate institutions that employ these future faculty*. In this white paper, I will address both aspects of this issue. After providing background information on the landscape of recent FFPD programs and initiatives in higher education, I will focus on a specific FFPD program, the Delta Program in Research, Teaching and Learning (hereafter referred to as the Delta Program or Delta; www.delta.wisc.edu) at the University of Wisconsin-Madison (UW-Madison). In addition to describing the format and structure of this program as well as some of its offerings, I will provide evidence of the impact of the Delta Program on both future faculty professional development in teaching as well as on undergraduate student learning. I will also discuss the assessment instruments and approaches being used. I conclude by discussing gaps in the research, areas where evidence is missing, as well as next steps for developing and demonstrating effectiveness of this type of professional development program for future Science, Technology, Engineering and Math (STEM) faculty.

The preparation of future faculty for their roles

There are roughly 4000 institutions of higher learning in the United States, a challenging number for any national faculty development initiative. However, approximately 80% of all United States Ph.D.'s are graduated from only 100 research universities(Walker, G.E., et al. (2008); Hoffer, T.B., et al., (2007)). Thus graduate schools represent a 40-to-1 leverage point for the preparation of the national faculty and the enhancement of undergraduate education.

Often, whether it is overt or not, the institutional philosophy of research universities values research above teaching. Therefore, while graduate students and post-docs receive excellent disciplinary research training, many receive minimal, if any formal training to teach (Boyer Commission, 2002). For example, teaching assistants (TAs) or gradate student instructors (GSIs) are likely to receive variable amounts of training before entering the classroom. For many, this training is not uniform, and may fluctuate from several hours to several days depending upon the student's college and department in the institution. Once they enter the classroom, there may be no follow-up training or discussion available. This is obviously not the case at all institution, but its prevalence impacts the preparation of these students for their roles as TAs or GSIs and beyond.

In the same way, the amount of training and preparation that graduate students and post-docs receive, beyond research training, for their future responsibilities as faculty (e.g. how to manage a research group, how to mentor their own graduate or undergraduate students, how to do outreach/service, how to teach, etc.) varies by institution. This lack of alignment between training received and the skills and knowledge that future faculty will need to be successful (Austin and McDaniels (2006)) is problematic. Fortunately, exceptions exist. For example, Michigan State University's PREP program (http://grad.msu.edu/stages/index.htm)provides future faculty with range of workshops covering early, mid and late graduate career issues on topics ranging from "Choosing an Academic Advisor/Mentor" to "Preparing for the Job Search". Other colleges and universities have institutionally-supported versions of their Preparing Future Faculty Programming. Colleges and universities may also offer some form of career day programming, in which potential career options beyond the faculty position at a Research 1 university are showcased. However, extensive professional preparation is the exception, rather than the rule.

Golde and Dore (2001) concluded that there is a three-way misalignment among (a) doctoral students' *goals* to be good educators, (b) their actual *training*, and (c) their subsequent *careers*. However, the situation is changing. With multiple reports identifying the need to improve STEM education and increase the number of STEM graduates (Committee on Science Engineering, and Public Policy, 2006; U.S. Office of Science and Technology Policy, 2006) the national focus has shifted toward addressing this misalignment. For example, some programs have examined the graduate school experience with an eye to changing the pervasive research culture. Prior to 2003, the Re-envisioning the PhD initiative (http://www.grad.washington.edu/envision/index.html) set out to develop strategies to effect change based on a new vision of the Ph.D., and support discussions at a local and national level about innovative practices in doctoral education.

In addition, over the last decade, there have been a number of "training" efforts to address this issue of mis-alignment. Importantly, an underlying assumption in these efforts is that *better training of future faculty will directly result in improved undergraduate STEM education.* In this white paper I will focus on the Delta Program in Research, Teaching and Learning at the UW-Madison as an example of a program that provides future faculty with formal training to teach, through the professional development activities it offers. Other examples of programs that provide professional development in teaching, or professional development more broadly, include the following: (a) the Center for the Integration of Research, Teaching, and Learning (CIRTL; www.cirtl.net), (b) the Wisconsin Program for Scientific Teaching (WPST; Handelsman, 2004), (c) the Graduate Students in K–12 Fellowship Program (GK–12; Trautmann & Krasny 2006)), (d) the Preparing Future Faculty program (PFF; Gaff, Pruitt-Logan, Sims, & Denecke, 2003), (e) the Carnegie Initiative on the Doctorate (Golde & Walker, 2006), (f) and the Responsive Ph.D. Program (Woodrow Wilson National Fellowship Foundation, 2005).

Importantly, there is only limited longitudinal research available that documents the success of teaching professional development programs on graduate students and post-docs as they assume new faculty roles. One such study identified 129 alumni of PFF programs who were subsequently hired in faculty positions. PFF participation was found to help these alumni negotiate challenging academic job markets and balance their teaching and research responsibilities (DeNeef, 2002). CIRTL has also undertaken a longitudinal study of participants in the Delta Program (Bouwma-Gearhart (2007)). Findings from this study, as well as proposed research in a recently funded NSF proposal to extend the CIRTL longitudinal study of Delta will be discussed later in this paper.

Building off of this landscape of FFPD programs and efforts, in the next section I will discuss the Delta Program as one example of a program that is providing professional development in teaching for future faculty, with the potential to impact not only their careers, but also undergraduate student learning.

The Delta Program in Research, Teaching and Learning at the UW-Madison

Because research universities such as UW-Madison provide all types of colleges and universities with Ph.D.-trained faculty, changing how UW-Madison graduate students and post-docs are prepared for their teaching role has the potential to improve undergraduate instruction not only at UW-Madison, but also at all of the institutions of higher education that hire these doctoral students and post-doctoral researchers. Delta participants are taught to engage in ongoing enhancement of student learning; this parallels and complements the world class research skills they develop at UW-Madison. This broad training prepares these individuals to better meet the challenges of new faculty positions. Undergraduate learning at UW-Madison, as well as at the hiring institution, stands to benefit greatly.

The Delta Program is a model program of the National Science Foundation-funded Center for the Integration of Research, Teaching, and Learning. Delta was created with the strategic vision that better training of postsecondary educators will directly result in improved undergraduate STEM education. The Program mission is *to enhance undergraduate education by promoting the development of a future national faculty in the natural and social sciences, engineering and mathematics that is committed to implementing and advancing effective teaching practices for diverse student audiences as part of their professional careers.* To achieve this goal, the Delta Program has worked to create, support, and sustain a vibrant interdisciplinary, intergenerational learning community of current and future faculty. The program strives to help each member of the community experience the support of diverse colleagues and develop ways to engage in meaningful inquiry about their teaching and their students' learning.

Delta's approach to providing professional development opportunities in teaching is based on three tenets (referred to as the "Delta Pillars"; http://www.delta.wisc.edu/delta_pillars/about_delta.html):

1. Helping graduate students, post-doctoral researchers, academic staff, and faculty (i.e., graduates-through-faculty) use their disciplinary approach to research as a model to explore whether their students are learning what they are teaching ("***Teaching-As-Research***"; TAR);
2. Cultivating communities of learners who generate new knowledge together about teaching and learning though mutual support ("***Learning Community***"; LC);
3. Discerning and valuing the diverse ways of knowing that have the potential to enrich every classroom and laboratory ("***Learning-Through-Diversity***"; LTD)

These three foundational concepts, which inform and support every aspect of the Delta Program, are the defining traits of Delta as a future faculty professional development program. The Program hypothesizes that these three core ideas, teaching-as-research, learning communities and learning-through-diversity, are essential ingredients for creating a successful FFPD program that not only trains excellent educators, but also results in improved undergraduate education both at the training institution as well as at the institution employing these future faculty. These three foundational concepts have proven to be a powerful approach to engaging future STEM faculty. Of equal importance, these concepts are engaging for current STEM faculty as well (Mathieu et al. (2008)).

The Delta Program offers numerous opportunities for participants to learn how to effectively integrate academic research, teaching, and student learning. Currently, Delta's core programming includes six courses, three small-group facilitated programs, internships, Roundtable Dinners, and a Certificate program; Delta also offers a small number of targeted workshops and informal discussion groups. As a program, Delta is deliberately structured to provide a combination of low- and high- commitment activities that attract a broad range of participants from all STEM and Social, Behavioral and Economic Sciences (SBE) departments. We attempt to have each Delta course and program taught by a research-active STEM faculty member often in partnership with someone from the social sciences (Pfund et al. (2006)).

Delta courses target graduate students and post-doc participants in the STEM and SBE disciplines. The *Instructional Materials Development* course is unique in requiring that graduate students and post-docs team up with a faculty or instructional staff member to address a teaching-as-research issue through development of new instructional materials. Likewise, Delta internships, which are in reality teaching-as-research assistantships that are akin to disciplinary research assistantships, pair graduate students and post-docs with a faculty or instructional staff partner and mentor. While Delta courses focus primarily on graduate students and post-docs, programs like Creating a Collaborative Learning Environment (Sanders, et al. (1997)) and Expeditions in Learning (Carlson-Dakes & Pawley (2005)) are designed to address the needs of graduates-through-faculty. In some instances, faculty-only sections of these programs are offered. Delta workshops have specific target audiences as well; there are versions of a workshop for both graduate students and faculty about addressing NSF broader impact requirements in grant proposals (Mathieu et al. (2008)). Finally, Delta's RoundTable dinners are open to all graduates-through-faculty on campus and are a learning community-building activity. The dinners create an opportunity for attendees to listen to a guest speaker introduce a teaching and learning topic of general interest or a provocative issue for discussion. These dinners are viewed as a low-effort entry point into the Program learning community.

Delta courses range from in-class instruction to a blend of classroom activities with a strong experiential component. Each course or program incorporates the three Delta pillars into the material presented. As an example, Delta's *Diversity in the College*

Classroom course encourages graduate student and post-doc participants to look critically at how they define "diversity" and for what purposes, and discuss the ways different definitions of diversity might influence what is included in a course's content as well as how the course is taught. In the second half of the course, students apply what they have learned in developing an action plan (Pawley et al. (2006)), which they are encouraged to turn into a teaching-as-research internship project.

In contrast, Expeditions in Learning follows an experiential learning model that is grounded in adult learning theory. In this program, new questions about teaching and learning are developed, methods of exploring them are created, and the discovery of new answers by individuals and groups is supported. Every other week, participants head out on campus on an "expedition" to experience a learning activity or environment that helps to stretch their understanding of diverse approaches to learning and teaching. In the weeks between the expeditions, the small groups come together to engage in a facilitated discussion of what they experienced the previous week, what they learned, and the implications it may have on their teaching.

Last, Delta courses and programs are open to all students, regardless of their background experiences in teaching and learning. Only Delta internships expect that a student take a semester-long Delta course as a pre-requisite. For some students the internship serves as the capstone in their Delta experience; other students continue to take Delta courses following completion of their internship.

Building on this description of the Delta Program, in the next section, I will focus on evidence of impact of the approaches used by the Program. I will further sub-divide this section to first address evidence of impact on future or current faculty, and follow this with a discussion of the evidence of impact on undergraduate learning. A variety of examples will be drawn from Delta courses and internship projects.

Evidence of impact

Evidence of impact on participants in the Delta Program, and on the undergraduate students that these participants in turn teach, is being gathered at multiple levels. For example, participant learning (e.g. knowledge and skills) is assessed in the individual Delta courses and programs. Participants reflect on their practice and measure undergraduate student learning in internship projects. They create a teaching and learning portfolio for the Delta Certificate Program. Their teaching practice is captured in participant presentations and publications about their work (e.g. Walz & Kerr (2007); D'Amato, et al. (2007)). In addition, between 2004-2007, a longitudinal study was conducted by CIRTL researchers; this study explored the impact of Delta professional development programming on Delta participants.

Evidence from a wide variety of these sources, as well as the implications for understanding the value of FFPD programs like Delta for the preparation of future faculty, will be discussed next.

Evidence of impact on future or current faculty

As described in the following table, in this section I will present four examples of the impact of Delta programming on current and future faculty, as realized through a variety of Program activities.

Table 1: Impacts of the Delta Program on current or future faculty

Type of impact	Intervention	Description	Individual(s) impacted
Mastery of broad content or concept/s (e.g., increased understanding of principles of how students learn	Delta's College Classroom course	Students learn pedagogical approaches, write a teaching philosophy, design a syllabus and learning plans, and complete a micro-teaching experience	Graduate student and post-doc participants (i.e. future faculty)
Development of teaching skills and techniques	Delta Internship Teaching-As-Research project	Students learn about both extracellular matrix engineering and active learning as a pedagogical approach	Graduate student participants in the course (i.e. future faculty)
Development of interpersonal skills (e.g. collaborative or cooperative work)	Delta Internship Teaching-As-Research project	Workshop materials for teaching assistants that provide an active introduction to cooperative learning	Graduate student participants in the workshop (i.e. future faculty)
Affective outcomes—evidence of changes in faculty/student motivations to learn, in values and attitudes about science, other attitudinal changes	Delta Diversity in the College Classroom course and Delta Internship Teaching-As-Research project	Development of resources on ways to address diversity in the classroom and grading practices	Astronomy instructors and teaching assistants (i.e. current & future faculty)

***Example 1:** Mastery of broad content or concept/s (e.g., increased understanding of principles of how students learn)*

Courses like Delta's *College Classroom* play an important role in preparing future STEM faculty to teach effectively. In this venue, students learn about various pedagogical theories and approaches, write a teaching philosophy, design a syllabus and learning plans, and complete a micro-teaching experience. The *College Classroom* course is a core offering in the Delta Program.

To analyze student learning, Delta instructors in this course used summative assessment measures, which included pre- and post-surveys, observations, a focus group discussion with outside facilitators, and the on-line Student Assessment of Learning Gains survey (SALG; www.salgsite.org Courter *et al.* (2006)). Their results are summarized in the following table.

Table 2: Gains in student learning in Delta's College Classroom course

Evaluation questions	Findings
What activities were significant in contributing to student learning and growth, specifically as a professional in the academic community?	Students reported in the SALG survey that the group discussions, peer reviews, teaching and learning philosophy examples and workshop, and the micro-teaching experience were important contributors.
In what areas did the students demonstrate significant understanding of STEM teaching and learning issues? How do we know this?	Assessment and teaching-as-research. This was evident in their learning plans, and in the improvements they made from one draft to another and from their peers' comments in the micro-teaching experience.
What learning experiences were most significant?	The microteaching experience was identified by most students as the most significant learning experience; this is important to know since the time-commitment to this experience is considerable.

The data presented speaks to the value of this type of immersion experience for increasing the understanding of future faculty both about how students learn, and how to use this knowledge to teach more effectively.

The next example describes a course for graduate students, which was designed to cover content *and* model active learning as a teaching approach, as a way of teaching the participants to use the pedagogical approach.

***Example 2:** Faculty skill development: Teaching skills and techniques among current or future faculty*

Engineering education cannot be successful by focusing on teaching content alone. Future engineering leaders require both a broad knowledge base and effective communication skills. This Teaching-As-Research Internship project examined the attitudes engineering graduate students have about effective teaching and learning practices.

In addition, teaching was used as a tool to both engage students in active learning and teach them about the approach (McNeil, E. and Ogle, B. (2008)).

To accomplish this, a new disciplinary course was developed to enhance student understanding of extracellular matrix engineering (ECM) and introduce students to active learning as a pedagogical approach. Student attitudes were assessed quantitatively through pre and post course surveys, and qualitatively through discussion about pedagogical approaches following each lecture. Surveys were used to gauge a range of topics including: students' teaching experience, confidence level in teaching, and opinions about teaching practices, including active learning techniques

In both the pre- and post-course surveys, students rated their confidence about various aspects of the course. As demonstrated in the following figure, students reported being more confident leading a discussion after completing the class. An improved confidence level of course content knowledge was also observed. A slight increase in confidence toward presenting a lecture or using new teaching techniques was observed (not statistically significant).

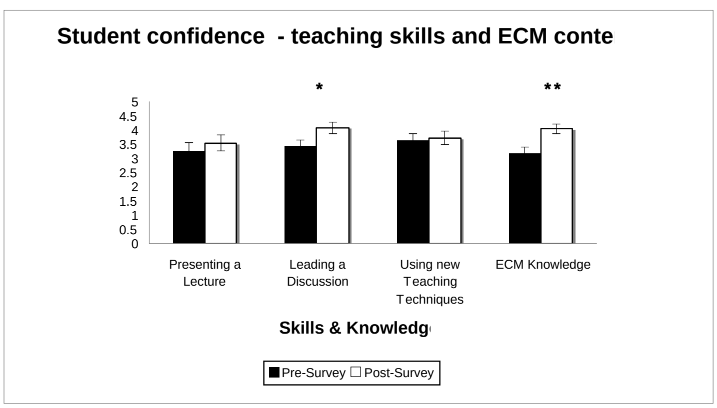


Figure 1. Student confidence increases for both teaching skills and ECM content knowledge. Students ranked their confidence on a scale of apprehensive (1) to very confident (5). Paired students' t test was used to compare pre- and post-survey results. *Indicates significant at .05 and ** indicates significant at .01.

In addition, in the pre- and post-survey, students were asked to list the steps that they would take if they were planning a lecture. After preparing a lecture and leading a class discussion in the EMC course, and talking about teaching throughout the semester, students' approaches to planning a lecture became more developed and specific. For example, six out of eleven students increased the number of steps that they would go through to prepare a lecture. Additional steps that were added included the following: (a) planning an active learning component (added by 27% of students in the class), (b) practice (added by 18%) and (c) development of learning goals around which to organize a lecture (added by 45% of students in the class).

These results demonstrate the efficacy of using teaching as a tool to both engage students in active learning and to teach them about the approach. The results also speak to the value of providing future faculty with an opportunity to experience effective teaching techniques, and the importance of providing them an opportunity to develop relevant skills.

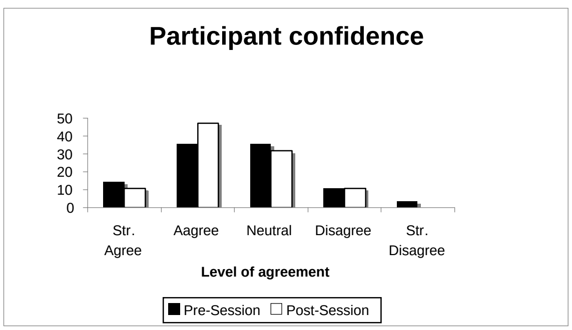
The example that follows explores the value of the guided workshop approach for teaching graduate student teaching assistants (TAs) to use cooperative group work with their undergraduate students.

Example 3: *Future faculty skill development: Interpersonal skills (e.g. collaborative or cooperative work) of students*

An ongoing effort to reform the introductory physics sequence at UW-Madison includes development of class materials that engage students as active learners. For example, in discussion sections, there is now a greater emphasis on the use of context rich problems in conjunction with cooperative learning groups. While exercise sets of this type are widely available, there is little in the way of supplemental materials that provide the instructors and/or teaching assistants with: (a) guidelines to effectively administer these problems, (b) experience using active and cooperative learning, or (c) motivation to move away from more traditional discussion and lecture styles

To address these needs, this Teaching-As-Research Internship project developed, implemented and assessed workshop materials that provide an active introduction to cooperative learning (Klukas, J. (2007)). This project aimed to generate a measurable difference in the following: (a) participants' motivation to employ active learning techniques, (b) their confidence in their ability to lead cooperative learning sessions, and (c) their effectiveness in increasing student learning.

Using pre- and post-session surveys, that serve as both formative and summative assessment tools, the intern observed moderate gains in the participants' feelings of confidence and competence in their ability to facilitate group work (Figures 2A and B). The data also show an increase in participant awareness of education research (as applied to teaching), and evidence of the community-building potential of such workshops and conversations among these new teachers in the Physics Department.



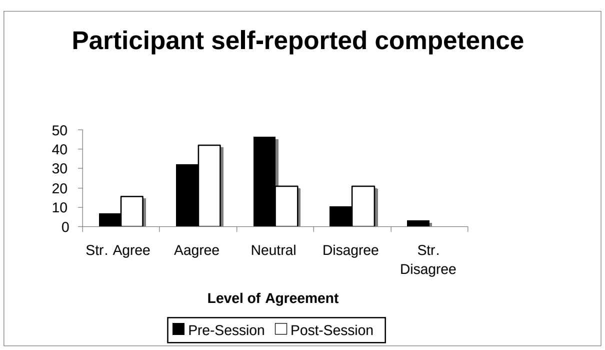


Figure 2: Distributions of answers for two baseline questions used to evaluate the effectiveness of TA training session materials. Participants were asked to rate their level of agreement with the following statements: (A) Participant confidence: I feel confident in my ability to run a discussion section focused on group work; (B) Participant self-reported competence: I feel competent in being able to help a group run smoothly and to encourage interaction between members of a group. The total numbers of participants responding are 28 for the pre-session and 19 for the post-session surveys.

The results of this project address the value of providing future faculty with an opportunity to experience effective teaching techniques, collaborative and cooperative group work in this case. A workshop format with relevant resources also provided these future faculty with a solid experiential foundation for changing their practice of teaching.

The final example in this section highlights a project that is in progress. This project aims to address attitudinal change in an introductory Astronomy course by first raising awareness of issues of diversity and inclusiveness, and second creating instructor-friendly resources.

***Example 4:** Affective outcomes—evidence of changes in faculty/student motivations to learn, in values and attitudes about science, other attitudinal changes*

The following Teaching-As-Research Internship project is in progress. It began as an action plan in Delta's *Diversity in the College Classroom* course. The description that follows is derived from the project proposal (Devine, K. (2008)).

Student diversity and how it may impact learning is currently not discussed or considered in Introductory Astronomy at UW-Madison. However, when reviewing final grade breakdowns for the course, the Delta intern noticed that white males received a disproportionate number of 'A' grades. The student went on to question whether ignoring diversity is negatively impacting *all* students, and if there are ways to improve teaching so that individuals typically underrepresented in the sciences—women and minority students—are provided equal opportunities to succeed.

This project is designed to do the following: (a) look for a correlation between Astronomy course grades and student gender and race, (b) examine Introductory Astronomy instructors' attitudes regarding diversity and their current teaching styles, (c) explore any influence instruction may have on any relationship between grades, gender, and race. The student's ultimate goal is to use the findings to create ongoing discussion of teaching and diversity in the Introductory Astronomy classroom as well as discipline specific resources for instructors to use to develop a more inclusive classroom environment.

To explore grade trends, students will be surveyed at the end of the fall 2008 semester; department faculty, staff lecturers, and graduate student instructors will be surveyed as well. The survey will ask about teaching experience, attitudes regarding teaching style, attitudes regarding diversity's role in the science classroom, and willingness to adopt new teaching techniques. Results from the survey of instructors will be incorporated into a write-up that also cites research regarding diversity and astronomy education; resources for instructors will be provided along with the write-up.

This project gets to the heart of the issue and explores the attitudes that faculty, instructors and teaching assistants hold about the relevance of diversity to teaching about the discipline. In time it will produce evidence of these attitudes, and provide tools intended to change these attitudes in a positive direction.

In the next section I will turn my focus to the impact future faculty professional development in teaching can have on undergraduate learning. Before exploring this through examples of projects developed by Delta participants, I will discuss how continued use of the product of a project (e.g. new instructional materials) has the potential to to impact undergraduate student learning across multiple semesters.

The true impact on undergraduate student learning, of any one project, is amplified

Participants in the Delta Program learn more effective approaches to enhancing learning through both their involvement in courses and their application of the knowledge that they gain in these courses. Delta courses, like *Instructional Materials Development,* for instance, require the application of participants' acquired knowledge in the form of a course project. Similarly, as evidenced by the examples given in the preceding section, the Internship Program requires this type of application and implementation of learning directly through the internship project. One of the *hypotheses* of the Delta Program is that if participants apply the pillars of teaching-as-research, learning communities and learning-through-diversity to their teaching, then their students will learn better. It is important to note that in the table that follows, the number of undergraduate students listed represents the number of individuals participating in the course or outreach activity at the time of the project. Many of these learning activities continue to be used in these classes and outreach projects. Thus, the *true impact* of any one project on undergraduate student learning is amplified by its continued use from semester to semester.

Table 3: Impact Data from Delta interns (Fall 2004 – September 2008) – Undergraduate students impacted

Discipline & location (if not UW-Madison)	Number of undergraduate students impacted
Bacteriology	50
Biology	120
Botany	231
Center for Limnology	14
Chemistry	550
Chemistry (Madison Area Technical College)	70
Engineering	100
Engineering (Biomedical)	155
Engineering (Electrical & Computer)	50
Engineering (Environmental)	50
Engineering Physics	4
Environmental Studies	92
Genetics	60
Geology	176
Materials Science & Engineering	4
Mathematics	100
Medical Microbiology & Immunology	24
Physiology	9
Zoology (Edgewood College)	15
TOTAL number undergraduate students impacted:	**1874**

Data in Table 3 were gathered from Delta interns. The discipline of the department in which the internship project was conducted, as well as location of off-campus internships is noted. Each intern did some form of evaluation of student learning in association with their project. Undergraduate students were the primary audience for these intern projects. Approximately 1874 undergraduate students were impacted by the instruction and new materials created by these interns between Fall 2004 and Summer 2008 (n= 47 interns/projects; Note: data from f'06 and sp'07 interns is not included). Similar data is available from participants in the *Instructional Materials Development* course (not shown).

A number of methods of evaluating undergraduate student learning were employed in the internship projects in Table 3. The pedagogical approaches and assessment designs students develop generally derive from things that participants learn in Delta courses and through the internship. Examples include the following:

- Surveys, test scores, interviews
- Student Assessment of Learning Gains on-line survey
- Multiple-choice assessment
- Pre- and post-questionnaire, student presentations, group projects.
- Midterm exam
- Pre- and post survey, pre- and post-experience essay, job shadow
- Concept tests; targeted exam questions, laboratory report

The data in Table 3 speak to the enormous potential for impact that a graduate student intern, working with a faculty or instructional academic staff member, can have on undergraduate student learning at UW-Madison and beyond.

In the section that follows, I explore this impact on undergraduate student learning; multiple Delta Internship Teaching-As-Research projects serve as illustrative examples.

Evidence of impact on undergraduate learning

As described in the following table, in this section I will present five examples of the impact of Delta programming on undergraduate student learning. These effects are indirect, in that Delta programming is designed for graduate students and post-docs, and these impacts are on *their* students.

Table 4: Impacts of the Delta Program on undergraduate student learning

Type of impact	Intervention	Description	Individual(s) impacted
Increased student understanding of specific STEM topics due to improved faculty teaching.	Delta Internship Teaching-As-Research project	The effectiveness of podcasts in achieving course learning objectives was evaluated	Undergraduate students in an introductory environmental studies course
Development of student scientific skills (e.g. measurements, observations, etc.)	Delta Internship Teaching-As-Research project	New course materials were designed to teach the experimental design process; a statistics tutorial was created	Undergraduate students in advanced Biology core curriculum
Development of student higher-order thinking skills	Delta Internship Teaching-As-Research project	Materials were created to help non-science majors apply concepts learned in lab to novel situations	Undergraduate students in Integrated Liberal Studies class
Development of student life-long learning skills (communication - writing, speaking, graphical presentations; quantification skills)	Delta Internship Teaching-As-Research project	Development of a new scientific writing curriculum designed to teach scientific reading and writing skills in a content integrated manner	Undergraduate students in an upper level geology course
Behavioral outcomes advancing curricular or institutional goals, such as increasing STEM retention; preparing students to engage learning in larger contexts of a discipline	Delta Internship Teaching-As-Research project	Real-life engineering design projects were incorporated into a curriculum of five integrated component courses	High school students in the Engineering Summer Program (ESP; a pre-college bridge program)

The first example Delta Internship Teaching-As-Research project I will present explores the effectiveness of podcasts in achieving course learning objectives. It provides an example of how improved faculty instruction can lead to increased undergraduate student understanding of topics in environmental studies.

***Example 1:** Increased student understanding of specific STEM topics due to improved faculty teaching.*

Technological tools have increasingly become a part of the college classroom. One of the intrinsic appeals is the potential of these tools to increase student engagement with course materials. Podcasts have gained popularity as tools to better inform students by providing access to lectures outside of the classroom. This Teaching-As-Research Internship project evaluated student preferences for using podcasts in an introductory environmental studies course assignment, as well as the effectiveness of podcasts in achieving course learning objectives (Vatovec, C. and Balser, T. (2008)).

When surveyed, students reported that podcasts were useful tools for learning, they were easy to use, and increased their understanding of course topics. Podcasts were also shown to be valuable tools for enhancing learning objectives. Regarding the course information that students found *most* helpful in improving their understanding of global climate change, they ranked a scientific video podcast highest (48%), followed by a scientific article (23%), an article from the popular press (17%), and a popular press podcast (12%). In a post-assignment survey, 62% of students who reported that podcasts were a useful tool for learning also responded that the assigned podcasts had given them a better understanding of global climate change (p=.0005).

The intern and their partner argue that as educators we should expand our course materials to include pre-published podcasts to both engage students with course topics and help them develop a broader skill set for evaluating readily available media.

The Delta Internship Teaching-As-Research project highlighted next provides an example wherein the creation and use of new instructional materials fostered undergraduate student scientific skill development.

***Example 2:** Student skill development: Student scientific skills (e.g. measurements, observations, etc.)*

Experimental design can be a challenge for undergraduate students to learn. In this Teaching-As-Research Internship project, a multidisciplinary team of intern (Zoology), instructional staff (Zoology) and faculty (Statistics) collaborated to create new course materials to reinforce the most challenging aspects of the experimental design process (Remsburg, A. (2007)). A series of survey and homework questions were developed to collect evidence about how well students achieved the stated learning objectives. In addition, open-ended questions were evaluated using a grading rubric that was based on the learning objectives. Many less formal assessments of student understanding were used, including the following: (a) worksheets, (b) calling on groups to answer aloud, (c) anonymous multiple choice questions using stickers, (d) research proposal presentations, and (e) asking students to explain concepts to each other.

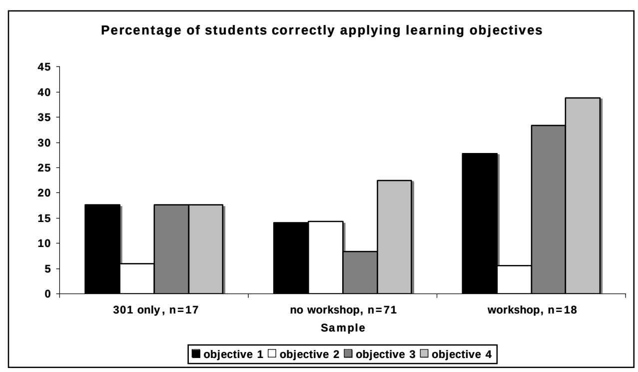


Figure. 3. Percentages of introductory biology students applying the four experimental design learning objectives in an un-graded critique of a flawed experiment. 17 students did not complete the course that included an experimental design unit (“301 only”), while 18 students completed both the course and an optional workshop focusing on experimental design (“workshop”). A significant learning gain for objective iii was observed (Fisher’s exact test p <0.05).

The percentage of students correctly applying learning objectives without and with exposure to the experimental design workshop was measured. As Figure 3 demonstrates, students who participated in the workshop applied the various learning objectives more correctly than students not participating in the workshop.

In addition, to being exposed to a workshop on experimental design, students in Spring 2007 were given the opportunity to use a new statistics tutorial developed as part of the Delta Internship. Student confidence in—and appreciation of—experimental design and data analysis, as a result of participation in courses in the standard sequence, and exposure to the Delta Internship project instructional intervention, was measured. Permutation tests (paired by student) were used to compare self-reported skills and student plans to take a statistics course that were derived from surveys given prior to the Fall 2006 course (n = 101) and again after the Spring 2007 course (n = 103). Students exposed to the statistics materials showed increased confidence in their abilities to determine statistical significance, conduct independent and paired t-tests, conduct ANOVAs, interpret statistical results, and draw conclusions. Significant differences (with $p < 0.005$, including Bonferroni-corrections for multiple tests) based on permutation tests paired by individual student, were observed for all applications, except determining statistical significance.

These results speak clearly to the value of this new instructional approach, a workshop on experimental design, and a statistics tutorial, for undergraduate student learning.

In the example Teaching-As-Research Internship project that follows, new instructional materials were used to foster the development of student higher-order thinking skills.

***Example 3:** Student skill development: Student higher-order thinking skills*

A disconnect exists for students between the focus of fundamental science labs (e.g. chemistry, physics, biology, geology) and the 'real world'. As a result, non-science majors are not fully scientifically literate. This Teaching-As-Research internship project asked whether a series of labs could be created to help non-science majors apply science concepts to novel situations outside the science realm (Riley, P. (2007)).

The labs were designed for an Integrated Liberal Studies class, *Ways of Knowing in Science.* The labs focused on implementing pedagogic tools such as hands-on learning, recreating historic experiments, and critical thinking questions. An overarching theme, heliocentrism, allowed the labs to be focused into a single module spanning three weeks. Course lectures supported concepts covered in lab by providing science background. To assess the students' learning, non-graded quizzes, which required higher order thinking skills (e.g. asking students to apply the learned concepts to situations not covered in lab), were conducted at the end of each lab. Assessment results indicated that the majority of students were able to correctly recognize how to apply the concepts covered in lab, but that they lacked a complete understanding of the definition of the concept. Results further indicated that the third lab, based on error and uncertainty, succeeded in getting the students to not only understand the concept, but also was effective at helping them learn to apply the concept to a novel situation (Figure 4).

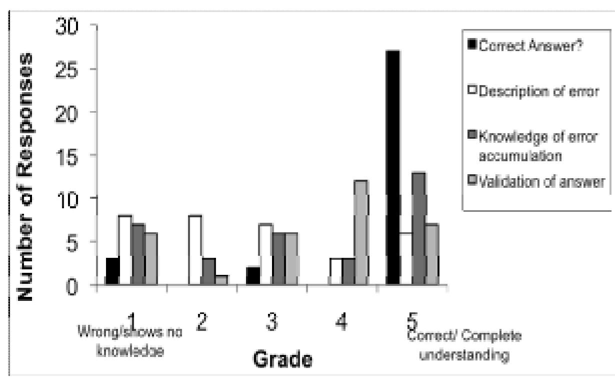


Figure 4: Student quiz results – Error and Uncertainty lab. Nearly all students were able to correctly answer the main question of the assessment, which was "What is the best way to construct a baseball diamond?" Most students were also able to both validate their answer, and provide a detailed description about how error accumulates.

This experiential approach resulted in deeper student learning, as evidenced by their ability to apply their understanding more broadly.

The Teaching-As-Research Internship project that follows takes a further look at skill development, focusing on the life-long skill, written communication.

__Example 4:__ Student skill development: Student life-long learning skills (communication--writing, speaking, graphical presentations; quantification skills)

Strong written communication skills are traditionally an important quality both inside and outside academia; however, many students leave their undergraduate education with poor scientific writing skills. This Teaching-As-Research Internship project evaluates the implementation of a new scientific writing curriculum in an upper level geology course at UW-Madison (Gage, J.A. (2008)). The specific goals of project included the following: (a) teaching scientific reading and writing skills in a content integrated manner, (b) developing a reusable writing curriculum for the course, and (c) creating a learning community where students feel comfortable, supported, and empowered to learn how to write.

To meet these goals, the Delta intern, in conjunction with their faculty partner, developed a writing curriculum to enhance the course content curriculum. Biweekly readings, chosen to complement course content being taught at that time, and short writing assignments were introduced. Students were also provided with guidelines for how to write each part of a scientific paper. Last, a two-part assessment of student learning was employed. This consisted of the following: (a) coding and ranking writing assignments, based on writing style/mechanics, form, and content, and (b) requiring students to self assess their learning gains.

The intern found that student writing improved in all three elements, style, form and content, over the course of the semester. Figure 5 demonstrates the decline in student errors in style/mechanics as the course, and implementation of the content-integrated writing curriculum progresses.

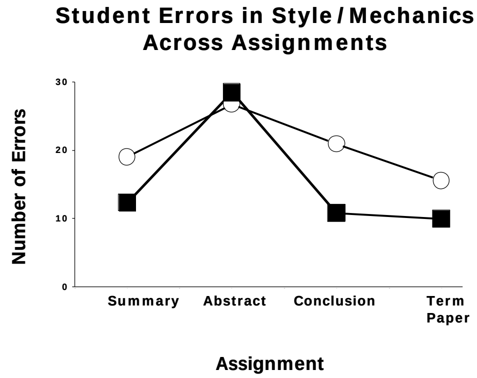


Figure. 5. Improvement in student performance across assignments. The number of errors in style and mechanics was lowest at the end of the semester, and was found to decreases between drafts for all assignments, except the abstract. In addition, the spread in the number of errors for any single assignment decreased throughout the semester.n - first draft; m - second draft of the same assignment.

These data demonstrate that implementation of a curriculum that is designed to teach scientific writing resulted in improved student writing.

As the final example Teaching-As-Research Internship project illustrates, integration of real-life engineering design projects into a pre-college bridge program curriculum resulted in both enhanced student understanding of the discipline as well as increased interest in a career in the discipline.

__Example 5:__ Behavioral outcomes advancing curricular or institutional goals, such as increasing STEM retention; preparing students to engage learning in larger contexts of a discipline, department or institution.

The Engineering Summer Program (ESP), a bridge program for high school students interested in engineering, has existed since 1977 at UW–Madison. During the summer of 2005, as part of a Delta Internship project, emphasis was placed on introducing real-life engineering design projects and integrating five component courses (Nimunkar, A., et al. (2006)). The goal was to encourage students to better appreciate: (a) why their math, chemistry, physics, technical communication and introduction to engineering courses are important in engineering studies, and

(b) how these courses work together to help students develop engineering skills. Assessment instruments in this Teaching-As-Research project included beginning, middle, and end-of-design experience questionnaires, as well as videotapes of student presentations, and a reflective letter that students wrote to their parents about their experiences.

Table 5: Enhanced student understanding of, and interest in, engineering as a result of a design project experience.

Questions	Findings
Are real-life student design projects an effective means of integrating different courses?	As students' work on the projects progressed, almost all of the students surveyed agreed that the group projects helped them learn more about the applications of physics, chemistry and mathematics in day-to-day life.
Did the real-life student design projects provide better student understanding of engineering in general?	The number of students enjoying group work increased during the course. In addition, all of the students recognized the importance of group work in design decisions. The design process involved in the project provided students with a very detailed idea regarding the steps involved in commercial product design. The hands-on experience reinforced the concepts regarding product design students had learned in classroom sessions.
Did the exercise of designing and presenting projects, stimulate student interest in science and engineering careers?	Students were better informed about potential career paths. In some cases the students were exposed to a greater number of engineering 'areas', which they might have not have considered before. Other students were able to narrow down and emphasize a particular engineering path of interest to them.

This experiential learning approach, with a focus on conveying the relevance of the topic to pre-college students, resulted in improved student understanding of engineering in a real world context. Similar to the other Teaching-As-Research Internship projects discussed in this section, this project illustrates clear benefits for student learning as a result of future faculty professional development activities in teaching.

In the next section, I will briefly discuss the impact of such FFPD programming on the broader career preparation of these graduate students and post-docs.

Impact on future faculty career preparation

A 3-year qualitative longitudinal study was initiated by the CIRTL Research and Evaluation team to document the progression of STEM graduate students from their experiences in programs like Delta into their early faculty careers (Bouwma-Gearhart *et al.* (2007)). This evaluation team was established in the original NSF-funded CIRTL proposal as a project group external to the development and administration of the Delta Program; it was responsible for overall evaluation of the development of Delta and the CIRTL Network. The longitudinal study was designed to address the research question: *What effect does teaching-related professional development during doctoral and postdoctoral training have on the attitudes, knowledge, teaching practices, and career trajectories of aspiring college/university educators in the STEM fields as they prepare for and move into their early careers.*

Table 6: Longitudinal data demonstrating the impact of teaching-related professional development on future faculty

Type of impact	Summary of findings
cognitive impact (knowledge and skills)	participants with a high level of involvement in programs like Delta said that their participation enabled them to gain *useable* knowledge and skills related to teaching
affective impact	interviewees stated that their experiences in programs like Delta resulted in an increase in their sense of preparation, their confidence and/or excitement with respect to teaching; the more time they spent in involved in this type of activity, the higher their motivation and confidence
impact on practice and application (including material outcomes)	participants with a high level of involvement in programs like Delta said that their participation enabled them to gain useable knowledge and skills related to teaching; this helped them adjust to the teaching-related demands of their new positions
impact of participation in networks	interviewees felt valued by the teaching professional development communities in which they participated
impact on career trajectories	Future faculty developed a broader view of the types of academic roles they could fulfill and the types of institutions that interested them as a result of participation in teaching professional development activities; about half claimed that participation in these activities had affected their career aspirations.

Fifty-one STEM future faculty (39 doctoral students and 12 postdoctoral researchers) who participated in at least one professional development program in teaching (e.g. Delta) at UW-Madison were followed in the study. Participants were interview in the spring each year, for three years beginning in 2005. The impact of programs, such as Delta was categorized into five types: (a) *cognitive* impact (knowledge and skills), (b) *affective* impact, (c) impact on *practice and application*, (d) impact of participation in *networks*, and (e) impact on *career trajectories*. Broad findings are included in Table 6.

As these data demonstrate, the impact on individuals, of participation in future faculty professional development programs in teaching, are broad. Studies like this are invaluable because they shine a light of analysis on graduate students and post-docs as they transition into their careers as faculty. This transition point is key because it is here, in these new positions, that these individuals will be called on to use the knowledge and skills gained as a result of participation in programs like Delta.

The impact of such experiences on career choices is further illustrated in the vignette that follows.

Vignette: Lois[1] was a doctoral student at UW-Madison. Earlier in her graduate studies, Lois was very uncertain about her career aspirations, but an opportunity to work with her research colleagues to plan and teach an on-line course, changed that. Student feedback from the previous semester suggested that its curriculum and instructional materials needed a major overhaul. Lois had a strong interest in teaching, but she lacked any formal classroom teaching experience. Fortunately for Lois, as part of the Delta program she had taken two Delta courses and in so doing had some ideas about 'best practices' and teaching pedagogy. Moreover, Lois's on-line course redevelopment plan was a good match for the scope and requirements of Delta's Internship program, so Lois jumped into this Teaching-As-Research assistantship with both feet.

During one semester, Lois developed instructional materials for one unit of the course that was closely related to her own dissertation research. She and her co-instructors met regularly to review the existing literature to find best practices in on-line education and to revise the course. Bi-weekly meetings with her Delta colleagues in the facilitated internship seminar gave Lois the chance to explore what it means to put the core concepts of teaching-as-research, learning community and learning-through-diversity into practice. She ended that semester well prepared for the on-line course to "go live".

Lois's internship experience reinforced her interest in teaching, and the effects of this were widespread. The semester following her Delta internship, Lois and her co-instructors implemented the on-line course, and she continued meeting informally with her peers from the internship seminar to share their progress. Lois then took her personal exploration of the Delta concept of Learning-through-Diversity back to her graduate program, where she organized and facilitated a discussion and working group about the topic. Working with Delta staff, Lois infused the Delta pillars into the departmental group (and incidentally satisfied the Learning Community requirement for the Delta Certificate in Research, Teaching and Learning). Lois subsequently 'defended' her teaching and learning portfolio. As a product of her experiences in the program, her Delta portfolio documents for others her scholarly approach to teaching, the same way a thesis documents one's accomplishments in disciplinary research.

Lois's participation in the program was a transformative experience. She is now a tenure-track faculty member at a liberal arts college, because her experiences gave her the confidence to teach and conduct research equally well. Had she not been involved in Delta, Lois might have abandoned her plans for a faculty career.

> "I was having a severe crisis and questioning continuing on in an academic track. I felt I could sort of handle research, but I wanted to be a professor, and the thought of teaching and putting together courses on top of research

[1] The participant's name has been changed.

> completely panicked me…. Delta, through its courses and internship, was a very key factor in making the professor track happen. I decided that if I was going to be a professor, I needed to do what it would take to make me feel comfortable with teaching, because if I didn't feel comfortable, I didn't want to continue on."
>
> Lois
> Delta Program Certificate recipient
> & alumna

While providing compelling examples of impact, the Teaching-As-Research projects, longitudinal study and vignette are but one facet of data collection in, or about, the Delta Program. In the sections that follow, I will first discuss more generally the assessment instruments and approach used by the Program. Next, I will explore assessments that are not available, but should exist, in the broader national context.

Assessment instruments and metrics

Evaluation of the Delta Program occurs at multiple levels, but has two real focal points: learning gains made by future faculty participants in Delta activities, and learning gains made by the undergraduate students of said Delta participants. Because measuring undergraduate student learning is an enormous undertaking, the Program made an intentional effort to focus the bulk of its evaluation efforts on measuring learning gains made by its participants. Measures of undergraduate student learning, as has been discussed, come as a result of deep engagement of graduate students and post-docs in Delta programming, and are evident in the reports they write summarizing their internship experiences, or in their teaching and learning portfolios.

The first level of Program evaluation is conducted by the instructors and facilitators of each course, program, workshop, etc. As part of the Program, these faculty and instructional staff members are responsible for designing and administering their own evaluation of learning gains made by Delta participants in their offering; they are also responsible for interpreting the data. This de-centralized approach is designed to encourage Teaching-As-Research among instructors and facilitators. In turn, data gathered from these efforts is collected and used by the Program primarily to inform changes to future offerings of the individual courses, programs, workshops, etc.

The second level of evaluation occurs at the program level. The Program evaluation plan is based on five "levels" of evaluation data (Kirkpatrick (1998); Colbeck (2003)): (1) Participation: Who attended? (2) Satisfaction: Were participants satisfied with the program? Did they get from participation what they expected? (3) Learning: What did participants learn? What attitudes or beliefs were acquired or changed? What skills were developed? (4) Application: Did participants apply and refine knowledge, attitudes, and skills in subsequent situations? (5) Overall Impact: What role, if any, did participation in the program play in improving undergraduate STEM education (Pfund, C. *et al.* (2006))? In addition to Kirkpatrick's model, development of this plan, and the assessment approaches used programmatically, were influenced by the 2002 User-Friendly Handbook for Project Evaluation (NSF 02-057).

To specifically address learning, application and knowledge, part of the Program evaluation plan involves the use of a limited number of common items or questions that are added to all individual Delta course and program end-of-semester evaluations. Open-ended questions, such as, *"Suppose that you were preparing to teach some concept from your discipline (e.g., the nitrogen cycle, amplitude, redox reactions, class, gender and racial inequality in education). Describe the steps that you would take to do so."* and *"What major concepts are you taking away from this course that will affect your future practice as an educator? If possible, please give 2-3 specific examples."* are used.

The core concepts of Delta, teaching-as-research, learning communities and learning-through-diversity, are touched upon in every program offering. Therefore, the open format of these and other questions allows Program staff to evaluate participant understanding of the concepts across the program in an effort to address the hypothesis that *these three core ideas are essential ingredients for creating a successful FFPD that not only trains excellent educators, but also ultimately results in improved undergraduate education.*

The third level of evaluation involves efforts of individuals external to Delta, like the CIRTL Evaluation and Research team. This team conducted a multi-year Longitudinal Study between 2004-2007 (described previously; Bouwma-Gearhart *et al.* (2007)). A new NSF-funded project at UW-Madison (Connolly, M. et al. (2008)) will continue the work of the original CIRTL Evaluation and Research Team. This new study will use a longitudinal, mixed-methods design that will follow two groups of STEM doctoral students from three research universities over 5 years. The study will address six research questions that range from "What are the general characteristics of FFPD programs, and which characteristics are most strongly correlated with positive and negative participant outcomes?" to "What degree of investment in FFPD must a doctoral student make, and for what length of time, to receive modest but significant benefits?"

The fourth and final level of evaluation takes the form of peer-reviewed publications, conference abstracts and presentations. It is important to note that while Delta participants engage in teaching-as-research, the focus is on measuring undergraduate student learning to improve teaching. Unlike the Scholarship of Teaching and Learning movement (Cross, K.P. (2006)) the bar is not set at peer-review publication of the research. When publications (e.g. Walz & Kerr (2007); D'Amato, et al. (2007)) and presentations at disciplinary society meetings (e.g. McNeil, E. and Ogle, B. (2008)) do occur they have value both for the faculty or staff internship partner, and as a professional development exercise and *curriculum vitae* 'builder' for the graduate student or post-doc intern.

In the next section, I turn my focus to lessons learned from evaluation of the Delta Program, and their implications for assessments that are not available, but should exist, broadly speaking.

Assessments that are not available, but should exist

While Delta presents a clear case for the impact of the Program on future faculty professional development, as well as on undergraduate student learning, limitations of our original approach are worth mentioning here in the larger context of *assessments that are not available, but should exist*.

As mentioned in the previous section, part of the Program evaluation plan involves the use of a limited number of common items or questions that are added to all individual Delta course and program end-of-semester evaluations. Prior to the use of these common items, instructors were responsible for designing and administering their own evaluations and interpreting the data. Although these approaches produced valuable data that led to improvements in subsequent offerings of these courses, the lack of any common evaluation items made it difficult to draw inferences about how Delta as a whole was performing, across all of the courses and programs (Pfund, C. *et al.* (2006)).

There is a national need for common instruments that look broadly at the impact of professional development programs in teaching, like Delta. Programs and funded projects can report out on the successes of individual efforts, but in the end, without common metrics, we will not know the core elements of successful future faculty training efforts. Once the key programmatic features and outcomes have been defined, and common items identified, programs will need to use these common items to evaluate their efforts. Then the effect of program variables like institutional priorities, amount of time spent doing professional development activities (e.g. dosage or engagement), the format of program activities (e.g. project-based courses or workshops), etc., can be considered.

As one example of using common items broadly to compare different FFPD programs, there is a collaborative evaluation effort underway across the CIRTL Network. The study involves the Delta Internship Program (http://www.delta.wisc.edu/programs/internship/internship.html) at UW-Madison, the FAST Fellowship Program (Future Academic Scholars in Teaching; http://grad.msu.edu/fast/) at Michigan State University and the Lead Graduate Teacher Network (http://www.colorado.edu/gtp/lead/index.htm) at the University of Colorado-Boulder. This collaborative effort arose because these CIRTL Network programs have similar aims for future faculty professional development in teaching. The goal of this collaboration is to conduct a multi-institutional study that addresses the question: *What are characteristics of programs that effectively prepare our graduate students for careers as 21st century faculty?* This effort has produced common items to be used across these three Network campuses in pre- and post-surveys of participants in these specific programs (Gillian-Daniel, Connolly, Border and Campa (2008)).

In addition to the need for common evaluation questions, there is also the need for a place to compare data from across program types. This need could be met with, for example, a database containing both common evaluation questions and data.

In the next section I will turn my focus to the broader landscape of FFPD programming and discuss gaps in the research and areas where evidence is missing.

Gaps in the research and areas where evidence is missing

Similar to CIRTL, other national reform efforts (e.g. the Wisconsin Program for Scientific Teaching (WPST; Handelsman, 2004), (c) the Graduate Students in K–12 Fellowship Program (GK–12; Trautmann & Krasny 2006)), (d) the Preparing Future Faculty program (PFF; Gaff, Pruitt-Logan, Sims, & Denecke, 2003), (e) the Carnegie Initiative on the Doctorate (Golde & Walker, 2006), (f) and the Responsive Ph.D. Program (Woodrow Wilson National Fellowship Foundation, 2005) have reported on measurements of learning or skill, or measures of changes in attitudes or behaviors, specific to their efforts. There are only two studies to date, that the author is aware of, that longitudinally document the true success of these teaching professional development programs on graduate students and post-docs as they assume their new faculty roles and put into practice what they have learned (DeNeef, (2002); Bouwma-Gearhart *et al.* (2007)). This limited scope of work makes the newly-funded CIRTL longitudinal study (Connolly et al. (2008)) and others future studies like it even more important for documenting the long-term value of professional development programs in teaching for future faculty.

In parallel, the reports that exist document moments in time of undergraduate student learning in various disciplines. For example, the work of Uri Triesman (1992) and John Wright et al. (1998) are true exemplars of this type of research on educational innovation and student learning. What is missing is a systematic way to answer whether student learning is sustained *across* the curriculum, beyond the moment in time that we read about. Longitudinal studies of this type would add greatly to our understanding of the value of these educational innovations, and to the value of training current and future faculty to use them.

In the final section of this white paper, I will explore some of the next steps for demonstrating the effectiveness of FFPD programs.

Next steps for developing/demonstrating effectiveness of professional development for future STEM faculty

If improved undergraduate student learning is also a true measure of success, then more needs to be done at both an institutional and a national funding level to develop and support the capacity of programs like Delta to document and report on the invaluable contributions to undergraduate student learning made by their participants. Making available these training opportunities, and diverse professional development in teaching activities, will also ensure that the faculty of tomorrow are well prepared to continue on in this scholarly approach to their teaching, both for the improvement of student learning in their classrooms, as well as for the contributions they will make as faculty to the larger conversation about teaching.

Specifically, there is a need to address the following: (a) determine the scope of current *and* past innovations and identify who the innovators are, and what their innovation is (e.g. process or products), (b) identify what is to be learned from these efforts, (c) create a mechanism for categorizing and archiving these innovations both in terms of products as well as people who have an expertise, (d) from these innovations, develop a national set of guidelines/recommendations for the desired change and more importantly, how to realize such change on diverse campuses, (e) create a way to broadly disseminate findings about what works (and doesn't) such that it is independent of a particular approach and is more generalized, (f) find funding sources to address limited campus budgets, (g) generate an approach for adaptation, rather than adoption of change, being sensitive to different campus philosophies and missions, existing programs, etc., (h) find support, beyond funding, for said adaptation, (i) develop nationally agreed upon benchmarks and evidenced-based outcomes for successful adaptation and implementation of such FFPD programs, and finally, (j) create a national forum for dialogue about the process and products of such an effort, so that it does not occur in disciplinary or institutional isolation.

A key feature to this plan is supporting this adaptation. Budgets are tight, and although it is an outdated model, it is pervasive—new funding effects campus change. NSF's broader impact requirement for research funding is a step in the right direction. If there is a requirement for educational innovation that is attached to research funding, then faculty, departments and institutions will take note, and the value of FFPD programs will increase (Mathieu et al. (2008)).

It will be important to draw on past, current and future longitudinal studies to help define the characteristics of FFPD programs that are most closely correlated with both positive and negative outcomes for participants. These evidence-based outcomes could be used to facilitate the development of cross-institutional measures of success. It will be imperative also to distinguish between the perception of value and value as measured by better job performance of future faculty as well as improved undergraduate student learning.

Evidence-based outcomes might include the following: (a) hiring of new faculty, (b) increased perception of preparedness for their new job, (c) ongoing engagement of new faculty in professional development in teaching activities, (d) buy-in by disciplinary societies, as evidenced by increase in the number of education-based sessions, and (e) clear evidence of improved undergraduate student learning. A clear articulation of what such a national initiative hopes to achieve as well as examples of the myriad of ways that an individual campus could get there will be needed.

Last, the issue of future faculty motivation to (learn how to) teach will need to be addressed. Some future faculty will just want to do research. Is such a reform a requirement of all future faculty? If not, how will faculty interested in research and faculty interested in teaching be seen as equitable without having the latter faculty viewed as 2nd class citizens?

We will succeed in our efforts to improve undergraduate education when future faculty enter their new positions believing and knowing that they are already a vital part of a larger reform movement in postsecondary education:

> "The biggest and most long-lasting reforms of undergraduate education will come when individual faculty or small groups of instructors adopt the view of themselves as reformers within their immediate sphere of influence: the classes they teach every day."
>
> --K. Patricia Cross
> (quoted in Tobias (1990) and thanks to M. Connolly)

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