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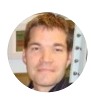

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Cottrell Scholars Collaborative New Faculty Workshop: Professional Development for New Chemistry Faculty and Initial Assessment of Its Efficacy

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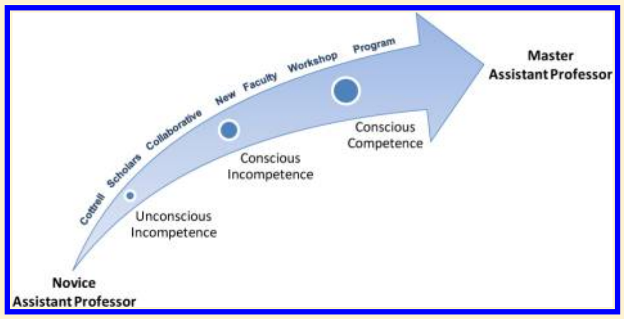
ABSTRACT: The Cottrell Scholars Collaborative New Faculty Workshop (CSC NFW) is a professional development program that was initiated in 2012 to address absences in the preparation of chemistry faculty at research universities as funded researchers and educators (i.e., teacher−scholars). The primary focus of the workshop is an introduction to evidence-based teaching methods; other topics including mentoring, work−life balance, time management, and grant writing are also addressed. A longer-term aim of the workshop is to develop lifelong teacher−scholars by encouraging workshop participants to engage with teaching-focused faculty learning communities through the CSC NFW and at their institutions. The workshop also provides a platform to investigate the adoption of student-centered pedagogies among new faculty, and a study of that process was initiated concurrently. Thus, the aim of the workshop program is to address professional development needs as well as understand the efficacy of that effort.



KEYWORDS: *Graduate Education/Research, Upper-Division Undergraduate, Second-Year Undergraduate, First-Year Undergraduate/General, Curriculum*

INTRODUCTION

Motivation

Calls for improvement to STEM education, including the widespread adoption of vetted pedagogies, termed here evidence-based teaching methods (EBTMs), have come from government, business, and universities.[1−3] Indeed, commentary on the attrition of students from chemistry due to ineffective teaching is older than this *Journal*.[4] Despite these persistent, long-term calls for changes, the uptake of EBTMs is limited and university teaching remains largely in the form of lectures.[5] Reasons for the lethargic rate of change in educational methods are the subject of much research.[5−18] In particular, the premium that universities place on success in the research laboratory not only deemphasizes and subjugates teaching to research but often is used to justify the acceptance of ineffectual teaching.[19] Thus, a national effort to improve STEM education persists with high profile activities from several sectors.[3,19,20]

A reasonable hypothesis is that faculty who are versed in EBTMs and have some understanding of why they are effective are more likely to adopt them in their classrooms. Furthermore, training students in an environment where mentors talk about teaching and make the intellectual work of teaching visible should promote a greater sense of balance between faculty's dual responsibilities of teaching and research. Anecdotal recollection from our own training as well as a cursory survey of program descriptions from the Web pages of doctoral programs in chemistry at research-intensive universities shows that, at most institutions, graduate students are not required to learn modern pedagogy as part of their formal training. This situation is naturally unfortunate for the advancement of EBTMs but also ironic given the fact that departments often have a teaching requirement for their Ph.D. students. Efforts to address this problem have arisen at the disciplinary level, with one example being the Faculty Institutes for Reforming Science Teaching (FIRST) series in biology,[21] and at the cross-disciplinary level, where the Center for Integration of Research, Teaching, and Learning (CIRTL) is perhaps the largest,

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involving 25 institutions.[22] Given recent statistics from the National Science Foundation Science and Engineering indicators showing that nearly 40% of all physical sciences Ph.D. recipients ultimately teach in 2-year and 4-year institutions, a large portion of the graduates from chemistry programs would likely benefit from some pedagogical training.[23]

Chemistry has lagged behind other disciplines in providing pedagogical and professional development to its faculty, in particular new faculty. For example, at least 25% of all new physics and astronomy faculty in the U.S. have participated in a multiday workshop geared toward EBTMs and professional development since 1996.[24] The American Chemical Society (ACS) has acted to address these needs by producing two programs, the Postdoc to Faculty Workshop (2008) and "Working in Higher Education" module (2012) of the ACS Career Pathways program.[25,26] These efforts have already impacted a number of graduate students and postdoctoral researchers, but they are too new to assess fully their degree of success. New faculty programs, like that in physics and astronomy, remain an attractive option because the attrition between postdoctoral positions and faculty appointments can be avoided and programming geared toward those who will be directly involved in educating students can be implemented.

Cottrell Scholars Collaborative New Faculty Workshop

In 2011, members of the Cottrell Scholars Collaborative,[27] which consists of current and former recipients of a Cottrell Scholar Award from the Research Corporation for Science Advancement (RCSA), considered this problem and potential solutions. With seed funding from RCSA and additional support from ACS, the Cottrell Scholars Collaborative New Faculty Workshop (CSC NFW) program was established in 2012 to address some of these issues in new chemistry faculty development at research universities. Consultation with the leaders of several of the other discipline-based new faculty programs ensured that known effective practices were incorporated.[28] A comprehensive and longitudinal study of the workshop was initiated simultaneously to measure the extent of the impact of the program on the participants' instructional practices.

■ CSC NFW DESIGN AND EXECUTION

Guiding Principals

Without training in pedagogy, most faculty will likely follow one of two models. They will either emulate the teaching they experienced when they were students or they will adopt the practices of their peers in their current department. In either case, the result will likely be similar: faculty will continue to teach using a style based predominantly on the lecture model. Thus, the CSC NFW program seeks to accomplish two goals: (1) foster a student-centered conception of teaching and learning and (2) promote a conscious and reflective teaching identity of participating faculty.

To promote a student-centered conception of learning, faculty need to know and understand the value and utility of EBTMs in STEM education. Thus, raising awareness of these methods among faculty and providing impetus to try them (i.e., diffusion[29,30]) is one of the main goals of the workshop. Likewise, providing support for faculty during their execution of EBTMs (i.e., implementation[31]) is an essential component to promoting successful adoption. Therefore, *the workshop is structured to provide an introduction to a set of EBTMs* (including assessment, collaborative work, flipping, and specific methods like Just-in-Time Teaching, among others, see Tables 2 and 4 for more detail) and a forum for faculty to develop a content piece or lesson using an EBTM(s) of their choice.

Using diffusion and implementation to help faculty to adopt EBTMs is well-known and has demonstrated value in the literature.[16,28,32,33] There are limitations to any approach to change, and naturally, a diffusion/implementation approach faces significant hurdles.[16,34,35] Of particular note, the supportive environment of the workshop ends abruptly, and the faculty members may lack interactions with supportive colleagues that are critical for persistence following initial uptake.[29,34] Furthermore, the workshop as a single intervention is problematic. Indeed, the literature suggests that several approaches are required to effect change in STEM higher education.[34]

Thus, the CSC NFW workshop extends beyond its schedule, prompting participants to become reflective teachers through ongoing interactions during the following academic year. More recently, we have sought to foster a shared vision on individual campuses by engaging department chairs and campus centers for teaching and learning.[16,34]

Audience

The inaugural workshop was held at ACS Headquarters in Washington, DC. The target participants are research university faculty immediately prior to their first year as well as those beginning their second year of tenure-track assistant professorship. Support from RCSA allowed for 25 participants to attend the workshop at no cost. With only a single mailing to department chairs, the anticipated enrollment was exceeded with many institutions funding their own faculty participant(s) (Table 1). Based on an e-mail inquiry to chemistry departments at research institutions classified as Very High Research Activity Institution by the Carnegie Foundation (79% response rate), it is estimated that the first two offerings of the CSC NFW impacted 29% of all new hires at this type of institution within the 2011−2013 time period. Moreover, workshop participants represented 40% of all institutions classified as Very High Research Activity Institution. The workshop has thus had an extensive reach in a short period of time. This level of response and increased numbers of applications annually (Table 1) is encouraging and provides evidence of a latent desire for such a program.

Table 1. Applications to and Attendance at the CSC New Faculty Workshops

	2012	2013	2014
Applicants, *N*	43	46	89
Attendees, *N*	38	43	54
Admission Rate, %	88	93	56

Program

The workshop is structured to provide a variety of activities in several formats including group discussion, individual work time, and hands-on activities (Table 2). The majority of content in the workshop centers on the use of EBTMs in the classroom. However, issues of mentoring, cultural competency, work-life balance, and grant writing, among others, are also included to ensure that critical topics for professional success and satisfaction are discussed.

Table 2. Schedule for the 2014 CSC New Faculty Workshop

Day 1	
3:00 pm	Workshop check-in; Just-in-Time Teaching exercise due
3:00 pm	Panel: *Writing proposals and managing grants*
6:00 pm	Opening session: *The Difference Between Teaching and Learning*
8:00 pm	Opening reception
Day 2	
8:00 am	Breakfast
8:30 am	Welcome session and introduction from ACS Executive Director and CEO
9:00 am	Just-in-Time Teaching: Model implementation of JiTT and explanation of the technique
9:45 am	Introduction to scientific teaching/research-based teaching
10:15 am	Break
10:30 am	Active learning exercises: participants play the role of students; organizers model actives
11:15 am	**Teachable tidbit project: Part 1**
	Goal: Learning objective, backward-design syllabi, and selection of content
12:15 pm	Teachable tidbit report-out
12:30 pm	Lunch: Learning taxonomies
1:45 pm	**Teachable tidbit project: Part 2**
	Goal: Make a content element active
3:15 pm	Teachable tidbit report-out
3:30 pm	Assessing student-learning
4:00 pm	Break
4:15 pm	**Teachable tidbit project: Part 3**
	Goal: Develop formative assessment to assist student learning
5:15 pm	Teachable tidbit report-out
5:30 pm	Engaging large classes
6:30 pm	Dinner (table topics: e.g., students' prior knowledge, designing a midterm exam)
7:30 pm	Addressing student diversity
8:00 pm	Time management
8:30 pm	Adjourn
Day 3	
8:00 am	Breakfast
8:30 am	**Teachable tidbit project: Part 4**
	Trial Run: Try out your project on your peers in small groups
10:30 am	**Feedback on Teachable tidbit projects**
	What worked? What was less successful? Were there trends?
11:00 am	Break
11:15 am	Mentoring students: Discuss mentoring issues through case studies and Problem-Based Learning (PBL) approaches; debrief case studies and PBL as an instructional strategy
12:30 pm	Workshop wrap-up and evaluation

The delivery of information regarding EBTMs is the central focus. Because there is a range of valid EBTMs, the workshop does not advocate for a single method, and the majority of the workshop is devoted to exploring different EBTMs and to help faculty identify approaches that best suit their own courses and learning objectives. The central design principle of the workshop is that participants are provided with a suite of EBTMs, discuss their effective implementation, and then they use those to deliver a piece of model content (diffusion followed by initial implementation, *vide supra*). For most methods, participants engage in an activity or are presented model content in the style of that EBTM, are given an explanation of the method, and discuss effective implementation thereafter. The goal of this process is not only to inform participants about these methods but also to provide them with an experience in each. A discussion on methods for larger classes and scale-up of introduced EBTMs is included because the workshop environment with only ~50 people in attendance cannot be a suitable model for a large classroom.

Exploring a complete set of EBTMs is impossible in the time allotted, and a sample set has been chosen based on ease of implementation, desired outcomes, and the organizers' experience. The fact that faculty have not widely sought to self-educate in EBTMs and note substantial barriers to changing teaching methods[5−18] prompted the workshop's aggressive schedule (Table 2) and the choice to cover a breadth of methods. Furthermore, scholarship on effective faculty development workshops in these methods is limited: optimized models for this kind of program do not exist. This observation prompted investigation of the efficacy of this workshop design, and preliminary results are reported here (see Impact of the CSC NFW on Participants' Instructional Practices).

The initial session "The Difference Between Teaching and Learning" focuses on common fears, challenges, and apprehensions for new faculty, particularly with respect to teaching. The session establishes a tone for the workshop, one in which the participants are experiencing the same concerns and can benefit from each other's experiences. Indeed, the workshop thrives on participants' interaction among themselves both during and after the event, and it is a goal of the workshop to foster the development of learning communities of participants over teaching among themselves and with colleagues in their home institutions.

The centerpiece of participants' efforts at the workshop is the development of a content module using an EBTM, a so-called "teachable tidbit",[36] specific to their own teaching assignment. There are four major reasons for the development of a specific active-engagement lesson throughout the workshop. (1) Development of the teachable tidbit provides the participants practice in implementing the EBTMs discussed in the workshop in a safe and supportive environment. Thus, a key component of the workshop is that participants execute their tidbit to a group of peers in a mock classroom setting. Participants having the opportunity to try methods rather than a purely theoretical experience are more likely to actually implement one or more EBTMs in their classrooms.[37] (2) Practicing the tidbit provides participants with valuable feedback both from peers experiencing the tidbit and from workshop facilitators who use these methods in their own classrooms. Constructive feedback facilitates participants' successful implementation of EBTMs in their own classrooms. Moreover, prompting meaningful exchanges over teaching is a fundamental goal of the workshop. (3) The selection of a teaching tidbit is preceded by a discussion of learning objectives and course design. Participants are engaged to consider how individual content fits within broader learning objectives. (4) The introduction of the tidbit segues into an introduction to assessment, including types and use to improving learning. Participants discuss and engage in various formative assessment techniques, which can be used in conjunction with their lesson.

Workshop follow-up is essential to help these new faculty continue to adopt EBTMs in their own classrooms and to persist in their efforts, particularly when their initial attempts at EBTM adoption are only partially successful, as is commonplace for initial implementation of new practices or curriculum. The format of the follow-up to the workshop has been evolving. In the inaugural year, participants were paired with a mentor from the members of the Cottrell Scholars Collaborative based on mutual research interest. This approach is attractive but highly labor intensive. After the first year, the mentor program was deemed beneficial but unsustainable, and alternative modes of extended mentorship were explored. In 2013, a series of interactive "webinars" was launched that invited current and prior participants to think about and discuss the challenges they faced while implementing EBTMs in their own classrooms and hear about the attempts of their colleagues to do the same. The webinar format was conceived to further foster an ongoing learning community among the workshop participants.

In 2014, the workshop was approximately one-half day longer to better accommodate the development and practice of the teachable tidbits (Table 2). Time is a constant challenge. A longer workshop may provide participants with a more complete overview and practice in implementation of EBTMs, but fewer faculty would likely participate based on discussions with past participants. The two-day format appears to strike a balance between the perceived value of this program and the time constraints of participants who are also trying to establish research laboratories and settle into new careers.

IMPACT OF THE CSC NFW ON PARTICIPANTS' INSTRUCTIONAL PRACTICES

Method

A quasi-experimental, mixed methods design[38] was implemented to evaluate the impact of the workshop. Herein, preliminary findings from survey data collected from two cohorts of workshop participants are presented. These data help evaluate the impact of the workshop on participants' level of awareness and intent to implement EBTMs as well as impact on participants' beliefs about teaching. Data related to these constructs were collected via online surveys 1 week before, 2 weeks after, and one year after the workshop. Recruitment of study participants and the data collection protocol have been approved by the Institutional Review Board of the University of Nebraska—Lincoln.

Analysis

Data were cleaned (e.g., eliminating incomplete surveys) and organized for analyses (e.g., identifying pre/post pairs for paired t test analysis). Descriptive statistics, analysis of variance (ANOVA), and paired t tests were conducted using the SPSS software 22.0. Assumptions of normality (skewness and kurtosis) for each statistical test presented here were met.

Study Participants

Table 3 summarizes the number of usable surveys collected from each workshop cohort. It further separates the data by participants' academic experience. The participation rate in the matched pre/post/delayed post survey study was 53% in 2012 and 65% in 2013.

Participants' Satisfaction

Overall, CSC NFW participants were extremely satisfied with the workshop. Analysis of the post surveys indicates that the majority (84%) felt that the workshop considerably or fully met their expectations. Moreover, 84% would recommend the workshop to a colleague without any reservations, and 15% would recommend it with reservations. Only one participant would not recommend the workshop. Nine of the 11 participants who had reservations came from the 2012 cohort. Over half of these reservations concerned the balance between the teaching component of the workshop and other advertised components (e.g., grant writing, balancing research and teaching, etc.). Workshop organizers adjusted the advertisement to reflect the focus on teaching for the 2013 workshop offering, which eliminated this type of concern. A year later, participants who answered both post and delayed post surveys felt even more strongly about recommending the workshop to a colleague: the number of recommendations without reservations from this group jumped from 85% in the post survey to 98% in the delayed post survey. While participants' satisfaction with the workshop is important as it indicates an alignment between participants' expectations and learning goals of the workshop, the purpose of the workshop is to influence the instructional practices of these new chemistry faculty. In the next sections, data demonstrating the extent of this impact is presented.

Table 3. Number of Surveys Collected from the 2012 and 2013 CSC NFW Cohorts

Year	Academic Experience	Pre Survey	Post Survey	Pre/Post Pair	Pre/Post/Delayed Post Pair	Total No. of WorkshoP participants
2012	Start first year of academic appointment	14	18	13	10	38
	Start second year of academic appointment	11	16	11	10	
2013	Start first year of academic appointment	19	19	16	14	43
	Start second year of academic appointment	18	17	15	14	

Impact on Awareness of Evidence-Based Teaching Methods

One of the goals of the workshop is to introduce new chemistry assistant professors to instructional practices that have empirical evidence for their effectiveness. Paired t test analyses of the awareness section of the survey allowed the characterization of the extent to which the workshop achieved this goal. In particular, the survey asks participants to identify their level of familiarity with methods presented in Table 4, from "I have never heard of it" to "I have heard the name but I do not know much else", "I am familiar with it but I have not used it", "I am familiar and plan to implement it", "I have used it in the past but I am no longer using it", and "I currently use it". Results of the paired t test analysis show a statistically significant increase in the number of EBTMs with which faculty are familiar (from 8.2 on the pre survey to 14.6 on the post survey; all selections were included in this analysis except "I have never heard of it" and "I have heard the name but I do not know much else"), $t(54) = -11.767$, $p < 0.001$. The eta squared statistic (0.72) indicates a very large effect size. Participants, who already knew on average eight of the 18 methods prior to the workshop, were introduced to, on average, six new methods.

Impact on Implementation of Instructional Practices

A second goal of the CSC NFW is to encourage implementation of these EBTMs. Workshop participants could indicate on the pre and post surveys whether they were interested in implementing any of the methods list in Table 4 during the following academic year (*vide supra*). A paired t test shows a statistically significant 3.5-fold increase (from 1.9 to 6.9) between the pre and the post survey in the number of methods participants were interested in implementing. The eta squared statistic (0.70) indicates a very large effect

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Table 4. Evidence-Based Teaching Methods (EBTMs) Targeted in the Survey

Evidence-Based Teaching Method	Example of Empirical Evidence for the Method
Case Studies	39
Chem Connections	40
Clickers[a]	41
Collaborative Learning[a]	42
Concept Inventory	43−45
Cooperative Learning	46,47
Computer Animations	48
Computer Simulations	48
Concept Maps[a]	49,50
Formative Assessment[a]	51
Interactive Lecture Demonstration	52
Just-in-Time Teaching[a]	53
Peer Instruction	54
Process Oriented Guided Inquiry Learning (POGIL)	55,56
Problem-Based Learning (PBL)[a]	56−58
Think-Pair-Share[a]	59
Student Assessment of their Learning Gains (SALG)	60
SCALE-UP	61,62

[a]Methods addressed in the workshop.

size. More importantly, the delayed post surveys show that 78% of the faculty who indicated in the post survey being interested in using at least one EBTM reported implementing one during the academic year following the workshop. In particular, 51% of the methods that participants identified in the post survey as those that they intended to use were actually implemented. The most implemented EBTMs by these faculty were formative assessment (39%), Think-Pair-Share (35%), Just-in-Time Teaching (20%), and collaborative learning (20%), methods emphasized in the workshop. EBTMs requiring students to work in groups followed closely: Peer Instruction, Case Studies, and Problem-Based Learning were each used by 17% of these faculty.

Workshop participants were also asked to describe the frequency of use of certain instructional behaviors such as lecturing or having students work in groups during lecture. One-way repeated measures ANOVA tests on the workshop participants who had already taught for one year before attending the workshop show statistically significant increases between the pre and delayed post survey in the frequency of implementation of lecture with premade visuals (e.g., slides, animations) and group work. No other differences were observed. Lecture with premade visuals shifted from being implemented nearly every class to being implemented multiple times per class, $F(2,22) = 5.031$, $p = 0.016$, multivariate partial eta squared = 0.314 (very large effect). As Figure 1 indicates, group work's frequency of implementation shifted toward "Nearly every class", $F(2,21) = 7.960$, $p = 0.003$, multivariate partial eta squared = 0.431 (very large effect). However, a closer look at the relationship between the frequency of implementation of group work and the claimed implementation of EBTMs requiring group work indicates some level of disagreement. For example, 25% of the faculty indicating implementing an EBTM based on group work marked that they never used group work in their course. These data indicate a potential disconnect between perception and reality in adoption of EBTMs. Indeed,

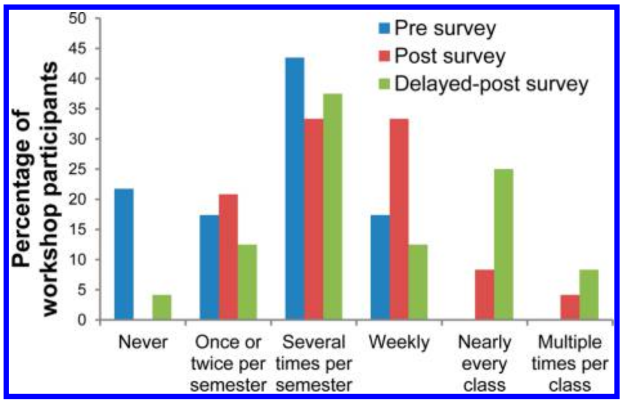

Figure 1. Frequency of implementation of group work before and after participation in the workshops for participants who were entering their second year as assistant professor.

limitations associated with self-reports of instructional practices have been reported previously.[5,63−65]

Impact on Teaching Beliefs

Research has shown a strong connection between instructional behaviors and beliefs about teaching;[16,17,66−70] more importantly, research indicates that effective professional development programs are able to change participants' beliefs about teaching.[12,17,32,66] To evaluate the extent to which the CSC NFW was able to shift participants' beliefs toward student-centered instructional practices, we integrated the Approaches into Teaching Inventory in the online survey.[17,71] Studies have demonstrated that the result of this inventory represents one's beliefs about teaching.[68,72] The inventory places faculty on two five-point scales: a teacher-centered scale and a student-centered scale. As Figure 2 indicates, workshop participants

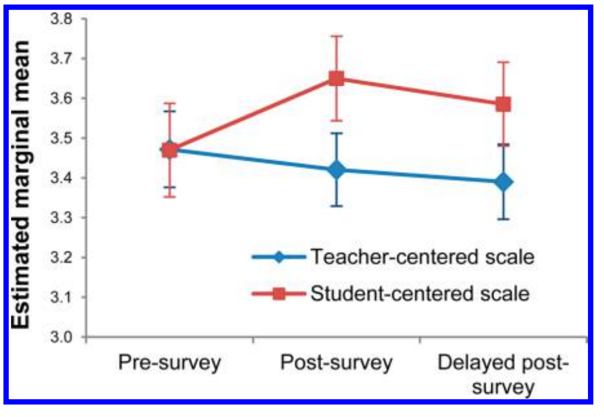

Figure 2. Changes on the student-centered and teacher-centered scale of the Approaches to Teaching Inventory over the course of one year based on matched pre/post/delayed post surveys.

significantly increased on the student-centered scale between the beginning and end of the workshops, $t(47) = -2.788$, $p = 0.008$, $\eta^2 = 0.14$ (large effect size), and decreased on the teacher-centered scale but not significantly, $t(47) = 0.873$, $p = 0.387$. A year later, the participants continued to decrease on the teacher-centered scale but also decreased slightly on the student-centered scale (Figure 2). A one-way repeated measures ANOVA shows that the change on the student-centered scale between the pre and delayed post survey is statistically significant, $F(2,46) = 3.818$, $p = 0.029$, multivariate partial eta squared = 0.142 (large). Post hoc tests show that this significant effect comes from experiencing the workshop (significant change on the student-centered scale between the pre and post survey) and that the decrease observed between the post and delayed post survey was not statistically significant. Therefore, the workshop is able to move participants toward student-centered beliefs in the short term and this change seems to be sustained over time.

■ FUTURE PLANS

The long-standing need for reform in STEM education thoroughly justifies new and continued efforts to help faculty adopt EBTMs, such as the one presented here. Furthermore, preliminary data show a positive impact of the CSC NFW program on faculty and justify its continuation. However, this workshop currently only addresses the needs of a limited set of faculty, those at research intensive institutions. Current plans are to expand the workshop program over the next few years to include faculty from master's granting institutions, predominately undergraduate institutions, and community colleges. Several years of concerted effort will be required to reach these populations by the development and implementation of programming commensurate with the unique challenges of these institutional environments.

As the program is expanded, study of research university participants will continue, and faculty from other institution types will form a new pool of study participants. As results are obtained and subject to critical evaluation in the field, the workshop model will be revised as necessary to provide the most effective experience for participants.

A tangential hypothesis is that, by increasing the numbers of faculty who are aware of EBTMs and issues in student learning, a gradual culture shift will be prompted. The data highlight the need to further engage with local teaching support networks on individual campuses (such as the Offices for Teaching and Learning or the local equivalent) to support the ongoing mentoring of these faculty upon their return to their campuses and departments. Thus, we also hope to seed long-term improvement in chemistry and STEM education through a bottom-up faculty-driven approach.

■ CONCLUDING REMARKS

The CSC NFW workshop is successful in introducing new research university faculty to EBTMs. Our initial data show that participant faculty have a greater awareness of EBTMs and report being more likely to use them in their own classrooms. Furthermore, the workshop program provides continuing support for these faculty as they engage in that effort, another critical factor in successful educational change. While these developments alone are a success in the broader effort to improve STEM higher education, they do not yet demonstrate that these newly motivated faculty are successfully implementing EBTMs. Thus, we are continuing to study these participants to understand their use of EBTMs as a result of the workshop and ongoing activities.

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Notes

The authors declare no competing financial interest.

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