Systemic Transformation of Education Through Evidence-based Reform (STEER): Results and Lessons Learned

Dr. Robert L Potter, University of South Florida

Robert Potter is Senior Associate Dean for Academics and Professor of Chemistry in the College of Arts and Sciences at the University of South Florida (USF). He has been actively involved in promoting more effective STEM instruction K-16 for over 20 years. As such he led or co-led multiple collaborative National Science Foundation and Department of Education funded projects to improve student outcomes in STEM. The most recent being the NSF funded "STEER" project (Systemic Transformation of Education Through Evidence-based Reforms) DUE 1525574 , a partnership between USF and Hillsborough Community College aimed at changing the culture of STEM teaching in a research intensive institution to achieve improved student success.

Dr. Gerry G. Meisels, University of South Florida

Dr. Gerry Meisels is a native of Vienna, Austria. He received his Ph.D. at the University of Notre Dame and worked for Gulf Oil and Union Carbide before joining the faculty at the University of Houston in 1965. He became department chair in 1972, and moved to the University of Nebraska-Lincoln in 1975, where he became Dean of Arts and Sciences in 1983. He joined the University of South Florida as Provost in 1988, a position he held until 1995 when he established the Coalition for Science Literacy. He continues to serve as its Director. He has worked on strengthening Science education in both the K-12 and post-secondary environments, and has led the development of the project "Systemic Transformation of Education Through Evidence-based Reforms", which he submitted to NSF; it was approved by NSF in 2015 (NSF-DUE 1525574). He now serves as PI of this 5-year, $3,000,000 IUSE project that seeks to get faculty in a research intensive university to adopt evidence-based teaching practices, and to change the system to one that values and rewards both teaching and research, with an end result of increasing graduation rates and numbers in the STEM disciplines

Prof. Peter Stiling, University of South Florida

Dr. Stiling is currently a professor in the Department of Integrative Biology at the University of South Florida

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Catherine Bénéteau is a Professor of Mathematics at the University of South Florida. Her research areas are in complex function theory and mathematics education. In mathematics, she has studied polynomial approximation, extremal problems in analytic function spaces and related applications. In mathematics education, she has done a lot of work supported by the National Science Foundation to integrate inquiry-based methods and applications of mathematics into the undergraduate curriculum. She has also been active in faculty development across the United States, in particular in connection with the use of Process Oriented Guided Inquiry Learning (POGIL). She was the recipient of the University Outstanding Undergraduate Teaching Award at USF in 2009. She has been a Project NExT (New Experiences in Teaching) fellow since 1999, and is a member of the Center for the Improvement of Teaching and Research at USF.

Kelley G Schuler, Coalition for Science Literacy, University of South Florida

Kelley Schuler is Project Coordinator for Systemic Transformation of Education Through Evidence-Based Reforms (STEER) – NSF DUE #1525574 and Assistant Director for the Coalition for Science Literacy at the University of South Florida. Kelley provides day-to-day oversight and support of STEER grant program activities, communications, documentation, and financial processes.

Mr. Alberto Danny Camacho, Hillsborough Community College

Mr. Danny Camacho serves as Academic Assistant Dean for the Math & Sciences Division in the Associate of Arts Program at the Dale Mabry Campus. In this capacity he is vital to the smooth running of this large academic division. He is Co-PI of the Systematic Transformation of Education using Evidence-based Reforms (or STEER) - a multi-year partnership with the University of South Florida funded by the National Science Foundation. He also oversees the Louis Stokes Alliance for Minority Participation (LSAMP) Tampa Bay Bridge to Baccalaureate Grant. This multi-year grant encourages minority high school students into STEM careers. This alliance partners Hillsborough Community College (Hillsborough) with State College of Florida (Manatee/Sarasota), and St. Pete College (Pinellas) to combine its efforts at reaching program goals in the entire Tampa Bay region.

Mr. Camacho has more than 20 years of experience in education, serving in a variety of roles. Prior to coming to Hillsborough Community College, he was an Assistant Principal for a charter high school that focused on Drop-Out Prevention, an English teacher working with incarcerated males for the Youth Services Division of the School District of Hillsborough County, as well as a music teacher for several years early in his career.

Mr. Camacho is also a proud veteran of the United States Air Force. After serving, he attended the University of South Florida where he graduated Magna Cum Laude, with dual Bachelor's Degrees in Education and Fine Art. He subsequently returned to the University of South Florida to earn a Master's Degree in Educational Leadership.

Mr. Camacho is proud to be a long-time Tampa resident, where he is active in many Hispanic community organizations. He has received accolades as a member of the Krewe of the Knights of Sant' Yago Education Foundation, the Hillsborough Community College Education Foundation, and previously as a Guardian Ad Litem in Tampa.

Prof. Scott W Campbell, University of South Florida

Dr. Scott Campbell has been on the faculty of the Department of Chemical & Biomedical Engineering at the University of South Florida since 1986. He currently serves as the department undergraduate advisor. Scott was a co-PI on an NSF STEP grant for the reform of the Engineering Calculus sequence at USF. This grant required him to build relationships with engineering faculty of other departments and also faculty from the College of Arts and Sciences. Over the course of this grant, he advised over 500 individual calculus students on their course projects. He was given an Outstanding Advising Award by USF and has been the recipient of numerous teaching awards at the department, college, university (Jerome Krivanek Distinguished Teaching Award) and state (TIP award) levels. Scott also was a co-PI for a Helios-funded Middle School Residency Program for Science and Math (for which he taught the capstone course) and is on the leadership committee for an NSF IUSE grant to transform STEM Education at USF. His research is in the areas of solution thermodynamics and environmental monitoring and modeling.

Systemic Transformation of Education Through Evidence-based Reform (STEER): Results and Lessons Learned

Abstract

We report here on the implementation over five years of a comprehensive project to improve STEM education at the University of South Florida, a large, public university. The STEER project, funded by NSF-IUSE, seeks to achieve this improvement by (1) advocating and incentivizing the adoption of Evidenced Based Teaching (EBT) methods in STEM courses and (2) facilitating change to a culture in which student-centered learning is valued within research-driven STEM departments. A number of synergistic thrusts have been implemented to support these efforts and include:

(1) Facilitating and Incentivizing Adoption of EBT Methods: Faculty can apply for development grants to incorporate EBT methods into their course. They can apply for travel grants to learn more about adopting EBT within their discipline. A peer observation program places STEM faculty from different disciplines into small groups where each member observes a class taught by the others and also a class taught by a separate faculty member versed in one or more EBT approaches. Teaching assistants for STEM laboratory courses are provided training in EBT methods. A new program developed during COVID solicited STEM faculty to produce videos in which they illustrate one or more methods useful in online teaching.

(2) Retreats: STEER facilitates departmental retreats in which faculty are guided to fine- tune their curricula and align departmental courses. These retreats include an introduction to EBT methods. STEER also hosts interdisciplinary retreats, in which STEM faculty from various disciplines are grouped and encouraged to explore ways in which their courses can build upon each other.

(3) Support for Transfer Students: Faculty from our campus and from our main feeder institution meet to align common courses at the two institutions. Students who have previously transferred from the feeder institution are hired as "STEER Peers". They advise students who are in the process of transferring, participate in transfer student orientation, and design and deliver workshops on study skills and professional/career development.

(4) Creating Momentum for Change: A seminar series attended by faculty, administrators, graduate assistants and advisors brings in nationally known presenters who speak on a variety of topics such as EBT methods, institutional change, and student retention (both overall and for under-represented groups). STEER members facilitate STEM Teaching Workshops sponsored by the university provost. Each year, STEM Scholar Awards are made to several faculty who have successfully applied EBT to their courses.

We described many of these thrusts at the 2019 ASEE conference. In this paper, we will focus more on describing the thrusts that have been implemented, or have evolved, since then. Also, as this grant is in its no-cost extension year, we will present results and lessons learned. Specifically, we will address the number of faculty, graduate assistants and undergraduate students directly impacted by each thrust and will quantify, to the extent possible, the effect of

that impact. Institutional data related to retention and graduation rates for STEM disciplines over the course of the project will also be presented. Finally, we will discuss lessons learned, with an eye towards helping institutions who are in the early stages of a program like

Background

We report here on a project undertaken to improve STEM education at University of South Florida (a large, public, research-intensive university), and a community college partner institution, Hillsborough Community College. The STEER (Systemic Transformation of Education through Evidence-based Reform) project seeks to achieve this improvement by encouraging and incentivizing faculty to adopt student-centered and inclusive teaching strategies in STEM courses and, more generally, by promoting a culture in STEM departments that values learning-centered inclusive instruction using evidence-based teaching (EBT) methods. The overarching goals for the project are to increase student preparation and retention in STEM disciplines.

We seek to meet these goals via a number of different thrusts (or categorized interventions), which were described in more detail in a previous paper [1]. Now, the project (funded by a five-year NSF-IUSE implementation grant, following an NSF WIDER planning grant) is in its no-cost extension year and we are positioned to do some reporting on project impacts, along with sharing some lessons learned.

We will begin by reviewing the program thrusts and estimating the number of faculty, graduate assistants and/or students impacted, as appropriate. Next, we will report results describing the value of some of these impacts. This will be followed by a discussion of culture change at the institution and by reporting of institutional data related to student retention and graduation. Finally, we will list some lessons learned, which we hope will be useful to those planning a similar project at their institution.

To help the reader place the descriptions of this paper in context, we will provide first some details about the University of South Florida (USF) and leadership team of the project. USF is a large public institution with student populations of approximately 31,000 undergraduates and 11,000 graduate students. About a third of these students major in a STEM discipline, defined here as any of the degree programs in Chemistry, Physics, Biology, Mathematics and Statistics, Geosciences and Engineering, and a little over 2000 students graduate each year in these programs. Roughly half of the students at USF transfer from another institution and about half of those come from the community college partner on the grant, Hillsborough Community College (HCC), with five local branches.

The leadership team for the project consists of USF and HCC administrators, faculty, department chairs, and professional advisors. At any given time, it has 9 to 15 members. The external advisory board for the project consists of seven nationally and internationally known experts in STEM education with particular knowledge about institutional change, student-centered instruction, and difficulties faced by transfer students and members of underrepresented groups. Project evaluation is done by Horizon Research, Inc.

Project thrusts and impacts

Here we describe the project thrusts and estimate the number of faculty, graduate assistants and undergraduate students impacted. The *value* of these impacts on participating faculty and graduate assistants was discussed in our earlier paper [1]. The value of these impacts on *undergraduate* students is described for some of the program thrusts in the next section.

In designing our interventions, we have found it useful to take note of the *Theory of Planned Behavior* [2], using it as a guide to design interventions that will be most likely to succeed. Of course, our own experiences as faculty members in our various disciplines have also been invaluable in planning and implementation.

(a) Course Redesigns

STEER provides grants to STEM faculty who wish to redesign a course to improve student outcomes. This might include changing the course content, adopting an evidence-based teaching (EBT) method, or both. Proposals are submitted to the project leadership team, who select awardees and offer them constructive suggestions. Funding is typically used to purchase instructional materials, support graduate or undergraduate assistants or to provide a small amount of summer salary.

Over the course of the project, STEER has funded 17 course redesign proposals involving 35 faculty members and including such topics as instituting peer leading in an engineering course, flipping a classroom in a biology course, and incorporating clickers into large sections of General Chemistry. In fact, most of these grants supported faculty teaching large sections of lower division science courses, with the idea of impacting the largest number of students. To that end, we estimate the impact of these course redesigns on students by counting the number of students enrolled in a redesigned course taught by the proposer of the redesign – for each course offered between when the grant was awarded and the present. *We find this enrollment to be over 28,000 students*. Obviously, the university hasn't graduated that many STEM students over the course of the STEER project, which means that a large number of students have been exposed to more than one of these redesigned courses, including a small minority of students who took these courses to satisfy General Education requirements but did not major in a STEM program.

(b) Peer Observation Program

To create more interest in curricular change among a larger group of faculty, in the third year of the project we introduced a lower stakes, lower key approach to introducing them to evidence based instruction: The STEER Peer Observation Program (POP). In POP, interested faculty are placed in groups of three (each from a different department) and observe a lecture from each other's course. In addition, all three group members are required to observe a lecture of another faculty member who employs an EBT strategy in his/her course. Participating faculty first attend a workshop to learn what elements of the classroom process they should focus on and how to provide helpful observations to their colleagues. They meet in their groups after the classroom observations have been made to debrief one another and then submit a reflection paper on their experiences to the project leadership team. The goal of the program is for faculty to be able to observe and be observed by colleagues in a non-evaluative environment.

The Peer Observation Program has been run three times (spring semesters of 2018, 2019 and 2020) with the number of *faculty participants at 11, 13 and 15, respectively*.

(c) SOS (Steering Online Success) STEM

During spring 2020 the university, like most, transitioned to fully online course offerings after students returned from spring break. This was a challenge for faculty, as those who had previous experience teaching online courses were in the minority. By the end of the semester, it was clear that both summer and fall 2020 course offerings would be online. To help STEM faculty transition to teaching online, the STEER Leadership Team quickly instituted a new thrust in which faculty would share tips and techniques for online teaching in short videos that they would prepare themselves. These videos covered a wide range of topics, such as engaging students in an online course, how to effectively use the tools in the Learning Management System, how to incorporate pen tablets into streaming lectures, and tutorials on software for discussion groups, online polling and virtual laboratories. After producing the videos, participants discussed best practices in disciplinary teams and then prepared summaries which they presented in departmental faculty meetings, thus disseminating the information to a larger group of faculty.

Thirty-five STEM faculty from USF and HCC produced videos of 8-15 minutes in length which were organized by topic, curated with a short description and then disseminated further to all STEM faculty at the end of summer 2020. *As of April 15, 2021, these videos had 1,430 views.* The interested reader may view these videos at the STEER YouTube channel https://www.youtube.com/channel/UCOZP2S1iUJk7PNgjvKJMVnQ/about

(d) Faculty Travel grants

As a way to expose faculty to individuals at other institution using EBT and also to promote faculty's own innovations, STEER awarded travel grants to faculty who wished to attend a conference or workshop related to STEM Education. Some faculty used the grants strictly to learn about recent advances in teaching STEM. Others presented their own work at these conferences. Travel grants were in the amount of $1000 and required matching from the proposer's department. Over the course of the project, STEER has awarded 28 travel grants for a variety of conferences. The two most popular conferences among grant recipients were the American Society for Engineering Education Annual Conference and the Biennial Conference on Chemical Education,

In Table 1, we summarize, by department, the number of faculty impacted by the four thrusts described so far. Twenty of the participants were instructors at HCC. Of course, there is some overlap in faculty between the different thrusts. In fact, this speaks to the synergistic nature of the project, where a faculty member might learn about a new teaching technique in the Peer Observation Program and then use a Course Redesign grant to apply it in her course. Or, the recipient of a Course Redesign grant may seek a travel grant to disseminate his experience to a wider audience.

Discipline	Travel Grant	Redesign Grant	Peer Observation	SOS STEM
Biology	3	15	7	6
Chemistry	7	7	6	6
Engineering	11	4	13	11
Geosciences	3	0	0	3
Math	3	3	12	4
Physics	1	5	1	5
Sociology	0	1	0	0
Total	**28**	**35**	**39**	**35**

Table 1. Number of faculty who have participated in SOS STEM or the Peer Observation Program or have been awarded Faculty Travel grants or Course Redesign grants, by department

Many recipients of Course Redesign or Faculty Travel grants have disseminated their results at conferences or in journals. We document these in Appendix A so that the interested reader might contact the lead author for detailed information.

(e) Training for graduate assistants in laboratory courses

Students in STEM spend considerable time with teaching assistants (TA's) in facilitated laboratories and discussion sessions. Therefore, it is important that TA's understand and implement effective teaching strategies that can help maintain students' enthusiasm for their science majors.

Before the start of a fall semester, new graduate students who will be assisting in STEM laboratory courses undergo 3 to 4 days of initial training. Since 2016, part of this training has been facilitated by STEER personnel, who model strategies for active learning and classroom management, culturally sensitive teaching, and facilitation of inquiry-based laboratory experiences. Follow-up sessions in the subsequent two semesters allow the graduate assistants to report on their use of these strategies and approaches, to ask advice of STEER personnel, and to learn from the experiences of their colleagues. Figure 1 shows, by department, the number of graduate assistants who have participated in this training since STEER became involved in the training.

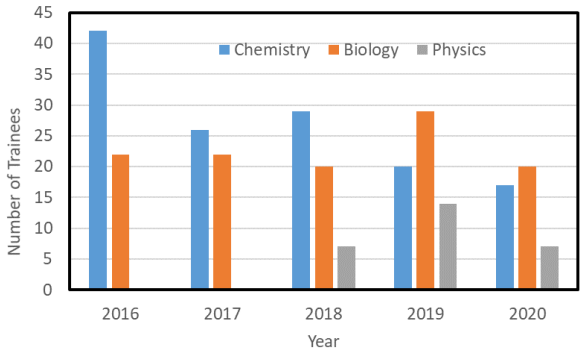

Figure 1. Number of graduate assistants who have participated in STEER-facilitated training for STEM laboratory courses

The average number of participants per year is 55 and each teaches one or (usually) two laboratory sections of 24 students per semester for two semesters. *The number of undergraduate students impacted by this training is therefore estimated to be about 4000 students per year.* This number does not account for students who had one of these graduate assistants for a laboratory course in semesters subsequent to their training.

(f) STEER Peers

Being a large public university with a large transfer population it was important to provide support for those STEM majors transitioning into the university. About 38% of STEM majors are transfer students and nearly 30% of those come from HCC. STEER Peers are undergraduate STEM students at USF who have transferred from HCC. They serve as peer mentors to students who are in the process of transferring from the community college to the university with a focus on our local community college population. STEER Peers are trained by professional advisors in the Colleges of Engineering and Arts and Sciences who also oversee their activities. The peers begin mentoring transfer students (via individual virtual meetings) while they are still at the community college. STEER Peers also meet transfer students when they arrive at the university for transfer student advising and design and deliver workshops on study skills and professional/career development. Often, the relationship between peer mentor and former transfer student is maintained well after the transfer process is complete.

Between fall 2016 and fall 2020, *seventeen students served as STEER Peers and they mentored some 944 unique transfer students via one-on-one sessions.* This is a very conservative estimate of the STEER Peers impact though, as it does not include the number of students who attended transfer orientations with advisors and STEER Peers or those who attended workshops led by STEER Peers.

(g) Retreats

Encouraging discussions about effective teaching and making teaching, like research, a much more team oriented and public endeavor, has been a primary strategy for STEER. To this end STEER sponsors two types of retreats – departmental and interdisciplinary. Departmental retreats typically last two hours or so and are tailored to the department's needs. This is accomplished by meeting in advance with the department chair to discuss the goals of the retreat and planning the retreat content accordingly. For instance, the Department of Industrial and Management Systems Engineering was interested to learn more about active learning methods, so a program was developed in which a number of such methods were modeled for them. The retreat for the Department of Mathematics and Statistics, on the other hand, focused on their interest in reforming their calculus sequence.

Over the course of the project, STEER has facilitated four departmental retreats (Mathematics and Statistics, Electrical Engineering, Industrial & Management Systems Engineering, and a subset of Chemistry and CMMB faculty who teach Biochemistry and/or Biochemistry and Cell Metabolism) *reaching a total of 64 faculty participants*.

Interdisciplinary retreats are used to bring together faculty who teach gateway science and math courses with the goal of fostering collaboration between instructors of different courses. Specifically, retreat facilitators discuss applicable concepts from learning science, and use

workshops to model active learning methods and promote discussions of integration of material between courses.

STEER has facilitated two interdisciplinary retreats with a total attendance of *72 faculty, 18 of which were instructors at HCC.*

(h) Seminar Series

Promoting a culture of student-centered learning is central to STEER's goal of improving STEM education at the university. To accomplish this, it is necessary to involve all stakeholders, not only teaching faculty. To this end, STEER instituted a speaker series featuring well-known experts in STEM education. These speakers addressed a variety of topics, including cultural change, engaging students in underrepresented groups, data-driven institutional reform, transfer student success, evidence-based approaches to student learning, and inclusive classroom teaching techniques. Attendees include faculty, administrators, graduate students and advisors. During their visit, each speaker held discussions with STEM Personnel and with other interested parties in the university community.

During spring 2021, in lieu of seminars, STEER sponsored a virtual workshop on Inclusive Teaching and three virtual faculty conversations related to online instruction. The topics of these three conversations were academic integrity, engaging students, and how faculty's online experience in the past year will change their teaching in the face-to-face classroom.

Over the course of the grant, *STEER sponsored 17 seminars/workshops/conversations with a combined attendance of 638 faculty, graduate students, and staff.* Of course, many of these people attended multiple events and a list of unique attendees is not available. However, the lower bound of unique attendees is 110, which is the largest attendance of any one event.

In addition to those described above, STEER instituted or participated in a variety of other activities and programs including the following: a $2,000 teaching award to recognize faculty implementing effective strategies in the classroom (STEM Scholars), a department level program in which an instructor interested in an EBT method is paired with a faculty member with the appropriate expertise to help them implement the approach, a series of Provost-sponsored workshops on High Impact Practices (HIP) in STEM Instruction, discipline-based meetings between HCC and USF faculty to align course content and outcomes, and reform of the way teaching is evaluated. The interested reader is encouraged to see our earlier paper [1] for additional details.

Evaluation of program impacts

In the previous section we provided estimates of the number of undergraduate students impacted by some of the program thrusts. Here, we will address the *value* of some of those impacts by looking at course-level data. This is difficult in that most STEER programs only impact a subset of sections offered for a given course. However, there are a few instances in which *all* sections of a particular course are impacted by a STEER program and we present three examples below.

(a) Chemistry for Engineers

The Chemistry Department at USF offers a course entitled Chemistry for Engineers – which is taken by all engineering disciplines except for Chemical Engineering and Biomedical Engineering. The course combines important concepts from General Chemistry I and II and allows engineering students in majors for which Chemistry is not a critical component to learn the key aspects of the subject in a single semester.

The instructor for the course compiled statistics that indicated that students taking Chemistry for Engineers underperformed compared to students who took the General Chemistry sequence. Surveys of her students indicated that there was simply too much content in the course – a natural consequence to combining two semesters into one. She then proposed a course redesign to STEER in 2016 in which she would meet with representatives from the relevant departments in the College of Engineering to determine which Chemistry concepts were most critical to the different engineering disciplines. The remaining material would be eliminated and the time formerly spent covering it would be devoted to group learning activities.

The DWF (percent of students who received a D, an F or withdrew from the course) rate for the Chemistry for Engineers course is shown in Figure 2. We believe a significant portion of the improvement in this rate can be attributed to STEER because all sections of the course have been taught by the proposer of the course redesign.

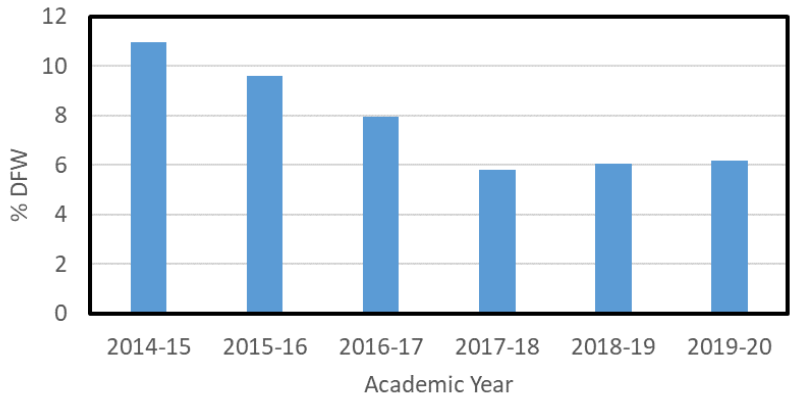

Figure 2. DFW rates in Chemistry for Engineers

(b) Calculus I

As a result of their spring 2016 departmental retreat, the Department of Mathematics and Statistics formed a committee to coordinate their Calculus I course. This involved coordinating assignments between sections, giving common examinations, and instituting peer leading in all sections. In Figure 3, we present the DFW rates for students in Calculus I over time.

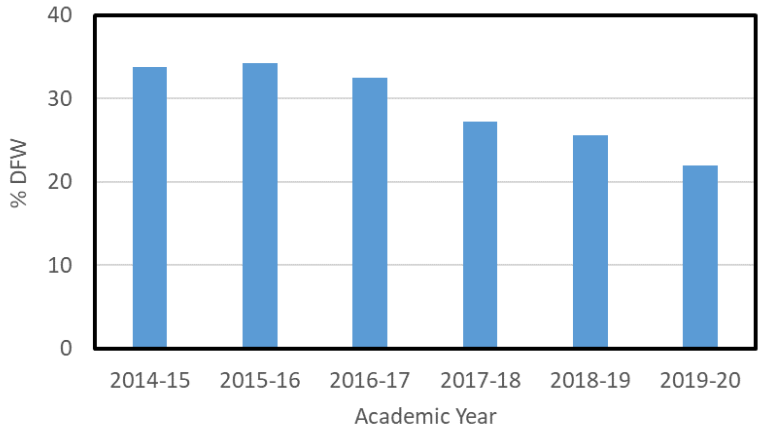

Figure 3. DFW rates in Calculus I

We believe STEER had a strong impact on the improvement in DFW rate in this course because the formation of the committee to reform the course occurred as a result of a STEER-facilitated department retreat.

(c) General Chemistry I Laboratory

This case study is selected because (a) the involvement of chemistry TA's in STEER laboratory training workshops has been high from inception, (b) almost *all* of the Chemistry graduate assistants are assigned to General Chemistry I laboratory and (c) laboratory exercises in General Chemistry I lab, unlike other laboratory courses, are inquiry-based and are considered very challenging to assist in by graduate students.

In Figure 4, the DFW rates for all sections of General Chemistry I laboratory are shown as a function of time:

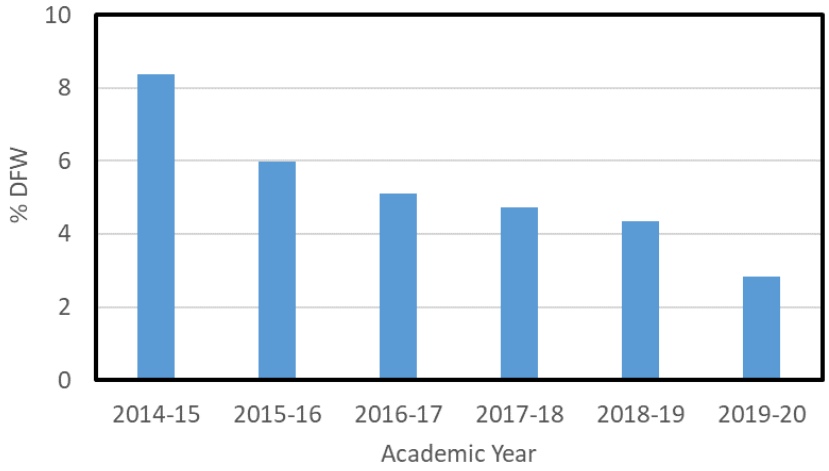

Figure 4. DFW rates in General Chemistry I Laboratory

Although the initial improvement in DFW rate shown for 2015-16 pre-dates the involvement of STEER, we believe that the continued improvement for this course can be tied, in part, to STEER because a significant component of the STEER training sessions involve modeling

instructional strategies and classroom management techniques that are useful for inquiry-based learning. As this example indicates though, we have to be careful about how much credit is given to STEER for the improvement in DFW rates, because, as we describe in the next section, other university efforts were driving changes as well.

STEM Culture

The STEER leadership team believes that improvements in STEM Education, leading to higher retention and graduation rates, can only be sustained if a culture of student-centered learning is developed and maintained in the STEM departments and colleges. In this section, we will discuss the role of STEER in promoting this culture.

It must be noted that STEER has not been acting in a vacuum, and that other efforts to improving student retention and graduation rates have started earlier, and have continued in parallel, with STEER. USF's Office of Student Success in particular, driven by demands of the State for improving retention and graduation rates, began instituting interventions in STEM education as early as 2010. Initial efforts included the raising of admissions standards and criteria, the creation of Living Learning Communities, and opening a large computer lab in the university library for use in early mathematics courses, to enable teaching in a modified emporium model. Recognizing that a sense of community and belonging were important to retention, the Office later created a persistence committee of 25 people who monitor data and coordinate individual student interventions between various professionals including advisors, student advocates and mental health counselors. The Office of Student Success also houses ATLE (Academy of Teaching and Learning), which supports faculty in their roles as teachers and mentors. ATLE supports faculty learning committees, provides classroom observation, individual consultation and on-demand training, and hosts workshops for improving instruction. Although ATLE does not use the word "culture" explicitly, their vision includes the desire to "forge and nourish relationships across campus."

So how does STEER fit within this structure? In the words of the Dean of the College of Arts and Sciences:

I think the STEER grant has been a very good thing for USF because it provides some of the pedagogical operational stuff behind the metrics. I think that our senior administration—the President, the Provost—are very concerned about outcomes. But I think the nice thing about the STEER grant is it leads you to focus on the "how" and not just the "what," in terms of how do you make this happen and what kind of culture do you have to create in order to sustain a commitment to high-impact practices and that sort of thing.

From its inception, a focus of STEER has been to adopt a theory of culture change that would ensure both buy-in from faculty and support (with resources) from the administration. Several change theories were examined [3-6] and elements of several have been applied but the model that has proven most generally effective for us is the Finkelstein Combined Outside-In and Middle-Out Change model [6], which *identifies academic departments as the unit of change*. In the Finkelstein model, the university is considered to consist of three levels (faculty, departments, and administration) with the department taking a mediator rule between administration and faculty. The influence of external change agents can be either "outside-in", targeting administration or faculty, which then affect the departments, or "middle-out", targeting

the department directly, and influencing faculty and administration indirectly. STEER has employed both strategies, including, for example, facilitation of departmental retreats (middle-out), funding of course redesign grants (outside-in, from faculty) and supporting the Provost's High Impact Practice workshops (outside-in, from administration).

A focus on the departments as units of change is particularly suitable if the goal is for faculty to adopt student-centered and inclusive teaching strategies. Improvement in a faculty member's teaching or course is most readily observed, and most likely to be emulated, by his/her departmental colleagues. Furthermore, if one is encouraged to adopt a new teaching strategy from a departmental colleague there is no sense of a "top-down" mandate, which faculty often resist. Finally, faculty often are skeptical that a method that has been successfully applied in a different discipline will translate to theirs. Having a departmental colleague demonstrate this feasibility can remove this last barrier.

The effectiveness of this approach can be illustrated with an example. An instructor in the College of Engineering decided that she wanted to use peer leading in a computer coding course. She received Course Redesign funding from STEER, which she used to support one section of her course with peer leaders. The other section was a control in which peer leading was not used. The same assessments were applied in both courses and she was able to show that students in the section with peer leading had statistically significant higher learning gains. After making her departmental faculty aware of this result, she began advocating the use of peer leaders to other faculty in the department – and offered to manage and train any peer leaders that they might use.

Just three years later, the number of courses in her department that use peer leading has increased to five and the number of peer leaders in the department has tripled. The faculty in her department had been aware of the concept of peer leading for years – but it took one of their own faculty applying it successfully to convince them that it was worthy of adoption on a departmental scale. Peer leading is now part of that department culture. Similarly, using course redesign support from STEER, a biology faculty member with her faculty and graduate student team fully "flipped" the introductory biology classroom, introducing active learning facilitated with the help of undergraduate learning assistants. Other faculty in the department have now started using this approach in their sections of the course.

There is some evidence that a student-centered culture is developing on a wider scale. Earlier, we indicated the large number of students that have been exposed to STEER-supported course redesigns. Horizon Research Inc, (horizon-research.com), the evaluator for this project, surveyed students taking an introductory STEM course during the fall 2018 semester and asked them to respond to questions about one introductory STEM course of their own choosing. One of the questions solicited information about whether students were exposed to learner-centered teaching strategies. Sixty-seven percent of the 400 students who responded indicated that clickers were used in EVERY class session. Fifty-two percent reported that the instructor had students work in pairs or small groups at least once per week. For thirty percent, a flipped class format was used at least a few times over the course of the semester (and for 10%, it was used exclusively). Taken together with the number of students impacted by Course Redesign proposals, we conclude that a significant number of STEM students are being impacted by a shift to using student-centered learning approaches.

Institutional Data

As indicated in the previous section, the efforts of STEER and of the Office of Student Success are entwined and cannot easily be independently assessed. A faculty member may have attended a workshop sponsored by ATLE, became interested in a particular teaching approach, and then received STEER funds to implement it. A struggling but ultimately successful transfer student may have been targeted for intervention by the persistence committee but may have also been positively influenced by a STEER Peer.

Earlier, we presented some examples of improvement in DFW rates for courses that we believe STEER had a significant impact on. Even for those, it is not possible to credit STEER as the sole instrument of improvement. When it comes to institutional data, it is even more difficult to assess STEER's impact. Nevertheless, it is helpful to provide here some institutional data related to retention and graduation – if for no other reason than the funding agency would expect to see it. Certainly, institutional data that was going in the wrong direction would not support a contention that this work was valuable – whether it had an impact on the data or not.

To set the context for the remaining data, the number of degrees awarded to engineering and science majors at USF over time are shown in Figures 5 and 6. Here, science majors are defined as any degree program offered by the departments of Chemistry, Physics, Biology, Mathematics and Statistics or the School of Geosciences.

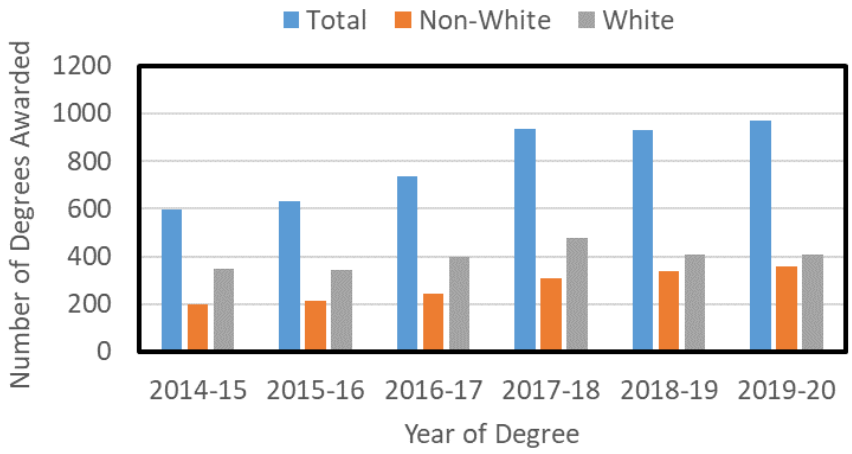

Figure 5. Undergraduate degrees awarded by the College of Engineering

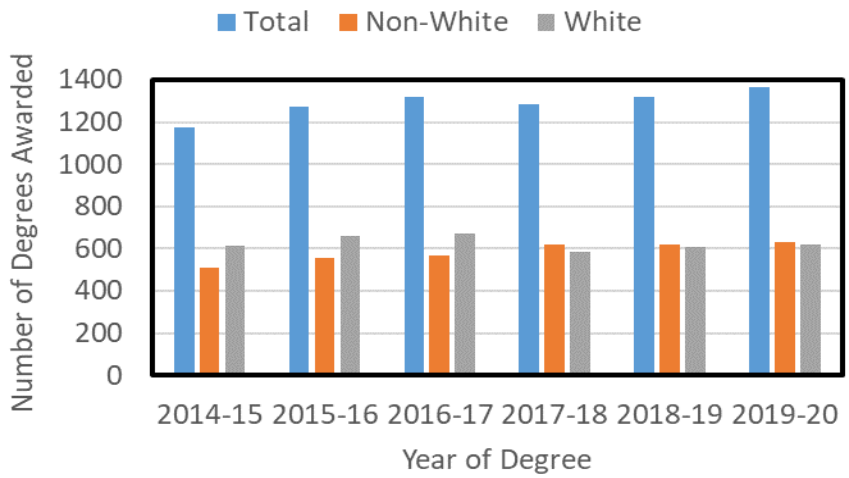

Figure 6. Undergraduate STEM degrees awarded by the College of Arts and Sciences

Figures 5 and 6 show the total number of STEM degrees, as well as the number awarded to white and non-white students. "White" is a descriptor used by the Office of Decision Support at USF. Non-white is a descriptor used by STEER and includes Hispanic, Black, Asian, American Indian, Pacific Islander, and students who reported they were multiracial. It should be noted that the number of non-white and white degree awardees do not add to the total because the total includes non-residents and the white and non-white categories do not. This is because race data was only available for residents or citizens. Figures 5 and 6 indicate that the number of STEM majors graduating is increasing with time and for the College of Engineering, increasing strongly, with a gain of 62% since 2014-15. Degrees awarded to non-white students have increased even faster and now account for about half of STEM graduates at USF.

Figures 7 and 8 show first year retention rates in major and average time to degree (in years), respectively, for FTIC STEM majors in the Colleges of Engineering and of Arts and Sciences:

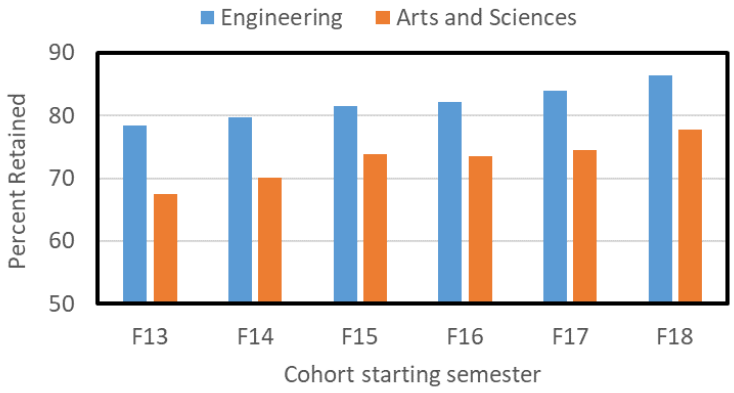

Figure 7. One-year retention rate (in major) for STEM students as a function of their starting semester

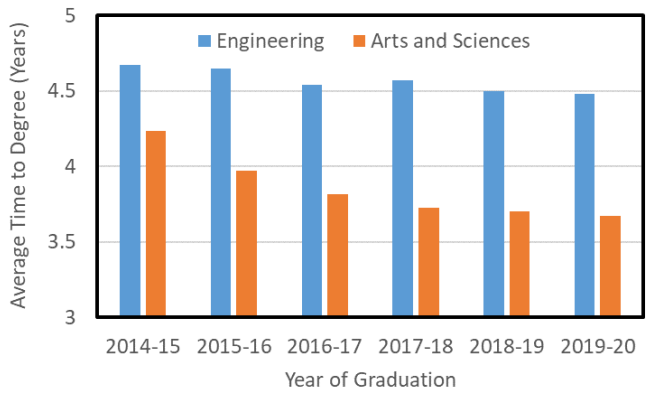

Figure 8. Average time to degree (in years) for STEM students as a function of their year of graduation

Figures 7 and 8 indicate that USF has seen significant improvement in first year retention and time to degree for STEM students, even in the face of increasing enrollments. While the contribution of STEER to these improvements cannot be quantified, the results are indicative of the development of a student-centered culture at the university, for which STEER has tirelessly advanced.

Lessons Learned

For the benefit of the reader who envisions implementing a similar project at their own institution, we conclude by sharing some lessons that the STEER leadership team learned from their project implementation:

1. Culture change takes three to four years to bear fruit.
2. The department is the unit of change but interdisciplinary STEM networks can be helpful.
3. Culture change requires a multi-vector approach to build awareness and engagement.
4. Programs with low barriers to participation generate more involvement.
5. Programs for full time faculty must be non-threatening to succeed in changing culture.
6. Faculty respond best to same-discipline outsiders with messages about evidence-based teaching practices but tend to reach out for help to knowledgeable faculty in their own department.
7. Time is a critically important commodity to all faculty and hence programs must be respectful of time costs and the value return.
8. Once faculty see the value of a change they are more likely to expend time and effort on it.
9. The true power brokers in a department are the senior research faculty - but most can only be targeted late in a program of culture change around teaching. They tend to value teaching changes that reduce their time investments. Team teaching or graduate students support can be incentives.
10. Chairs are critically important partners and can be powerful allies in supporting teaching and learning improvements. However, their own biases, along with university reward structures, may restrict their committing significant departmental efforts to these ends.
11. Incentives for departments (such as discretionary money for the chair) are often necessary for a program to succeed.

12. Monetary incentives must match the perceived need: even graduate students ignore $100 stipends sometimes in order to skip a half-day training mid-semester.
13. Students react well when interacting with knowledgeable peers, as applied, for example to mentoring of transfer students, use of learning assistants to increase active learning in the classroom, or the use of more senior TAs in new TA workshops. Training and good oversight of the peers in all cases is critical to success.
14. Continuous review of programs and constant ideation will help sunset less effective programs, and lead to the development of better replacements. An attitude of, “Let’s try it, evaluate it and move on if it’s not working”, is useful for maintaining momentum. Ideas need at least 3-4 partners to shepherd into practical reality.
15. An action-oriented bias is essential to keep moving forward.
16. The make-up of the culture-change leadership team is essential; champions on the leadership team must, in combination, a) bring wisdom/experience about both EBT and department politics, b) be able to influence the right people, c) be flexible and collegial so that when decisions are not unanimous (which happens frequently), the project continues to move forward without hard feelings and d) have the energy and willingness to commit time to the project.
17. The culture-change leadership team should broadly represent the disciplines being targeted.
18. Leadership meetings need to be frequent enough to generate urgency and accomplishment of tasks, but not so frequent as to create burnout. A biweekly model, 90 minutes per meeting with agenda and minutes works well.
19. The change campaign needs to involve the teaching & learning center or provide funding to staff a professional development expert. Much of the work of culture change occurs via events and programming that are familiar to teaching centers.
20. Challenges also represent opportunities that should be exploited. Example: coronavirus campus shutdowns with transition to "remote" learning meant that many faculty used the Learning Management System and many other valuable technologies for the first time, to their future benefit.
21. Communicate early and often about your efforts and success to those in upper administration. Aligning programs to University priorities can lead to additional resources and help promote the intended culture change.

Conclusions

STEER seeks to improve STEM education at the University of South Florida by advocating for student-centered learning in STEM courses and the eventual creation of a student-centered teaching culture in STEM disciplines. In this paper, we reviewed the various project thrusts and estimated the number of faculty and students impacted by them. We provided case studies showing improvement in several STEM courses for which we believe STEER to have had a significant impact. The impact of STEER on observed improvements in first year retention and time to degree for STEM majors cannot be quantified but are indicative of a student-centered culture that is evolving at USF. We concluded with a list of lessons learned that we hope will be useful to those instituting a similar project.

The STEER leadership team and the many faculty supported through the grant activities have been active in disseminating information about the program and its successes at a wide variety of conferences and meetings. A list of such presentations is given in Appendix B for the reader

who would like more detailed information about a particular aspect of STEER. The reader is also encouraged to contact members of the leadership team directly.

Acknowledgement

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Appendix A. Presentations and publications resulting from Faculty Travel grants and Course Redesign grants

C. Bégin, K. Daniel, U. Kulatunga, D. Gosh, and A. Helip-Wooley, "Best practices in interdisciplinary and inter-institutional projects," *Sunshine State Teaching and Learning Conference, St. Petersburg Beach, FL, 2017.*

S. Pettit, "Strategies for Success in Large Classrooms," *ASEE Chemical Engineering Summer School, Raleigh, NC, July 2017.*

S. Pettit, "Peer Led Team Leading in Chemical Engineering," *Session in Education Division, AIChE Annual Meeting, Minneapolis, MN, October 2018.*

E. Jones-Mason, "Investigation of gene mutations in Drosophila: Integrating research into laboratory curriculum," *Sunshine State Teaching and Learning Conference, St. Petersburg, FL, January 1 to February 2, 2018.*

U. Kulatunga, “Professional development of peer leaders in general chemistry with the use of Toulmin’s argumentation framework,” *Biennial Conference on Chemical Education (BCCE), University of Notre Dame, Indiana, July 29-August 2, 2018.*

D. Cruz-Ramirez, “Using clickers for peer instruction in large enrollment lectures of general chemistry,” *Biennial Conference on Chemical Education (BCCE), University of Notre Dame, Indiana, July 29-August 2, 2018*

J.E. Gaines, “Engineering skills and not people through the first-year design experience and service learning,” *ASEE 126th Annual Conference and Exposition: First-Year Programs Division, Tampa, FL, June 2019*.

J.E. Gaines, O. Akintewe, S. Small, and T. Henry, “Engineering design instruction using Slack for project support and teamwork,” *ASEE 126th Annual Conference and Exposition: Design in Engineering Education Division, Tampa, FL, June 2019.*

T. Lane, J.E. Gaines, S. Willis, S. Ahmad, K. Morgan, and E. Vomvoridi-Ivanovic, “Culturally responsive pedagogy in an engineering summer intervention program (Research),” *ASEE 126th Annual Conference and Exposition: Minorities in Engineering Division, Tampa, FL, June 2019.*

E. Vomvoridi-Ivanovic, T. Lane, J.E. Gaines, K. Morgan, S. Willis, and S. Ahmad, “Teacher perceptions of incorporating engineering design in mathematics and science instruction (Research),” *ASEE 126th Annual Conference and Exposition: Educational Research and Methods Division, Tampa, FL, June 2019.*

J.N. Kuhn and V.R. Bhethanabotla, "Materials Science and Engineering Research Perspective within the Functional Materials and Manufacturing Institute REU Program at University of South Florida," *ASEE 126th Annual Conference and Exposition, Tampa, FL, June 2019.*

M. Al Busaidi, C. Garcia, C. Brown, and R. Guldiken, “Towards flipping the undergraduate fluid mechanics class,” *ASME IMECE 2019, Salt Lake City, Utah, Nov 11-14, 2019.*

M. Rahouti and K. Xiong, “A customized educational booster for online students in cybersecurity education,” *Proceedings of the 11th International Conference on Computer Supported Education, Heraklion, Crete, Greece, May 2-4, 2019.* Vol 2: 535-541.

S. Pettit, “Peer-to-Peer Instruction,” *Workshop, ASEE Annual Conference, Tampa, FL June 2019.*

S. Pettit, “Creating Meaningful Learning Experience,” *Panel, SWE Annual Conference, Anaheim, CA, Nov 2019.*

S. Pettit, “Establishing a Learning Assistance (Peer Leader) Training Program,” *Session in Education Division, AIChE Annual Meeting, Orlando, FL, November 2019.*

A. Kaw, “Effect of letting students choose the weight of each assessment category on semester grade,” *Proceedings of ASEE-SE Annual Conference and Exposition, Auburn, AL, March 8-10, 2020.*

S. Sheffield and V. Ricchezza, "Scientist of the Week: measuring the effects of diverse representation in STEM classrooms," *Earth Educators Rendezvous (online), July 13-17, 2020.*

C. Garcia and R. Guldiken, "Active Remote Learning or Active No More Learning? A Lessons Learned from an Undergraduate STEM Course in Fluid Mechanics," *STEMPowered State University System of Florida Faculty Symposium. Online Symposium, University of Florida, Oct. 20-21, 2020.*

S. Hoskins, and C. Bégin, "Taking it up a notch: From engaging clicker integration to a flipped large-scale class," *STEMPowered State University System of Florida Faculty Symposium. Online Symposium, University of Florida, Oct. 20-21, 2020.*

L. Shea, C. Bégin, C. Osovitz, and L. Prevost, "Comparison of student success between high clicker and low clicker frequency in a large-enrollment introductory biology course," *Journal of College Science Teaching,* vol. 50(2), pp.78-87, 2020.

M. Nanjundan, P. Rao, and A. Upadhyaya, "Transformative interventions in cell biology: Motivating cell and molecular biology majors using instructor/student-interactive demonstrations of key concepts,". *Asian Conference on Education & International Development, Tokyo, March 22-24, 2021*.

Appendix B. Dissemination of STEER by Project Personnel

R. Potter, A. Helip-Wooley, M. Goodwin, P. Stiling, J. Wysong, and G. Meisels, "On the road to culture change: Making evidence-based teaching the norm in STEM at a Research 1 university," *Envisioning the Future of Undergraduate STEM Education (EnFUSE): Research and Practice. Washington, DC, April 28, 2016.*

J.E. Lewis, A. Helip-Wooley, C. Partin, and M. Mayberry, "(Un)disciplining pedagogy: Transdisciplinary analysis of TA professional development programs," *American Association for the Advancement of Science. Boston, MA, February 18, 2017.*

R. Sears, R. Potter, A. Helip-Wooley, S. Campbell, and G. Meisels, "On the road to culture change: Making evidence-based teaching the norm at a Research 1 university," *Workshop on Diversity and Inclusion hosted by SMTI/ASCN. New Orleans, LA, June 24-25, 2017.*

R. Sears, R. Potter, V. Raley, and G. Meisels, "STEER Case Study," *Workshop on Diversity and Inclusion hosted by SMTI/ASCN. New Orleans, LA, June 24-25, 2017.*

G. Meisels, "Case Study: "STEER" Systemic transformation of education through evidence-based reforms," *Network of STEM Education Centers (NSEC) National Conference, New Orleans, LA, June 23-24, 2017.*

G. Meisels and R. Potter, "From building capacity to creating cultural change in research-intensive STEM departments," *AAC&U 2018 Transforming STEM Higher Education Conference. Atlanta, GA. November 8-10, 2018.*

R. Potter and J. Wysong, "Peer advising for STEM transfer student success: A community college-university partnership," *AAC&U 2018 Transforming STEM Higher Education Conference. Atlanta, GA. November 8-10, 2018.*

R. Potter, G. Meisels, R. Sears, K. Yee, J. Wysong, and E. Banilower, "Reinvigorating the leadership of a project to promote use of evidence-based teaching strategies: or, How to re-engage an influential but busy team," *NSEC (National STEM Education Centers) 2018 National Conference. Columbus, OH, June 6-8, 2018.*

R. Sears, R. Potter, and G. Meisels, "Teamwork makes the dream work: Systemic transformation of education through evidence-based reforms," *NSEC (National STEM Education Centers) 2018 National Conference. Columbus, OH, June 6-8, 2018.*

G. Meisels, V. Harwood, and R. Potter, "Reaching tenure-line STEM faculty," *NSEC (National STEM Education Centers) 2018 National Conference. Columbus, OH, June 6-8, 2018.*

R. Sears and G. Meisels, "Top 10 things to consider in promoting students' success in STEM fields," *Sunshine State Teaching and Learning Conference, St. Petersburg, FL, January 1 to February 2, 2018.*

R. Potter, J. Wysong, M. Goodwin, and J. Feliciano, "STEERING" community college transfer students toward success in STEM – A peer approach," *National Student Success Conference. Tampa, FL, February 21-23, 2018.*

J. Wysong and D. Camacho, *"*STEERing students to success in their 2+2 STEM transfer experience," *NISOD International Conference on Teaching and Leadership Excellence. Austin, TX, June 15, 2018.*

R. Sears, G. Meisels, and R. Potter, "STEERing the systematic approach to improve learning: A Hillsborough Community College-University of South Florida partnership," *10th Understanding Interventions Conference. Baltimore, MD, March 2-4, 2018.*

R. Sears and R. Potter, "Supporting STEM lab teaching assistants enactment of an effective operational curriculum via a year-long professional development initiative," *NSEC 2019 National Conference. Omaha, NE, May 31 – June 2, 2019.*

R. Sears, R. Potter, and G. Meisels, "Utilizing effective features of professional development to support STEM lab teaching assistants to exhibit good teaching practices," *NSEC 2019 National Conference. Omaha, NE, May 31 – June 2, 2019.*

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K. Yee and A. Helip-Wooley, "Quickly moving the needle for multi-section courses: the "Hackathon" approach," *NSEC 2019 National Conference. Omaha, NE, May 31 – June 2, 2019.*

J. Hoffman and J. Davis, "Peer mentors: STEER-ing themselves and mentees through the transfer experience," *2019 National Conference on Students in Transition. Orlando, FL, October 12-14, 2019.*

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J. Hoffman and J. Davis, "Practitioner Panel: STEM transition programming - University of South Florida STEER Peer mentor program," *National Institute for the Study of Transfer Students (NISTS) Annual Conference. Atlanta, GA., February 5-7, 2020.*

R. Sears, R. Potter, G. Meisels, and K. Schuler, "Using professional development to support equitable learning opportunities in STEM lab settings," *NSEC 2020 National Conference. Virtual.*