Enriching Undergraduate Experiences With Outreach in School STEM Clubs

By Michael Ferrara, Robert Talbot, Hillary Mason, Bryan Wee, Ronald Rorrer, Michael Jacobson, and Doug Gallagher

The need for a more robust, well-trained STEM workforce is becoming increasingly acute in the United States, and there is a clear need to recruit and retain a larger and more diverse population of undergraduate STEM majors. Although numerous efforts to improve engagement and support in the traditional P–16 classroom have been implemented successfully, it is also critical to explore other types of activities that have potential for high impact. The STEM Club Leadership for Undergraduate STEM Education, Recruiting and Success project at our large public research university in the Mountain West presents an outreach model to engage undergraduate STEM majors in developing and facilitating activities in local middle and high school STEM clubs. Through case studies, built on data from reflective journals and semistructured interviews, the project has identified a number of benefits to the first cohort of participants, which is comprised of 11 undergraduate students operating in interdisciplinary teams across five schools. In this article we describe the essential elements of our outreach model and suggest benefits related to undergraduates' content knowledge, communication skills, metacognition, and identity as a future STEM professional.

One of the most pressing challenges facing the United States in the coming decades is the need to recruit, train, engage, and retain a diverse, well-prepared workforce in science, technology, engineering, and mathematics (STEM; National Research Council, 2010; President's Council of Advisors on Science and Technology, 2012; Stine & Matthews, 2009). The need is particularly pressing from traditionally underrepresented populations in STEM (Cole & Espinoza, 2008; Harper & Newman, 2010; National Science Foundation, 2017).

Participation in after-school, summer, and other informal STEM programs is viewed as an experience that is critical to positive outcomes for learners (cf. Chubin, Donaldson, Olds, & Fleming, 2008; National Academy of Sciences, 2007). Documented benefits for participants in informal STEM programs include an increase in attitudes and interest in science and technology (Hayden, Ouyang, Scinski, Olszewski, & Bielefeldt, 2011) and a stronger understanding of STEM concepts and processes (McGee-Brown, Martin, Monsaas, & Stombler, 2003). In-school communities can play a significant role in encouraging students to consider further study and careers in STEM (Aschbacher, Li, & Roth, 2010). Likewise, STEM outreach programs can support improved perspectives of STEM, STEM professionals (Laursen, Liston, Thiry, & Graf, 2007), and an increased likelihood of pursuing a STEM major (Sahin, 2013). Organizing and implementing outreach activities can promote outreach providers' ownership of their own learning and nurture a sense of belonging and engagement (Abernathy & Vineyard, 2001). There is, however, a paucity of research on undergraduate STEM majors in K–12 settings and the outcomes related to their experiences in the context of outreach.

We present a model that broadens the STEM education experience for undergraduate outreach providers (hereafter referred to as "Fellows"), specifically with respect to the development of their content knowledge, communication skills, metacognition, and STEM identities, through immersive experiences in school STEM clubs. We leverage communities of practice (Lave & Wenger, 1991) as a theoretical lens and guiding framework.

Community STEM clubs

Although our model can be applied to a variety of outreach settings, our program specifically tasks undergraduate STEM majors with organizing in-school and after-school STEM clubs and teams in middle and high schools. The STEM CLUSTERS project, funded by a National Science Foundation (NSF) Improving Undergraduate Science Education (IUSE) award, organized and supported five STEM clubs at a diverse collection of partner schools in the Denver, Colorado metropolitan area under the umbrella of the Community STEM

Clubs (CSC) program at the University of Colorado Denver (Table 1).

All school names that follow have been anonymized. The CSC program was piloted in 2014–2015, partnering with Gold Meadow High School (GMHS), Young International Academy (YIA), Eastern Leadership Academy (ELA), and Larimer High School (LHS); a separate pilot program partnered with the Western Regional High School (WRHS) automotive team. The CSC pilot program helped GMHS and ELA restart their school STEM clubs, both of which had been inactive for 4 or more years, and provided support to the long-standing Technology Student Association (TSA) chapter at LHS. The pilot program at WRHS was integrated into the school's STEM coursework and provided support for the WRHS automotive team. The YIA TSA chapter, which we discuss next, had met 2 to 3 times in the year before the start of our partnership, but the departure of the sponsoring teacher left the club defunct until 2015–2016.

Our partner schools also represented the broad socioeconomic diversity inherent in our city and region. For instance, between 19% and 82% of students in each partner school (41.5% overall) were from groups underrepresented in STEM (Black, American Indian, Alaska Native, Asian-Pacific Islander, Hispanic or Latino). Further, between 25.1% and 70.7% (38.5% overall) of students in each partner school received free or reduced lunch. This information provides some evidence that the outcomes reported here are achievable in varied schools and communities.

Lead teachers at each school helped publicize the clubs, assisted with curricular alignment and classroom management, and collected informal feedback from participating students. The insights of the lead teachers supported Fellows' development and implementation of activities and strengthened connections between the program and our partner schools. Hence, replication of this outreach model should include committed lead teachers at partner institutions.

Core tenets of outreach model

The intent of this project is for the four central components of our outreach model to collectively enrich the Fellows' experience, contributing to student learning and personal growth, and strengthening communities of practice.

Full student responsibility

The model requires the Fellows to take responsibility for research, planning, and execution of activities. Although faculty mentors and lead teachers provide feedback and support, "ownership" of the outreach process lies with the Fellows.

A breadth of examples of club activities developed and deployed by the Fellows appears in Table 1. In the teams preparing for competitions, activities were often driven by the skills needed to succeed in various categories. These included drilling on "day-of" TSA challenges, such as technology-themed debates and helping students acquire proficiency with

TABLE 1

Summary data for partner schools and clubs in 2015–2016.

School	Club type	Club activities
Gold Meadow High School (GMHS)	High school STEM club	As a general-interest STEM club, activities varied. Examples include designing balloon-powered Mars rovers, a Rube Goldberg machine design competition, investigation of conductive properties of liquids using ice-cube tray batteries, and red cabbage juice pH testing.
Young International Academy (YIA)	Middle and high school TSA* chapter	Fellows in this International Baccalaureate school helped prepare students for the TSA state tournament. Example projects include building robots, car design, water systems engineering, creative storytelling, and mock debate.
Larimer High School (LHS)	High school TSA chapter	Fellows helped prepare students for the TSA state tournament. Example projects include: design software, 3D printing, technical writing and speaking, Arduino programming and activities centered on general design principles.
Eastern Leadership Academy (ELA)	Middle school STEM club	As a general-interest STEM club, activities varied. Examples include "mathemagical" card tricks, exploring gravitational waves and the LIGO project, cow eye dissections, disease transmission and tracking, and an introduction to information theory.
Western Regional High School (WRHS)	High school Automotive design team	Students designed, built and tested prototype and urban concept hydrogen fuel cell cars at the Shell Eco-Marathon of the Americas in Detroit, MI (2015). Fellows provided mentorship, training and informal support throughout the process.

*Technology Student Association (TSA) is a national student organization that aims to foster personal growth, leadership and opportunities in STEM.

3D design software and techniques like carbon fiber compositing. When planning for both general STEM clubs and TSA chapters, Fellows were encouraged to directly use or adapt existing activities from reliable online sources. A repository of these resources and a library of outreach activities implemented by the program is maintained and updated on the CSC website (Resources, 2017).

All Fellows complete a three-day summer workshop with team planning sessions to prepare them for their outreach experiences in STEM clubs. The workshop includes an overview of instructional resources, a conversation with outreach-experienced peers, discussions on effective communication and classroom issues, and advice from lead teachers. The workshop culminates with each team presenting their outreach plan for the first 6 weeks of the semester, with feedback from their peers and faculty.

STEM communication seminar

At the heart of outreach is the need to clearly communicate STEM topics to a diverse audience. This skill is also crucial for future STEM professionals to further public understanding of science (cf. Weigold, 2001; von Winterfeldt, 2013), and function more effectively within teams. The Fellows' growth as STEM communicators is supported by a key component of the STEM CLUSTERS outreach model: the (1-credit) "STEMmunication" seminar.

Once each month, Fellows meet to explore effective STEM communication through written, audio (podcast), video, and oral presentations. Fellows are asked to find and analyze examples of these media, and assess the benefits/challenges of each. Although there is often a great deal of conversation related to their core task of outreach with middle and high school students, the seminar focuses on STEM communication for all audiences. STEMmunication also serves as an important source of mentoring in our outreach model, as it allows Fellows to discuss the challenges and successes they encounter in various clubs. These regular meetings create and nurture a community of practice in which participants develop understandings, norms, relationships and identities relevant to their roles as outreach Fellows (Handley, Sturdy, Fincham, & Clark, 2006).

Support from peers and faculty mentors

Our model includes support mechanisms that allow Fellows to draw on the experiences of faculty mentors and their peers. The "share-out" portion of the STEMmunication seminar encourages Fellows to candidly discuss their experiences, presenting an opportunity for meaningful reflection, as discussed next. Faculty also share experiences that inform planning for upcoming club activities and contribute to discussions on different modes of STEM communication.

Additionally, the Fellows share tips for outreach and support each other as they navigate the challenges of their assignments in their respective clubs. Our recognition of the importance of peer support arises in part from interviews with and reflections by the initial 2015–2016 cohort of Fellows, who identified the value of this peer interaction.

In addition to faculty and peer support throughout the STEMmunication seminar, every team is observed each semester by a faculty mentor, followed with suggestions to enhance future activities and growth. In-class support is also given by the lead teachers at each partner school.

Reflection

At the outset of the STEM CLUSTERS project, written reflections and semistructured interviews were viewed as research data. As the project progressed, the value of reflection to the Fellows became more apparent. We now recognize these activities as integral components of learning and a key driver of their growth. Through written reflections linked to the STEMmunication seminar and 1-hour interviews each semester, Fellows are asked to reflect on their participation, particularly their perceived successes and challenges in engaging middle/high school students. Fellows are also asked to share their views on STEM and STEM communication in the context of their clubs and overall experiences in the project.

Introspective teaching and learning has been shown to be valuable in a number of settings. The process of critically assessing one's teaching is a central part of reflective pedagogy (Zeichner & Liston, 2013), as it allows educators to disentangle their perspectives and contexts from those of their students (Brookfield, 1995).

Tanner (2012) noted that reflective journals are an effective method to build metacognitive awareness in students, as is awareness of diverse learning strategies (Pintrich, 2002; Zohar & David, 2009). Reflecting on how to best promote learning in their clubs, explicitly writing and verbalizing their observations on teaching/learning strategies as well as problem-solving approaches, served as drivers of metacognitive growth in the Fellows.

Theoretical foundations

We contend that learning occurs through social participation (Lave & Wenger, 1991; Sfard, 1998; Vygotsky, 1978) as well as through the acquisition of knowledge. The rich type of participation necessary for developing meaningful epistemologies (Elby & A-Sep Hammer, 2001) and mental models (Redish, 1994) occurs as individuals engage within communities of practice. Further, expertise develops as participants become more involved in that community (Chi, 2006; Lave & Wenger, 1991) and are doing so in a meaningful way. Therefore, learning occurs *through* participation, and being a participant refers to "a more encompassing process of being active in social communities and constructing identities in relation to those communities" (Wenger, 1998, p. 4). Figure 1 depicts our conceptual model.

Content knowledge and communication skills are related to participation in these communities, whereby Fellows' interactions augment their abilities to understand and convey information in ways that support meaning-making processes at multiple levels. *Metacognition*, though a decidedly more cognitive construct, is shaped and developed as Fellows work with others, observe problem-solving strategies, and make explicit their own contributions to a group (Pintrich, Marx, & A-Sum, 1993; Pintrich, Wolters, & Baxter, 2000; Schraw & Moshman, 1995). *Identity* is shaped by participation that involves understanding the self in relation to individual and collective norms within communities of practice (Handley et al., 2006). We situate Fellows' identity in relation to their views of STEM and perceived competencies as a future STEM professional. Collectively, these shared outcomes deepen our understanding of diverse, interdependent communities and the learners within them (Table 2).

Shared outcomes

Each STEM club is conceptualized as a case, and all clubs and Fellows together comprise a set of interrelated cases. Our case study approach is meant to situate the Fellows within distinct communities of practice, within contexts, and along varied dimensions of learning.

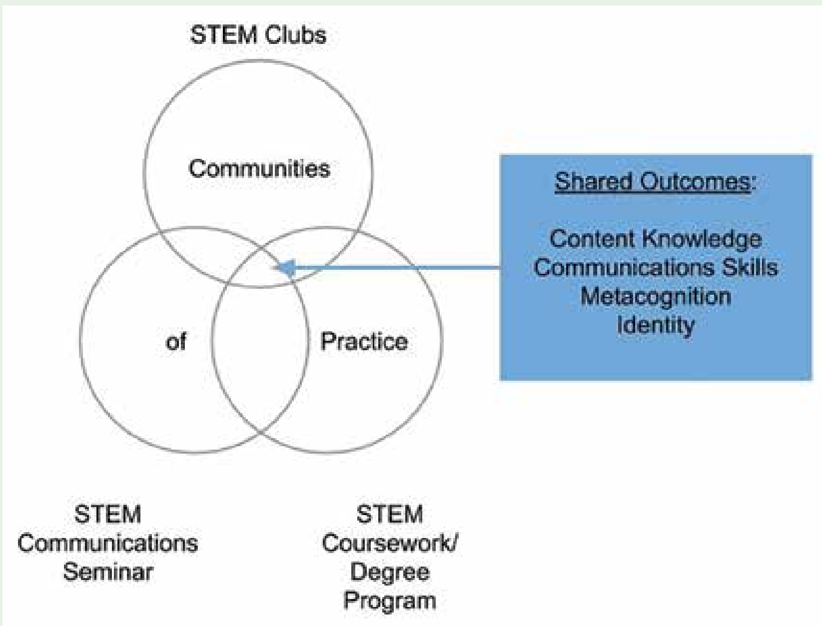
A diverse collection of undergraduate students participated in the CSC program during Year 1 (Table 2). This includes STEM majors with prior degrees in the arts, a U.S. Navy veteran, a retired firefighter, and a majority (8 out of 13) of women representing a range of ethnicities. It has been documented that underrepresented graduate students are overrepresented in outreach programs (Thiry, Laursen, & Liston 2007); our cohort of Fellows provides some evidence that this may also be the case for undergraduate students.

In the discussion of study outcomes that follows, we focus on the 11 undergraduate Fellows who participated for the entire year. All names given below are aliases. Multiple sources of data were gathered from each Fellow including a personal biosketch, which provided valuable insights into each Fellow's background and prior experiences; two semistructured interviews; and monthly reflections. Interviews and reflective prompts included questions related to content knowledge, communication skills, metacognition, and identity.

Each member of the research team completed an independent reading and analysis of all data related to each Fellow within the context of their STEM club. Emergent patterns in the data were identified using open coding in an iterative process of inductive analysis that aligned with the outreach model and shared outcomes of content knowledge, communication skills, metacognition, and identity (Figure 1).

FIGURE 1

Communities of practice with shared outcomes from our outreach model.



Evidence of shared outcomes: YIA

In this section, we present evidence for some of the shared outcomes mentioned in Figure 1 through the case of YIA. We highlight YIA as the Fellows provide a good snapshot of the breadth of students and academic majors involved in the CSC program. The shared outcomes described next, while arising at YIA, are also indicative of the experiences and growth reported by Fellows across all five clubs (Table 3).

The club at YIA is part of the TSA, which is a national student organization that aims to foster "personal growth, leadership and opportunities in STEM" (http://www.tsaweb.org/Our-Mission) through sponsorship of middle and high school competitions.

YIA is the International Baccalaureate (IB) school for its home school district, and all students are expected to adhere to the strict academic standards of the IB program. The school's diversity and high percentage of students on free and reduced lunch are reflective of demographics in the district. Recognized as standouts at their feeder schools, some YIA students excel and move on to top colleges after graduation. At the same time, a large proportion of the students struggle with poverty and other challenges, which contribute to issues with engagement and completion of academic requirements.

Fellows visited 8th- and 10th-grade technology classes at YIA for one 90-minute block each week to help students prepare for the TSA state tournament. Activities included circuit design using conductive ink pens, a technology-themed student debate, and a "60-minute maker challenge," in which students were given basic materials and a list of constraints and were asked to use their design skills to complete a simple task in limited time.

The unique contexts at YIA presented a challenge for the Fellows there: How best to engage a diverse group of students in the context of a yearlong TSA preparation process? Although the TSA chapter at YIA did not send any competitors to the 2016 state tournament, the groundwork laid by the 2015 Fellows resulted in a healthy group of 15–20 competitors in the 2017 TSA state tournament.

YIA STEM Fellows

The following biographical descriptions are informed by Fellows' biosketches, reflections, and interviews.

Karl is a second-year mechanical engineering major who studied engineering because of his successes in mathematics through high school. In his application for the CSC program, he expressed great enthusiasm about the opportunity to work with students and share his love of STEM.

Sandra is in her second year of college after serving 4 years as a passive sonar technician in the U.S. Navy. A prebioengineering major, she was still exploring other options in STEM at the start of the program. In particular, she expressed possible interest in teaching mathematics after graduation, although she ultimately decided to study engineering by the end of her year in the CSC program.

Marcus is an electrical engineering major one year away from graduation. He is broadly interested in STEM and was a TSA participant in high school. He worked for 10 years as a firefighter until an injury forced his retirement, and he now works part-time as an emergency medical technician. Marcus speaks passionately about his desire to promote equity across STEM and was motivated to apply to the program by his young daughter. It is his hope that he can be part of a STEM community where she will have the same opportunities he has had.

Colleen is in her final year as a double major in economics and psychology. She has extensive coursework

TABLE 2

Summary data for undergraduate Outreach Fellows in 2015–2016.

School	Name	STEM Major	Gender	Ethnicity
Gold Meadow High School (GMHS)	Delilah	Biology	Female	Hispanic
	Nora	Math/Bio	Female	White
Young International Academy (YIA)	Sandra	Bioengineering	Female	White
	Karl	Mech. Eng.	Male	Asian Am.
	Marcus	Elec. Eng.	Male	White
	Colleen	Psych/Econ	Female	White
Larimer High School (LHS)	Kelly	Math	Female	Hispanic
	Aaron*	Bioengineering	Male	White
	Joel*	Mech. Eng.	Male	Hispanic
Eastern Leadership Academy (ELA)	Burt	Math/Bio/Psych/English	Male	White
	Allison	Biology	Female	White
Western Regional High School (WRHS)	Sharon	Mech. Eng.	Female	Black
	Lorna	Mech. Eng.	Female	White

*Participated for one semester.

in biology and served as the president of the university's Biology Club where she had her first outreach experience through dissection demonstrations at local schools.

Shared outcomes: Content knowledge

To best attract a breadth of students, the YIA team designed their club to highlight ideas from across STEM. Sandra reported that "I am learning a lot more about different subjects and am enjoying it." Karl expressed how he benefitted from the club's breadth:

> Every week we do something different. Whether it's demos, or different projects, I always take something away from them. Whether it's learning a small detail or just reinforcing topics I've learned, working with the students helps me better understand STEM.

Marcus related how preparing for students' detailed and insightful questions forced him to conceptualize content at a deeper level and sensitized him to the equal importance of generalized as well as detailed knowledge in STEM:

> How am I going to explain this to someone who hasn't had calculus? And it's that explaining, whether you want to call it translating or making it accessible or whatever, that's caused me to go back and learn more.

Sandra noted that she "spent quite a few hours" on preparatory research and pointed out that her preparation time was beneficial, stating, "By doing this research I end up learning a lot about the topic that I didn't know before." Colleen, the team's only nonengineer, had the opportunity to broaden her horizons through the TSA's focus on technology. As an example, she stated that "I don't know a single thing about circuitry . . . [although] I do now, because I had to learn it to teach it."

Shared outcomes: Communication skills

Activity planning and interactions with students shaped Fellows' communication skills. Karl directly attributed this growth to his experiences with his club and opined "This growth in communication skills is difficult to occur naturally because if you are not in a position where you have to teach others, it won't happen."

Fellows devised ways to explain complex topics to middle or high school students, which impacted their overall communication skills. Karl stated this most directly when he wrote, "Working with younger students every week and trying to convey science topics in order to spread the ideas that revolve around STEM was a bit challenging at times, but I was able to gain a lot from it"

Sandra often used an interesting two-stage process. After building her own content base, she would look to other resources as she prepared to communicate: "[After reviewing resources

TABLE 3

Additional evidence of shared outcomes.

Outcome	Examples
Content knowledge	"The fixes required during the build [of the hydrogen car] have exposed me to engineering techniques I have not yet encountered." —Lorna "Without CSC, I might not have brushed up on principals of chemistry and physics, nor would I have learnt some basic properties and tools at the disposal of engineering students and professionals." —Nora
Communication	"You have to start with foundational things. You cannot assume the audience or the students know too much. Not everybody knows what everybody knows." —Kelly "By effectively communicating their work to the public, scientists (or mathematicians, engineers, etc.) can awaken within their audience the same appreciation of and curiosity toward the natural world, providing not only intellectual enrichment but a greater appreciation for the culture of discovery." —Burt "I think many people in the public have interest in learning about STEM but it may seem inaccessible to them due to the terminology that can be used. I think . . . it's important to find ways to approach STEM communication in the least technical way." —Sharon
Metacognition	"[We] did a lot more experiments when students would sometimes have to reason a lot more through what they were doing and that sometimes you have to fail. This was important for the students to know as well as a good reminder for me." —Delilah
Identity	"That's really what a lot of it is when you break it down. Engineering's trying to solve a problem, math's trying to solve a problem, biology's trying to figure out how nature solved a problem, technology's trying to make less problems . . . it all ties in there." —Allison

and] taking notes of key points . . . I went on to websites aimed at children to see how they attempted to teach the subject to younger students and found good examples that they could understand."

Colleen took the lead on a presentation and activity about DNA, which led to a number of deep and interesting questions from the club members. Reflecting on this process, she shared an opinion widely held by many Fellows—that communicating STEM should include an emphasis on revealing how content is applicable in the "real world." She stated that "effective communication [is] creating a working understanding of STEM concepts and how to apply them."

Significantly, we noticed an emerging motivation from Fellows to promote better STEM communication in our society, specifically breaking down the walls between the STEM community and the broader public. Marcus stated, "My colleagues tend to talk about 'translating' when speaking with the public. . . . We must not only translate, we must become more approachable."

Sandra, in recognizing the importance of sharing STEM with the public, states: "If scientists and other professionals don't communicate what they are doing, the public doesn't get a say in anything that impacts them."

Shared outcomes: Metacognition

Evidence of metacognitive growth arose from both Fellows' need to learn new knowledge to bring to their clubs and their reflections and observations of how their students' learning mirrored or otherwise influenced their own. For instance, Sandra explained how her efforts to find different sources of information for her club changed how she prepared for her own classes: "I find that I learn a lot better by using all kinds of resources and not just by the lectures in class and the textbook." She also spoke about difficulties in her physics coursework and her struggles to grasp physics concepts. However, she reported in the fall that "[Relating physics concepts to club students] ends up helping me in [physics] class to understand the equations and conceptual ideas," and that "relating the physics concepts . . . to everyday things actually helps me."

Marcus observed that he was processing material in his own classes differently and stated:

> Prior to joining the project, I read the text, took my class notes, and digested the material by summarizing the material. In short, I would ask myself: "How would I teach this to college students?" Now, I ask myself "how would I teach this to my 10th graders?"

This led him to an important conclusion about how he might support his own learning:

> Trying to digest material prepared for questions that hit more at the basics of the topic is far better (for me at least) than trying to synthesize a topic at the "50,000 foot" level that we, as college students, tend to do.

Problem solving is often viewed as a metacognitive skill enabling learners to apply different types of knowledge in unfamiliar contexts (Kuhn & Dean, 2004; Shraw, Crippen, & Hartley, 2006). Karl articulated his own understanding of breaking down a problem sequentially as he assists students in the club: "First off, you've got to think analytically. Think step by step, see how things work, and that's the big thing about problem solving. I think you need to have a strong base of content knowledge before you can approach problem solving."

Identity as a future STEM professional

Feeling competent in the role of a STEM professional is not only about cognitive attributes, such as content knowledge, it is also about having a set of skills to learn and maneuver successfully in STEM. As a community of practice, the CSC program experience presented an opportunity for Fellows to assess their views of STEM and their role as future STEM professionals. Given the link between identity and the successful retention of STEM majors from underrepresented groups (cf. Lane, 2016), this outcome may be particularly critical for future cohorts that reflect the diversity demonstrated in Table 2.

A recurring theme was a view of STEM that is interdisciplinary, yet bounded by perceptions of self in relation to discipline-specific competencies. For Sandra, implementing physics-heavy activities proved especially challenging despite her broad view of STEM and the fact that she was concurrently taking her second undergraduate physics course. She described this scenario during a demonstration on angular momentum using trebuchets: "I didn't feel comfortable teaching it. It turned out Marcus actually knew a whole lot, so he kind of took over."

In this case, Sandra relied on but also deferred to, the expertise of her peers. This was a common occurrence across the YIA club and reflects the constraints and affordances of having a discipline-specific identity in STEM. Colleen described her own competencies similarly in relation to the DNA activity: "Since I'm the biologist, I chose to do a DNA extraction." Across multiple instances, Fellows' self-identified their expertise and sense of belonging to one or more STEM disciplines. Marcus described in an interview how one particular experience has a profound impact on his identity as an engineer: "[A quiet, reserved student] came up afterwards and asked what exactly a short circuit was . . . [To] be able to translate that into something that he understood was probably the first time I've ever felt like an engineer."

Evidence of shared outcomes across other clubs

Evidence of growth and shared outcomes were present across Fellows in other clubs in CSC program. Additional examples are provided in Table 3.

Conclusions and future work

We have presented evidence that outreach experiences can provide authentic learning opportunities not only for K–12 students, but also for those organizing the outreach activities. Beyond the outcomes described here, Fellows described (a) the importance of collaboration and communication in STEM, (b) the need for knowledge outside their major areas of expertise, and (c) the need to persevere through challenges as a STEM student and future professional. In short, participation in the CSC program provided insights into the *realities* of STEM for these Fellows, bringing their professional futures into clear focus.

Given our diverse cohort of Fellows and their learning outcomes in the CSC program, we are interested in further exploring how outreach experiences might encourage broader participation by undergraduates in STEM. We also believe that the Fellows provide some interesting insights into the experiences, positive and negative, that are part of being an undergraduate STEM major and that may inform our community's approach to campus- and classroom-based educational experiences.

In our future work, we plan to transfer the CSC program model to other outreach contexts to determine if the observed impacts can be replicated. Outreach models are often implemented without dissemination, and we look forward to discussions about how our model aligns with those of our colleagues across STEM education. ■

Acknowledgment

This research was supported by NSF grant #1504535 (STEM CLUSTERS) through the Improving Undergraduate Science Education (IUSE) program.

References

Abernathy, T. V., & Vineyard, R. N. (2001). Academic competitions in science: What are the rewards for students? *The Clearing House*, *74*, 269–276.

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching*, *47*, 564–582.

Brookfield, S. (1995). The getting of wisdom: What critically reflective teaching is and why it's important. In *Becoming a critically reflective teacher* (pp. 1–28). San Francisco, CA: Joseey-Bass.

Chi, M. T. H. (2006). Two approaches to the study of experts' characteristics. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 21–30). Cambridge, England: Cambridge University Press.

Chubin, D., Donaldson, K., Olds, B., & Fleming, L. (2008). Educating generation net—Can US engineering woo and win the competition for talent? *Journal of Engineering Education*, *97*, 245–257.

Cole, D., & Espinoza, A. (2008). Examining the academic success of Latino students in science, technology engineering and mathematics (STEM) majors. *Journal of College Student Development, 49,* 285–300.

Elby, A., & A-Sep Hammer, D. D. (2001). On the substance of a sophisticated epistemology. *Science Education*, *85*, 554–567.

Handley, K., Sturdy, A., Fincham, R., & Clark, T. (2006). Within and beyond communities of practice: Making sense of learning through participation, identity and practice. *Journal of Management Studies, 43*, 641–653.

Harper, S. R., & Newman, C. B. (Eds.). (2010). Students of color in STEM. *New Directions for Institutional Research* (No. 148). San Francisco, CA: Jossey-Bass.

Hayden, K., Ouyang, Y., Scinski, L., Olszewski, B., & Bielefeldt, T. (2011). Increasing student interest and attitudes in STEM: Professional development and activities to engage and inspire learners. *Contemporary Issues in Technology and Teacher Education*, *11*, 47–69.

Kuhn, D., & Dean, D. (2004). A bridge between cognitive psychology and educational practice. *Theory into Practice, 43*, 268–273.

Lane, T. B. (2016). Beyond academic and social integration: Understanding the impact of a STEM enrichment program on the retention and degree attainment of underrepresented students. *CBE—Life Sciences Education*, *15*(3), ar39.

Laursen, S., Liston, C., Thiry, H., & Graf, J. (2007). What good is a scientist in the classroom? Participant outcomes and program design features for a short-duration science outreach intervention in K–12 classrooms. *CBE—Life Sciences Education*, *6*, 49–64.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, England: Cambridge University Press.

McGee-Brown, M., Martin, C., Monsaas, J., & Stombler, M. (2003, March). *What scientists do: Science Olympiad enhancing science inquiry through student collaboration, problem solving, and creativity*. Paper presented at the annual conference of the National Science Teachers Association, Philadelphia, PA.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

National Research Council. (2010). *Rising above the gathering storm, Revisited: Rapidly approaching Category 5*. Washington, DC: National Academies Press.

National Science Foundation, National Center for Science and Engineering Statistics. (2017). *Women, minorities, and persons with disabilities in science and engineering: 2017* (Special Report NSF 17-310). Arlington, VA: Author. Available at www.nsf.gov/statistics/wmpd/

Pintrich, P. R. (2002). The role of metacognitive knowledge in learning, teaching, and assessing. *Theory into practice*, *41*, 219–225.

Pintrich, P. R., Marx, R. W., & A-Sum, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research*, *63*, 167–199.

Pintrich, P. R., Wolters, C. A., & Baxter, G. P. (2000). Assessing metacognition and self-regulated learning. In G. Schraw & J. Impara (Eds.), *Issues in the measurement of metacognition*. Lincoln, NE: Buros Institute of Mental Measurements.

President's Council of Advisors on Science and Technology. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics.* Washington, DC: White House.

Redish, E. F. (1994). Implications of cognitive studies for teaching physics. *American Journal of Physics*, *62*, 796–803.

Resources. (2017). *Community STEM clubs*. Denver, CO: University of Colorado Denver. Retrieved from http://www.math.ucdenver.edu/~stemclubs/2016/home.php

Sahin, A. (2013). STEM clubs and science fair competitions: Effects on post-secondary matriculation. *Journal of STEM Education: Innovations and Research*, *14*(1), 5.

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review*, *7*, 351–371.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher*, *27*(2), 4–13.

Stine, D. D., & Matthews, C. M. (2009). *The U.S. science and technology workforce* (Federal publication 644). Washington, DC: Congressional Research Service. http://digitalcommons.ilr.cornell.edu/key_workplace/644

Tanner, K. D. (2012). Promoting student metacognition. *CBE—Life Sciences Education*, *11*, 113–120.

Thiry, H., Laursen, S. L., & Liston, C. (2007). Valuing teaching in the academy: Why are underrepresented graduate students overrepresented in teaching and outreach? *Journal of Women and Minorities in Science and Engineering*, *13*, 391–419.

von Winterfeldt, D. (2013). Bridging the gap between science and decision making. *Proceedings of the National Academy of Sciences*, *USA, 110*(Suppl. 3), 14055–14061.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Weigold, M. F. (2001). Communicating science: A review of the literature. *Science Communication*, *23*, 164–193.

Wenger, E. C. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge, England: Cambridge University Press.

Zeichner, K. M., & Liston, D. P. (2013). *Reflective teaching: An introduction* (2nd ed.). New York, NY: Routledge.

Zohar, A., & David, A. B. (2009). Paving a clear path in a thick forest: A conceptual analysis of a metacognitive component. *Metacognition and Learning*, *4*, 177–195.

Michael Ferrara** is an associate professor in the Mathematical and Statistical Sciences Department, **Robert Talbot** is an assistant professor in the School of Education and Human Development, **Hillary Mason (hillary.mason@ucdenver.edu) *is a PhD candidate in the School of Education and Human Development, **Bryan Wee** is an associate professor in the Department of Geography and Environmental Sciences, **Ronald Rorrer** is an associate professor in the Mechanical Engineering Department, **Michael Jacobson** is a professor in the Mathematical and Statistical Sciences Department, and **Doug Gallagher** is an instructor in the Mechanical Engineering Department, all at the University of Colorado Denver.*