Integration of Strategies that Support Undergraduate Education in STEM: Linking Local and National Initiatives*

September 25-26, 2014
Hyatt Regency Crystal City, Arlington, VA

Executive Summary

Thirty-seven representatives from scientific societies, funding agencies, the Association of American Universities (AAU), the Association of American Colleges and Universities (AAC&U), and American Public and Land-Grant Universities (APLU) met in Arlington, VA on September 24 and 25, 2014 to discuss ways of linking nationwide programs, such as the faculty professional development programs organized by the scientific societies, with local undergraduate STEM education initiatives, such as those part of the AAU Undergraduate STEM Education Initiative. The group heard presentations about the outcomes from the January 2014 *Integration of Strategies that Support Undergraduate Education in STEM* (ISSUES) meeting, on the AAU Initiative, on research into faculty adoption of research-based pedagogy, and on broader perspectives on undergraduate STEM education initiatives. Working group sessions focused on articulating advice for STEM professional societies and for academic institutions.

After the meeting, the Organizing Committee articulated several recommendations for STEM professional societies, higher education organizations, and colleges and universities:

1. Leverage the common vision for undergraduate STEM education among STEM professional societies and academic institutions to achieve systemic and sustained change in undergraduate STEM teaching and learning, including the commitment to implement effective practices in education and faculty professional development that enhance diversity in STEM fields.

2. Build connections on campus among participants in the disciplinary faculty professional development programs, local teaching-learning centers (TLCs), and local STEM education efforts.

3. Foster collaborations among STEM professional societies and academic institutions to align goals across STEM disciplines to improve undergraduate STEM education.

The slides from the workshop presentations can be found at http://serc.carleton.edu/issues/index.html.

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Report on the Meeting

Organizing Committee

David Bressoud, Macalester College
Robert Hilborn, American Association of Physics Teachers
Cathy Manduca, Carleton College
Emily Miller, Association of American Universities
Susan Musante, American Institute of Biological Sciences
Jodi Wesemann, American Chemical Society

Part I: Linking Local and National Initiatives

A. Introduction

Although the need for enhanced undergraduate STEM education is well established and the deficiencies with current programs well known (President's Council of Advisors on Science and Technology, 2012 and National Research Council, 2012) progress in addressing these issues has been very slow. We argue that there are three related difficulties:

1. It has long been recognized that college and university faculty members receive little or no training in how to teach. To address that issue, many STEM professional societies have established faculty professional development programs (Hilborn, 2013). These programs focus on informing STEM faculty members (including early career faculty) about research-based teaching methods and the evidence for their effectiveness. The participants also get experience trying out those methods at the workshops. Research studies (Henderson, 2008; Dancy & Henderson, 2012; Ebert-May et al., 2011) demonstrate that workshops are indeed effective in making the faculty members aware of those teaching methods and provide the impetus for faculty members to use those methods in their teaching. However, the same studies show that a significant number of these faculty members revert to standard passive lecture techniques after their initial use of the research-based instructional strategies (RBIS).

2. At the same time, it is well known that many undergraduate STEM education projects, often led by one or two "champions" on a campus, stop operations after the funding for the projects ends or when the project leaders move on to other activities, even when the project has been judged successful.

3. A third issue is that many undergraduate STEM education projects at a particular institution in different STEM disciplines seem to run independently, often with one project's leaders unaware of similar projects on the same campus.

All of these issues have a common theme: the absence of integrated, collaborative linkages among faculty members interested in improving undergraduate STEM education, with other institutional efforts, and with STEM education programs run by STEM disciplinary societies and by higher education associations. To find ways to integrate these disparate efforts, the Mathematical Association of America (MAA) received NSF funding (grant 1344418) to host a meeting on "Integration of Strategies that Support Undergraduate Education in STEM" (ISSUES) in January 2014 in Washington, D.C. A report of that meeting is available at http://serc.carleton.edu/issues/index.html.

One of the recommendations from the ISSUES meeting was to organize another meeting to focus on one specific example of such integration: linking the participants from scientific society faculty development workshops with the eight university project sites part of the Association of American Universities (AAU) Undergraduate STEM Education Initiative funded by a generous grant from The Helmsley Charitable Trust. Consequently staff members from the AAU, American Association of Physics Teachers (AAPT), the American Chemical Society (ACS), the American Institute of Biological Sciences (AIBS), and David Bressoud, the PI on the NSF ISSUES grant, organized a second ISSUES meeting held on September 25-26, 2014 in Arlington, VA. This second meeting brought together 37 participants, including representatives from the eight AAU STEM Initiative project sites, the leaders of seven faculty professional development workshops run by scientific societies, representatives from AAU, the American Association of Colleges and Universities (AAC&U), the American Association for the Advancement of Science (AAAS), the American Public and Land-grant Universities (APLU), the National Science Foundation (NSF), the Howard Hughes Medical Institute (HHMI), and The Helmsley Charitable Trust. The meeting schedule and list of participants are included as appendices to this report.

In the first part of the report we give some background on the overall ISSUES effort and then describe the discussions and resulting suggestions and recommendations from the participants for the specific goal of the September 2014 meeting: finding ways to link the participants in the faculty professional development workshops run by disciplinary societies to the undergraduate STEM education projects supported by the AAU Undergraduate STEM Education Initiative. In the second part, we summarize many of the meeting's discussions that ranged broadly across the landscape of undergraduate STEM education. Section L contains the key recommendations as distilled by the meeting's Organizing Committee.

References for Section A

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Henderson, C. (2008). Promoting instructional change in new faculty: An evaluation of the physics and astronomy new faculty workshop. *Am. J. Phys., 76,* 179-187.

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Hilborn, R. C. (Ed.) (2013). *The role of scientific societies in STEM faculty workshops*. College Park, MD: American Association of Physics Teachers.

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B. Background to the ISSUES Project

David Bressoud, Macalester College, provided a review of the Janauary 2014 ISSUES meeting, its motivation, and results. A summary of that presentation follows.

The *Integration of Strategies that Support Undergraduate Education in STEM* (ISSUES) project[1] is a collective effort of disciplinary societies, educational associations, and other organizations with an interest in the improvement of undergraduate education in Science, Technology, Education, and Mathematics (STEM). The mission is to build awareness and encourage adoption of best practices in collegiate STEM education and to foster national multi-disciplinary collaboration that supports campus-based communities and activities.

The project arose from the recognition of two developing trends: First, several college and university consortia, including AAU, APLU, and AAC&U had come to recognize that many of their institutions were under-performing in the production of graduates entering into or preparing to teach in STEM fields. They had begun multi-disciplinary efforts within member institutions to improve the teaching and learning of undergraduate science and mathematics with the goal of improving this performance. Second, many of the disciplinary societies had, for many years, been developing discipline specific programs to introduce faculty, especially new faculty, to the active learning approaches that are known to improve student long-term learning. These societies were also providing programs to support faculty in their attempt to implement these approaches. It was becoming increasingly clear that all of these efforts would benefit from the sharing of information, cooperation, and some degree of coordination.

[1] Supported by NSF grant #1344418. The opinions expressed in this report do not necessarily reflect those of the National Science Foundation.

It was with the goal of generating seed ideas for areas of collective action to improve undergraduate education in the STEM disciplines that the first ISSUES workshop was held in Washington, DC on January 30–31, 2014. It built directly on earlier efforts to share information across disciplines about STEM Faculty Workshops, and in particular the conference on *The Role of Scientific Societies in STEM Faculty Workshops*, which had been held on May 3, 2012.[2]

The ISSUES workshop brought together representatives from disciplinary societies in science, engineering, and the mathematical sciences, as well as AAU, APLU, AAC&U, AAAS, HHMI, and NSF. On the first day, we identified six common elements of our collective agendas. These consisted of:

1. Building an undergraduate student body in STEM that reflects national demographics,
2. Moving undergraduate teaching so that it aligns with research on teaching and learning,
3. Encouraging the development of Discipline–Based Educational Research (DBER) (National Research Council, 2012; National Research Council, 2015) and assuring that its fruits are integrated into the practice of teaching,
4. Building inclusive communities of learning within individual STEM departments and combining these with departmental commitments to improving undergraduate instruction,
5. Building opportunities for and awareness of robust and diverse professional pathways for STEM majors as well as an awareness of the essential nature and the applications of science, engineering, or mathematics among the students taking courses in these disciplines, and
6. Increasing awareness within the research communities of the value of undergraduate education and need for serious attention to its challenges as part of one's professional identity.

By the end of the second day of the January meeting, the participants had identified five areas where our STEM disciplinary societies could, through collective efforts, influence cultural norms, offer resources including professional development, and provide direct programming for students.

1. **Supporting Early Career Faculty.** Within the disciplinary societies, the task is to develop workshops for and to build communities of early career faculty, as well as partnering with the DBER community to assess the long-term effectiveness of this work. On individual campuses, the task is to work with deans and chairs to build cross-disciplinary networks of faculty who have been through these experiences, supported by networks of mentors both from the individual's profession and from within the individual's home institution.
2. **Strengthening Departments.** There is a need to increase the value placed on the department chair and to provide support for the chair by supplying tools for departmental self-assessment of teaching effectiveness and practical suggestions that chairs and other departmental leaders can implement to improve teaching effectiveness.

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[2] Supported by NSF grant #1230391. The report of this workshop can be found at www.aapt.org/Conferences/newfaculty/upload/STEM_REPORT-2.pdf

3. **Communicating Career Pathways.** We need to increase the diversity of students within our disciplines by increasing student awareness of the variety of pathways that are available to them, actively recruiting students to these pathways, preparing them for a variety of careers, and introducing them to a network of potential employers.
4. **Shifting Cultural Norms.** Disciplinary societies should use policy statements, rubrics for assessing effective educational processes, and active promotion to encourage their members to embrace teaching practices that align with what educational research has shown to be most effective and toward a mindset of continual efforts to improve undergraduate teaching and learning. Part of the collective goal is the adoption of consistent language that reinforces this message across disciplinary boundaries.
5. **Measuring the Impact of Our Own Programs for Improving Undergraduate Education.** The disciplinary societies need to develop common measures for assessing the effectiveness of their own programs and use these to help frame discussion and dialog across the societies.

In particular, we saw an opportunity to link the faculty development programs undertaken by the disciplinary societies with institution-based efforts, such as the AAU STEM Initiative, to improve undergraduate education in the STEM disciplines. This became our first action item.

References for Section B

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C. Building a STEM Reform Network

Building a STEM Reform Network: The Experience of the AAU Undergraduate STEM Education Initiative

James S. Fairweather, Michigan State University, and Emily R. Miller, Association of American Universities, discussed the AAU's Undergraduate STEM Education Initiative and the broader theoretical perspectives about organizational and cultural change in academia and about faculty work and rewards that inform the initiative. Their summary of their presentation follows.

The AAU is in the middle of a five-year initiative in collaboration with member institutions to improve undergraduate teaching and learning in STEM fields. The overall objective of the initiative is to influence the culture of STEM departments at AAU institutions so that faculty members are encouraged and supported to use teaching practices proven by research to be more effective in engaging students in STEM education and in helping students learn. The goals of AAU's STEM Initiative are to:

1. Develop a *Framework for Systemic Change to Undergraduate STEM Teaching and Learning* for assessing and improving the quality of STEM teaching and learning,
2. Support AAU STEM project sites at a subset of AAU universities to implement the framework, and develop a broader network of AAU universities committed to implementing STEM teaching and learning reforms,
3. Explore mechanisms that institutions and departments can use to train, recognize, and reward faculty members who want to improve the quality of their STEM teaching;
4. Work with federal funding agencies to develop mechanisms for recognizing, rewarding, and promoting efforts to improve undergraduate learning, and
5. Develop effective means for sharing information about promising and effective undergraduate STEM education programs, approaches, methods, and pedagogies.

The initiative offers an alternative to traditional STEM education change efforts focused on individual faculty members and the students in their classrooms (Dancy & Henderson, 2005; Fairweather, 2009). Much of this work and literature centers on micro-level assessments of the classroom, which are crucial to assessing the effect of pedagogy on student learning, but do not address the importance of the dissemination and institutionalization of reforms. It often ignores the larger environment, such as institutional culture, disciplinary and departmental contexts, and the role of philanthropy, governing bodies and accrediting organizations (Fairweather, 2008). In addition, a micro-level focus on reform does not take into account the costs and political challenges in scaling up reforms (Fisher, Fairweather & Amey, 2003). Concern about more macro-level environments requires a change in assessment from looking for benefits and learning outcomes to a more nuanced consideration of factors that facilitate, impede, or influence wide-spread transformation in undergraduate STEM education.

The AAU Undergraduate STEM Education Initiative seeks larger and more permanent reform by influencing academic cultures to encourage STEM faculty members to use teaching practices proven by research to be more effective in helping students learn (Freeman, et al, 2014; Handelsman et al, 2004; Singer, et al, 2012; NRC, 2015; PCAST, 2012). With a focus on changing the culture of higher education as its overreaching goal, the AAU STEM Initiative took a more systemic view of educational reform within academia, including understanding the wider setting in which educational innovations take place – the department, college, institution, and national discipline (Austin, 2011, 2014). In addition to fostering and assessing changes in faculty pedagogy and attitudes toward teaching, the AAU STEM Initiative seeks to reform faculty reward systems to enhance the value of undergraduate teaching at research universities. Eight AAU institutions are currently implementing projects for the AAU STEM Initiative. All 62 institutions have appointed a liaison for the AAU STEM Initiative and most are engaged in a larger AAU-related network in support of this effort.

Based upon our assessment, it is clear that the initiative is having a positive impact. It has catalyzed institutional action toward reforming undergraduate STEM education, enhanced communication and collaboration on, within, and between AAU member campuses, leveraged campus support (financial and other resources) from all levels of the institution, and aligned and coordinated efforts to improve undergraduate STEM education with key norm-driving organizations at multiple levels. It is too early to see the longitudinal impact on items such as student learning and other barometers of cultural change such as promotion and tenure. This is

not unexpected—achieving cultural reform is difficult and long-term. And any measures of cultural change will be difficult to attribute directly to the initiative, but AAU through the initiative is attempting to achieve widespread and sustainable change to undergraduate STEM education at its member campuses.

References for Section C

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D. Working Group Sessions

The meeting included a series of breakout sessions in which the participants formulated advice and recommendations aimed at two groups: (1) STEM professional societies and (2) college and university administrators. In the next two sections, we summarize the key themes from those working groups.

E. Participants' Suggestions for STEM Professional Societies

In this session, participants addressed the following questions:

1. How can we make use of institutional and national projects to support continued engagement of faculty professional development workshop alumni once they are back on campus?
2. What can STEM professional societies do to encourage collaboration among the alumni of the various discipline-based professional development workshops on individual campuses?

Here we summarize, in compact form, participants' comments and suggestions for professional societies:

1. Contact teaching-learning centers on campuses to develop more robust support for faculty members enrolled in their professional development activities on return to the home campus.
2. Develop faculty workshop follow-up activities for participants once they are back on campus.
3. Work with colleges and universities to develop a consistent message conveying the importance of STEM faculty members implementing research-based instructional strategies.
4. Integrate education programming into professional society conferences.
5. Design mentoring networks for new STEM faculty members.
6. Coordinate efforts with other initiatives to provide pedagogical training for graduate students and postdoctoral scholars who are considering careers in academia.
7. Partner with leaders of STEM faculty professional development workshops to conduct longitudinal studies of how past participants of workshops implement at their institutions what they have learned at the workshops.

F. Participants' Suggestions for Academic Administrators

In this session, participants addressed the following questions:

1. How can institutions make use of the expertise, experience, and enthusiasm of the alumni of discipline-specific STEM professional development workshops?
2. What role might local teaching and learning centers play in building local linkages among STEM education projects and alumni of STEM education professional development workshops?

Here we summarize, in compact form, participants' comments and suggestions for academic institutions and their leaders:

1. Work to align promotion and tenure guidelines with the national efforts to improve undergraduate STEM education.
2. Encourage incorporation of teaching professional development funds into all start-up packages for faculty member hires.
3. Use information from STEM societies to identify people who have expertise to review tenure packets.
4. Set up mentoring networks for new STEM faculty members.
5. Support academic leaders to give keynote addresses at national meetings on education.
6. Leverage institutional accreditation discussions to move forward STEM teaching and learning reform efforts.
7. Make use of STEM professional society recommendations and guidelines on undergraduate education (for example, those of the American Society for Biochemistry and Molecular Biology and those of the American Chemical Society) to encourage enhancements in undergraduate STEM education.
8. Encourage departments to tie regional accreditation reviews to disciplinary society guidelines and recommendations for STEM undergraduate programs.
9. Recognize challenges to education reform efforts on unionized campus. Work towards policies that encourage and reward education reform.
10. Engage with the activities of the teaching and learning centers on their campus.
11. Build connections between institutional undergraduate STEM education efforts and national organizations dedicated to supporting faculty members' usage of effective teaching practices (e.g. Professional and Organizational Development (POD) network; Center for the Integration of Research, Teaching, and Learning (CIRTL), APLU STEM Centers Network).
12. Provide resources for STEM faculty members to attend professional society new faculty workshops, regional meetings of disciplinary societies, and meetings of interdisciplinary networks focusing on undergraduate education such as the Lily conferences, PKAL/AAC&U, SENCER, National Academies Summer Institutes, POD co-conferencing, Partnership for Undergraduate Life Sciences Education (PULSE) regional meetings, etc.

G. Instructor Use of Research-Based Pedagogy: Sources of Knowledge, Persuasion, and Support for Sustained Implementation

Charles Henderson, Western Michigan University, provided an overview of the findings of several studies related to instructor adoption of research-based instructional strategies (RBIS). His summary of his presentation follows.

Many research-based instructional strategies (RBIS) exist for undergraduate STEM. These have been shown to improve student outcomes on a variety of measures, such as learning, engagement, attitudes, and persistence. An important unsolved problem is how to propagate and scale the use of these instructional strategies so that more undergraduate STEM students can benefit.

Rogers' (2003) innovation-decision process can be thought of in terms of three stages: knowledge, persuasion, and support. Instructors have different needs at each stage, and there are different questions that change agents must answer in order to meet the instructor needs:

- Knowledge: How do instructors learn about new instructional practices?
- Persuasion: What motivates instructors to try something new? What do faculty perceive as affordances and barriers?
- Support: What leads instructors to sustain vs. discontinue use? What leads to robust vs. superficial use?

a. Knowledge: Imprecise language hinders communication and knowledge acquisition

Self-reported discontinuation is a significant problem in the innovation-decision process and is relatively easy to measure. It is more difficult to identify instructors who say that they are using a RBIS, but are not using it as recommended by the developer. For the case of Peer Instruction, we have several sets of data that suggest relatively few (between 6% and 47%, depending on the data set and criteria used) of self-reported Peer Instruction users actually use all of the core features of Peer Instruction. In fact, in an interview study, about ¼ of instructors who said that they knew about Peer Instruction, only used the term as related to peer-peer interaction in a help room setting. This lack of shared language makes communication about RBIS difficult.

b. Knowledge: Personal interactions with colleagues are a very important source of exposure

Interactions with local and non-local colleagues are the most common first exposure to Peer Instruction. They are also the most common sources of knowledge about SCALE-UP (http://scaleup.ncsu.edu/). It appears that potential users first hear about new teaching ideas from colleagues and then, if they are interested, turn to other sources of information (such as web sites, talks/workshops, papers, and books).

c. Persuasion: Instructors are most persuaded by personal experiences

In an interview study of 35 physics instructors who were familiar with Peer Instruction, most interviewees (whether users or not) felt that Peer Instruction was effective. These instructors

most commonly reported being persuaded by personal experiences. Data about the effectiveness of Peer Instruction was primarily useful to confirm decisions, not to sway opinions.

d. Persuasion: Time required and fears of lower content coverage are important perceived barriers to the use of RBIS

Interviewees reported that time to learn about and implement Peer Instruction as well as fears of lower content coverage were major barriers to the use of Peer Instruction.

e. Support: Discontinuation of new instruction after trying is an important unsolved problem

In 2008, Henderson and Dancy conducted an online survey of physics faculty. One set of questions asked about knowledge and use of 24 named RBIS. Results show that support is the phase of the innovation-decision process with the largest losses of adopters: 12% of respondents lack knowledge of any RBIS, another 16% have knowledge, but are not motivated to try, while 23% have knowledge and have tried a RBIS, but no longer use any RBIS. This 23% means that about 1/3 of the instructors who try a RBIS discontinue use of that and all other RBIS.

It is notable that, while the Physics and Astronomy New Faculty Workshop (NFW) significantly improves knowledge (only 1% of NFW attendees lack knowledge of any RBIS) and persuasion (3% of NFW attendees have not tried a RBIS), discontinuation rates are not significantly different between NFW attendees and non-attendees. This finding corroborates other evidence that even high quality traditional dissemination mechanisms do not provide the support that adopters require to be successful.

f. Support: Local community, administrative support, and visibility of the change efforts appear to be helpful in promoting sustained use of RBIS

In case studies of departments where SCALE-UP has been successfully implemented, a local community of users, administrative support, and visibility (e.g., a SCALE-UP room) appear to be helpful in supporting sustained use.

References for Section G

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Part II: Broader Discussions of Undergraduate STEM Education

H. Broad perspectives on undergraduate STEM Education

Shirley Malcom, Head, Education and Human Resources, American Association for the Advancement of Science, shared a series of reflections about STEM education and ways of understanding STEM education enhancement efforts. She engaged the participants in a dialogue about the tough questions we need to be asking to improve undergraduate STEM education. Dr. Malcom shared her thoughts about the current state of efforts to improve STEM education. She noted that her background in biology, which is a systems-based field, influences her perspectives and helps her see interconnections. The following description is based on notes taken by members of the organizing committee during Dr. Malcom's presentation.

Disciplinary interconnections

Dr. Malcom noted that advances in STEM education are happening at the edges of our disciplines and cited three areas as examples:

- Disciplinary service to other fields
- Interaction with those in other fields in both research and education
- Preparing students in other fields with appropriate skills, knowledge, and habits

Disciplinary contributions to large problems

Dr. Malcom asked participants to consider the following questions as disciplinary societies and higher education organizations continue their collaborative work:

- How do we listen to those outside of our field (both adjacent and further afield)?
- How do we help solve large problems?
- What should be the primary disciplinary contributions to science literacy?
- What is our relation to overall science literacy?
- How do we understand what is accepted as evidence in other disciplines?

Our disciplinary lenses shape our view of and contributions to the world. They will be more powerful when combined.

Faculty interconnections

We tend to think about what makes a good faculty member on a case-by-case basis, often in a sub-disciplinary way. Dr. Malcom encouraged a broader consideration of faculty effectiveness using portfolios as an example. She then suggested several ways to broaden our questions about undergraduate STEM education. What follows is a condensed version of her comments:

- Systemic thinking
  - How do US universities leverage the benefits of having their missions focused on both research and education?
  - How do we avoid the system failures that truncate opportunities for people?
  - How do we discuss shared responsibility with students?
  - What opportunities do we have for engaging students in the exploration of what we don't know?
- Academic responsibility
  - How do we educate the students of today and meet their needs?
  - How do we implement the research on learning, avoiding the things that don't work and using those that work better?
  - How do we facilitate degree completion, and support students' success?
- Faculty preparation and professional development
  - How do we reach faculty on a more regular basis, instead of interacting with them less infrequently only at periodic events such as annual society meetings?
  - How do we better prepare graduate students and postdoctoral scholars for faculty careers?
- Departmental skill sets:
  - Who is being intentional about building a department?
  - Who is devoted to the scholarship of teaching?
  - Who has cultural competence and understands where students are coming from?
  - Who is thinking about careers?
  - Who is comfortable in the community outside campus?
  - Who brings global perspective and is crossing across borders?
  - Who has familiarity and facility with K-12?
  - Who has familiarity and facility with business and industry?
- Faculty resources
  - Are we using the tools we have?
  - How do we use technology to transform what is possible?
  - What do we need to be invented?

Dr. Malcom also reflected on what it takes to transform a system. In regards to STEM education, we need to collectively:

- Make use of our knowledge and know how,
- Provide incentives,
- Remove disincentives,
- Dedicate time to improving undergraduate STEM education, and
- Foster belief in the need for and importance of transformational change.

Critical issues

Dr. Malcom identified three of the "elephants in room," which need to be addressed more explicitly in higher education generally and in STEM education in particular.

1. Diversity

We must educate the population we have, not the one we wish we have. We must believe in and invest in educating those of different genders, races, and ethnic groups, persons with disabilities, and veterans.

Society assumes people should look a certain way. We must help overcome concerns about being judged differently (higher or lower – both a problem). We must provide students with tools to thrive in a hyper-competitive environment. Academics in leadership positions must recognize that teaching evaluation scores will be different for faculty members who are under-represented minorities or female.

2. Promotion and tenure

There has been plenty of talk about the issues but there is a dearth of solutions to "fix" the academic rewards structure. Do we just accept the current system or can we figure out how to reward teaching prowess the way we do research prowess? If we do reward teaching, how do we measure teaching effectiveness? Is the problem the promotion and tenure system or is the problem the people who make the promotion and tenure decisions? Perhaps colleges and universities should offer differentiated contracts with different faculty members having different fractions of their work dedicated to teaching, research, and service, but with all three equally valued.

3. Soft money problem

Often grant money for educational projects is focused on projects within the STEM education system as it is, rather than aiming at transforming the system. Teaching and learning centers often are fragile because they depend on external money. Colleges and universities should be encouraged to endow teaching/learning centers by using capital campaigns to raise money for them.

I. Participant Discussions

It was noted several times during the meeting that a change in departmental and institutional culture is needed in order to improve undergraduate STEM education. The culture of higher education recognizes and rewards traditional STEM research activities while scholarly work to improve teaching and learning often goes unrecognized and is rarely rewarded. Scientific societies can play an important role in defining what it means to be a successful faculty member because faculty members base their professional identity more on their disciplines than on their home institutions. Disciplinary societies, in essence, define the cultural norms of the discipline. Although scientific societies can influence individual faculty members, their influence on institutions is limited.

The group recognized that societies such as the American Association of Physics Teachers and the National Association of Geoscience Teachers focus almost entirely on education while other scientific societies focus mainly on research. Others do both and it is important to understand the differences between societies, their foci, and therefore their reach.

At the institutional level, the criteria for promotion and tenure are often dominated by research activities and related products, such as publication rates. The group recognized that changing those criteria is often very difficult and requires action from faculty, administrators, and boards of trustees. How these criteria are weighted and evaluated varies among institutions and types of institutions, e.g., criteria for promotion and tenure at four-year colleges are different from those at two-year colleges. Part of the difficulty of having disciplinary societies and higher education organizations support specific recommendations is that there is a lack of common criteria for what constitutes effective teaching and the lack of tools to determine if effective teaching has occurred.

J. Participant Suggestions for Professional Societies

1. Develop at least one journal that publishes scholarly work about teaching and learning.
2. Publicize and distribute assessment tools to measure student outcomes for all aspects of undergraduate STEM education (content, conceptual understanding, science and engineering practices, and essential professional skills).
3. Offer workshops and conferences for department chairs in their disciplines since the department is the fundamental unit for change in American higher education.
4. Emphasize the importance of effective pedagogy and teaching facilities in professional society guidelines and recommendations for undergraduate programs.
5. Build speakers bureaus with experts on STEM reform to serve as resources for institutions and STEM departments.
6. Organize presentations to the university presidents at AAU, APLU, and AAC&U meetings on undergraduate STEM education.
7. Act collectively (perhaps through the Council of Scientific Society Presidents) to build connections with college and university presidents, summarizing information about undergraduate STEM education and tangible ways presidents can support undergraduate STEM education reform efforts.
8. Distribute to members frameworks for improving undergraduate STEM education: for example, AAU Framework for Systemic Change in Undergraduate STEM Teaching and Learning, AAC&U Guide to Systemic Institutional Change in STEM Education (PKAL/KECK), and PULSE Vision and Change Rubric.
9. Share the stories of members who have redesign and reformed undergraduate STEM courses.

K. Participant Suggestions for College and University Administrators

1. Develop effective means to share strategies and approaches to improve undergraduate teaching and learning with other universities.
2. Leverage involvement in national STEM education projects such as the AAU Undergraduate STEM Education Initiative and the various other funded programs by The Helmsley Charitable Trust, NSF, HHMI, and Sloan to promote wide-spread undergraduate STEM education improvements.
3. Dedicate institutional resources to improve undergraduate STEM education. For example, provide teaching & learning center grants for course redesigns and department activities.

4. Develop strong measures to assess teaching excellence and to measure departmental commitment to evidence-based teaching.
5. Think about how programs such as "writing across the curriculum" might be extended to STEM education ("science across the curriculum").
6. Provide guidance and assistance to general education programs such as geoscience and astronomy, which provide many courses for non-STEM majors.

L. Final Recommendations and Suggestions for Future Work

Based on the plenary presentations and the results of the breakout session discussions, the Organizing Committee makes the following recommendations for STEM professional societies, higher education organizations, and colleges and universities:

1. Leverage the common vision for undergraduate STEM education among STEM professional societies and academic institutions to achieve systemic and sustained change in undergraduate STEM teaching and learning, including the commitment to implement effective practices in education and faculty professional development that enhance diversity in STEM fields.
2. Build connections on campus among participants in the disciplinary faculty professional development programs, local teaching-learning centers (TLCs) and local STEM education efforts.
3. Foster collaborations among STEM professional societies and academic institutions to align goals across STEM disciplines to improve undergraduate STEM education.

In addition, the Organizing Committee suggests that professional societies, STEM faculty members, and college and university administrators:

1. Remember that undergraduate STEM courses serve future leaders in many fields, not just STEM majors and that supporting undergraduate education to develop a science-savvy citizenry is an important goal of all STEM education.
2. Articulate clearly the collective STEM education commitment to diversity and its importance in education and in faculty professional development and to the implementation of effective practices that enhance diversity in STEM fields.

Short Term Actions

The Organizing Committee will work with the conference participants and their institutions to:

- Continue the discussion about academic responsibility, quality teaching and learning and how it can be measured, and tools for action--speaking with common voice.
- Make connections on campus among participants in disciplinary professional development:
  - Share the names of participants in disciplinary professional development workshops
  - Use Teaching and Learning Centers (TLCs) as a focus of short-term and long-term follow-up after the professional society workshops.
  - Build awareness of the disciplinary professional development opportunities and broadcast them through the Professional and Organizational Development (POD) network.

- Promote successful TLCs and STEM Education Centers as models for schools that don't have this type of campus entity.

- Move forward with linking the participants in the AAU STEM Initiative with the participants of the disciplinary society faculty workshops. Those connections can serve as a pilot for larger-scale actions.
- Make public our collective commitment to the power of diversity and its importance in our professional development activities, learn more from each other and others about what are effective practices for enhancing diversity in STEM fields, and disseminate and adopt these ideas. Make diversity issues more explicit at professional meetings.
- Bring together AAU, APLU, and AAC&U, with their ability to engage the highest level of institutional leadership, and the STEM profession societies, which have the ability to engage the highest level of scientific leadership, to forge systemic change in college and university STEM education.

Recommendations for Future Work

The participants and the Organizing Committee agreed that there is much work yet to be done and a need for the organizations they represent to figure out how to:

1. Work with regional accreditation organizations in order to align our efforts and to offer our expertise,
2. Align efforts for faculty development and learn from each other's programs,
3. Do a better job of supporting faculty members who undertake significant education reform efforts,
4. Be more effective in addressing diversity issues,
5. Efficiently measure success in changing the educational system by always coupling action and assessment, which is key to knowing what is going on in a rapidly changing system,
6. Define the role of professional societies, if any, in engaging college and university trustees and boards in efforts to enhance undergraduate STEM education,
7. Support adjunct and other non-tenure-track faculty members, and
8. Build the necessary leadership to change culture and values of disciplinary groups or institutions.

M. Reflections on the Meeting

Cathy Manduca
Carleton College

Undergraduate STEM education has, in many aspects, come a long way in the past two decades. We have campus leaders from Project Kaleidoscope Faculty for 21st Century who are now senior faculty; we have Carnegie Fellows from the past decade; we have leaders from all of the disciplinary professional development programs; we've created excellent leaders in the two-year colleges; we have many leaders in the various disciplinary societies including officers in the education sections who have been working hard to have sessions, workshops, and publications for the members; we have DBER scholars as well as tenured appointments in departments aimed at teacher preparation. We can always use more leaders, but in contrast to 20 years ago when faculty professional development efforts were relatively rare, teacher preparation wasn't in the vernacular of most STEM departments, and we didn't understand the importance of two-year colleges, we have made progress.

However, the two big issues that require major shifts in values—promotion and tenure and deep understanding within the scientific disciplines of teaching, learning and the education system—are barely moving. We collectively don't yet value teaching on a par with research in the work of a faculty member or a professional society. We have leaders who could move forward in the professional societies, but they are barely heard above the "noise" of research. We have scholars producing assessment instruments and research-based teaching strategies in STEM education, but they are not being adopted widely. We need more than leaders—we need other strategies that empower them and support change. This doesn't mean that we should stop developing leaders—but maybe we need other things too. And perhaps we don't yet have the right mix of leaders. I think we are further along in colleges and universities in knowing what we need to do than we are in the STEM disciplines. But the two groups need to work together, if significant and long-lasting changes in undergraduate STEM education are to take root and flourish.

Appendix A
Integration of Strategies that Support Undergraduate Education in STEM
Linking Local & National Initiatives

September 25-26, 2014
Hyatt Regency Crystal City, 2799 Jefferson Davis Highway, Arlington, VA

Thursday, September 25

6:30–7:00 pm	Participants give brief (30 second) introductions describing their involvement with faculty professional development workshops/institutes and their institutional efforts to improve STEM education. Review the goals for the meeting, quick overview of the schedule – Led by the meeting planning group
7:00–8:00 pm	Dinner
8:00–9:00 pm	David Bressoud, "ISSUES Overview" Informal discussion

Friday, September 26

8:45–9:00 am	Welcome and Overview of the Day
9:00–10:00 am	Jim Fairweather, Michigan State University, and Emily Miller, Association of American Universities, "AAU Undergraduate STEM Education Initiative: Building a STEM Reform Network" Moderator: David Bressoud
10:00–10:45 am	Working Groups I: Advice for STEM professional societies
10:45–11:00 am	BREAK
11:00–11:45 am	Reports from Working Groups, formulation of recommendations Moderator: Jodi Wesemann
11:45–12:30 pm	Charles Henderson, "Instructor Use of Research-Based Pedagogy: Sources of Knowledge, Persuasion, and Support for Sustained Implementation" Moderator: Bob Hilborn
12:30–1:30 pm	LUNCH
1:30–2:15 pm	Working Groups II: Advice for academic institutions to connect faculty who attend PD institutes/workshops to local STEM education initiatives.
2:15–2:30 pm	BREAK

2:30–3:15 pm Reports from Working Groups, formulation of recommendations
Moderator: Susan Musante

3:15–4:15 pm Shirley Malcom, AAAS, "Broad perspectives on undergraduate STEM education initiatives"
Moderator: David Bressoud

4:15–5:00 pm Full Group Discussion
Moderator: Cathy Manduca

- Specific actions to take back to home institutions and professional societies.
- List of other ideas to be explored by this meeting's leaders, professional society workshop leaders, and university project leaders.
- How to extend these actions to other STEM education initiatives?
- Final words

Working Groups – Session I

Theme: Advice for STEM professional societies.

1. How can we make use of institutional and national projects (such as the AAU Undergraduate STEM Education Initiative) to support continued engagement of professional development workshop alumni once they are back on campus?

2. What can STEM professional societies do to encourage collaboration among the alumni of the various discipline-based professional development workshops on individual campuses?

Working Groups – Session II

Theme: Advice for campus STEM education leaders and for organizers of multi-institutional STEM education projects.

1. How can institutions make use of their expertise, experience, and enthusiasm of the alumni of discipline-specific STEM professional development workshops?

2. What role might local teaching/learning centers play in building local linkages among STEM education projects and alumni of STEM education professional development workshops?

Appendix B

Participants

Nancy Bakowski
American Chemical Society

Cynthia Bauerle
Howard Hughes Medical Institute

Linda S. Braddy
Mathematical Association of America

David Bressoud
Macalester College

Peter Bruns
Cornell University (retired)

Linda Columbus
University of Virginia

Sue Cui
Helmsley Charitable Trust

Diane Ebert-May
Michigan State University

Cori Fata-Hartley
Michigan State University

Andrew Feig
Wayne State University

Jeffrey E. Froyd
Texas A&M University

Catherine Fry
American Society for Pharmacology and Experimental Therapeutics

Howard Gobstein
Association of Public and Land-grant Universities

Ellen Goldey
Wofford College

Kelly A. Gull
American Society for Microbiology

Charles Henderson
Western Michigan University

Jack Hehn
American Association of Physics Teachers

Robert Hilborn
American Association of Physics Teachers

Amy Chan Hilton
National Science Foundation

Kelly Hogan
University of North Carolina at Chapel Hill

Rachel Horak
American Society for Microbiology

Jenny Knight
University of Colorado

Dave Kung
St. Mary's College

Jay Labov
National Academy of Sciences

Shirley Malcom
American Association for the Advancement of Science

Cathryn Manduca
Science Education Resource Center/Carleton College

Emily Miller
Association of American Universities

Kathryn Miller
Washington University in St. Louis

Susan Musante
American Institute of Biological Sciences

Mathew L. Ouellett
Wayne State University

Michael Pearson
Mathematical Association of America

Edward Prather
University of Arizona

Kacy Redd
Association of Public and Land-grant Universities

Susan R Singer
National Science Foundation

Linda Slakey
Association of American Universities

Jodi Wesemann
American Chemical Society

Michelle Withers
West Virginia University