ASEE's 123rd Annual • Conference & Exposition • New Orleans, LA • June 26-29, 2016

New Orleans Jazzed about Engineering Education

Paper ID #16921

Sustaining Innovation in Engineering Education through Faculty Communities

Dr. Geoffrey L Herman, University of Illinois, Urbana-Champaign

Dr. Geoffrey L. Herman is a visiting assistant professor with the Illinois Foundry for Innovation in Engineering Education at the University of Illinois at Urbana-Champaign and a research assistant professor with the Department of Curriculum & Instruction. He earned his Ph.D. in Electrical and Computer Engineering from the University of Illinois at Urbana-Champaign as a Mavis Future Faculty Fellow and conducted postdoctoral research with Ruth Streveler in the School of Engineering Education at Purdue University. His research interests include creating systems for sustainable improvement in engineering education, promoting intrinsic motivation in the classroom, conceptual change and development in engineering students, and change in faculty beliefs about teaching and learning. He serves as the webmaster for the ASEE Educational Research and Methods Division.

Dr. Laura D Hahn, University of Illinois, Urbana-Champaign

Laura Hahn is Director of the Academy for Excellence in Engineering Education at the University of Illinois at Urbana-Champaign. She is also an adjunct assistant professor in the Department of Agricultural and Biological Engineering. Her interests include communities of practice, classroom discourse, and intercultural communication for engineers.

Prof. Matthew West, University of Illinois, Urbana-Champaign

Matthew West is an Associate Professor in the Department of Mechanical Science and Engineering at the University of Illinois at Urbana-Champaign. Prior to joining Illinois he was on the faculties of the Department of Aeronautics and Astronautics at Stanford University and the Department of Mathematics at the University of California, Davis. Prof. West holds a Ph.D. in Control and Dynamical Systems from the California Institute of Technology and a B.Sc. in Pure and Applied Mathematics from the University of Western Australia. His research is in the field of scientific computing and numerical analysis, where he works on computational algorithms for simulating complex stochastic systems such as atmospheric aerosols and feedback control. Prof. West is the recipient of the NSF CAREER award and is a University of Illinois Distinguished Teacher-Scholar and College of Engineering Education Innovation Fellow.

Sustaining innovation in engineering education through faculty communities

Introduction
Improving the quality of engineering education requires that we understand not only what teaching methods are effective but also why faculty choose to adopt and continue to use those teaching methods[1]. Studies guided by the Diffusion of Innovations have shown that faculty are generally aware of Research-Based Instructional Strategies (RBIS), but they either fail to incorporate them into their teaching methods or quickly abandon their adoption of RBIS shortly after beginning to use them[2-6]. The first challenge suggests that faculty need to perceive the value that RBIS bring to their own classrooms[6]. The second challenge of "adopt and drop," suggests that faculty need support structures or supportive environments that enable them to continue using RBIS[6]. Critically, these findings are robust across organization types as both teaching-focused and research-focused institutions face similar challenges[6]. These findings suggest that common concerns about tenure and promotion practices may not be as prominent a barrier to effective instruction and the adoption of RBIS as many faculty intuitively expect.

The college of engineering at the University of Illinois at Urbana-Champaign has been deploying the Strategic Instructional Innovations Program (SIIP) to support faculty-led innovation of teaching practices[7]. The primary emphasis of SIIP has been the creation of communities of tenure-track and specialized faculty that will motivate faculty to adopt RBIS and then sustain their use beyond the initial financial investment in creating that community[7]. The emphasis on community simultaneously addresses both challenges identified in the literature (i.e., perceived value and supportive environments). When tenure-track faculty are the champions for the adoption of RBIS, they are better able to communicate the value of RBIS and encourage their adoption by other tenure-track faculty. Additionally, SIIP creates communities of practice that situate learning, enabling organic faculty development and mutually-supportive relationships[8,9]. These new communally-oriented teaching environments create new value for participation in the use of RBIS.

Constructed under the guiding principle that education innovations will be sustainable only if they are owned and championed by the faculty, SIIP was structured as a competitive grant program through which faculty applied to conduct large scale renovations of a course or a set of related courses[7]. We (the SIIP administrative team) required that proposals be led by teams of at least three principle investigators, two of which needed to be tenure-track faculty members. From prior efforts, we had learned that too often innovative course reforms championed by a single faculty member quickly disintegrated when the faculty member was reassigned to a different course or left the university. This requirement of community-based innovation was created to enable reforms to survive this natural turnover.

In our early experiences in administering SIIP, we became keenly aware that although our faculty are enthusiastic about improving their courses and are experts in their content, they lack training in how to demonstrate or evaluate whether their reforms and innovations are successful. These observations sparked the creation of a new model for SIIP and a new central message for communicating its central mission. Our faculty are now rallied around the simple message of "teach like we do research[7]." This message is enacted through a three-stage model of transformation illustrated in Figure 1. First, faculty are organized into Communities of Practice (CoPs) through which they will innovate their courses. Second, faculty commit to an implement-evaluate development cycle for which the CoP must commit to collecting data about their innovations and using the data to inform iterative development. Finally, we expect that the adoption of RBIS will naturally emerge without any mandates from the leadership team or administration.

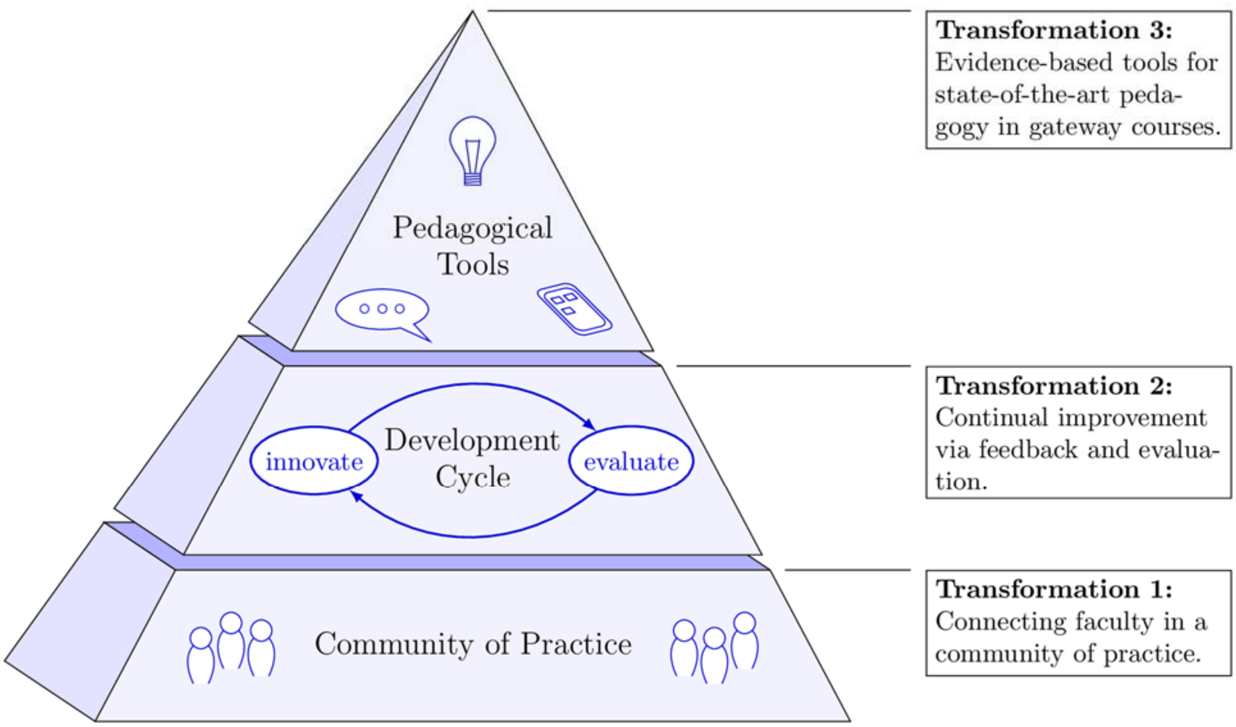

Figure 1: The three key levels of transformation that form the objectives of this project; each layer supports the transformations above.

In this paper, we provide evidence that SIIP has not only increased the use of RBIS, but is also sustaining their use beyond the initial financial investments in the creation of those communities.

Organizational Change Theory

Educational change efforts can be categorized along two axes (See Figure 2): the intended outcome of the change effort (prescribed vs. emergent) and the aspect of the system to be changed (individuals vs. environments and structures)[1,3]. Change efforts in engineering education have historically focused on changing either individuals through dissemination, faculty development (i.e., developing reflective teachers), or by developing policies such as through accreditation standards[1]. There have been few efforts to change engineering education that are both emergent and focused on the environments and structures in which faculty practice engineering education[1]. Yet these long-term approaches that address faculty's belief systems, motivation, and institutional culture have generally been more successful than other types of change strategies[1,3,10,11].

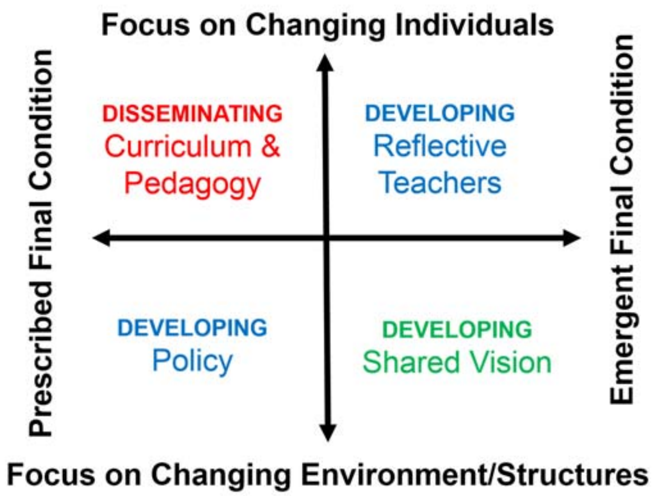

Figure 2: Taxonomy of change efforts categorized along two axes: focus on individuals vs. on environments and prescriptive vs. emergent.

Learning theories such as transformational learning theory [12-14] and other situative frameworks such as Communities of Practice (CoPs) [8,9] provide insights into why emergent, environmentally-focused change strategies can be effective. Decision-making during instruction and curriculum development are driven by faculty's implicit epistemologies, beliefs, and commitments [2,15-18]. When these implicit value systems do not align with the implicit value systems of RBIS, faculty resist the initial adoption of those RBIS or will fail to persist in their use[19]. Transformational learning theory posits that implicit value systems can be changed only through mutual reflective engagement about communal practices such as teaching practices or curriculum design practices[19]. CoPs provide a place for this mutual reflective engagement, inviting faculty to engage in continuously deeper levels with RBIS, from the periphery to the core[9].

At research-intensive universities, faculty primarily engage in research CoPs. The primary mark of membership within these CoPs is recognized depth of understanding in a field of study, as demonstrated by key cultural artifacts such as dissertations and research articles[20]. These communal practices create a central identity of faculty as researchers and as experts[20]. In contrast, the practices promoted by most RBIS deemphasize the role of faculty as researchers or as experts, promoting student-centric practices that build on students' prior knowledge and experience[20]. The mismatch in values can create a psychological "immune response" that seeks to guard existing identities and value systems and ward off invading identities[19].

CoPs provide a safe environment for challenging this immune system, surrounding resistant faculty with respected colleagues, thus mitigating the perception of identity threat[9]. Within CoPs, faculty engage in long-term situated learning, participating in community-valued practices[9].

To create and sustain functional communities, community leaders must be committed to creating a sense of fair process[21]. In other words, participants must perceive that the workload is evenly distributed, that their contributions are evaluated fairly, and that everyone has equal access to co-created materials. Even if faculty achieve desired outcomes such as better prepared students or improved retention, they will resist full participation in change-oriented communities if they do not experience fair processes, complete information sharing, or sufficient provision of resources[22]. When these senses of fair process are violated, faculty will refuse to engage in even the most basic organizational duties such as sharing teaching materials or collecting evaluation data[23]. When these senses of fair process are supported, faculty will go above and beyond expectations, supporting change efforts even if they are not fully convinced that the best pathway to change has been chosen[23].

Spreading innovation through Faculty Communities of Practice

The faculty teams with SIIP funding now essentially function as communities of practice (CoPs). These CoPs are required to meet on regular (i.e., weekly) basis to create a shared vision for how reforms would be designed and executed. To maximize the value of these weekly meetings, we embedded at least one member of the SIIP leadership team into each of the innovation CoPs. These leadership members, Education Innovation Fellows (EIFs), provide three primary benefits to the CoPs: 1) cross-pollination of ideas and practices across CoPs, 2) just-in-time faculty development, and 3) representation of each CoP during policy decisions. Additionally, the presence of the EIFs in the weekly team meetings provides a deep and detailed perspective for the SIIP administrative team during project evaluations.

Because each EIF is embedded in multiple innovation CoP meetings as well as the weekly leadership team meetings, these EIFs have become the conduits for sharing RBIS among CoPs. This function is most readily apparent in the spread of context-rich collaborative problem solving (CCPS) methodologies across SIIP (See Figure 3)[24]. Dr. West (an EIF) first learned about CCPS when co-teaching an engineering section of Calculus II. He pioneered the use of CCPS in Theoretical and Applied Mechanics (TAM) 212—our Dynamics course. He promoted the teaching practice among other TAM instructors and the practice spread to Statics and Mechanics of Materials through the TAM CoP (seven faculty members). Dr. Herman served as the integrated leadership team member for TAM during 2013–2014 and translated the use of CCPS to the Electrical and Computer Engineering (ECE) courses Introduction to Computing and Introduction to Electronics. The ECE CoP has had a variable membership but ten faculty members have overseen the delivery of this teaching method. Inspired by the success of TAM, Dr. Trinkle (another EIF) championed the translation of CCPS into the Materials Science and Engineering (MatSE) Mechanics for MatSE course. The integration of CCPS into this course led to the formation of a MatSE CoP (six faculty members) that translated the practice to the Thermal and Mechanical Behaviors of Materials course. At the same time, Dr. West was attending the weekly meetings of the Computer Science (CS) CoP (five faculty members). He shared his experiences with the CS CoP and guided their integration of CCPS into four of their courses. This spread of CCPS can be directly mapped to the embedded participation of the leadership team in multiple innovation CoPs.

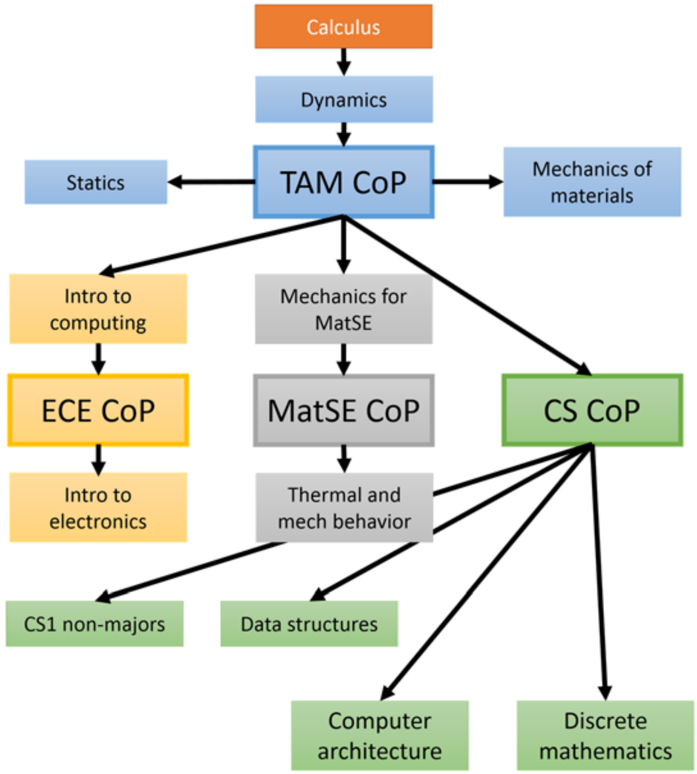

Figure 3: Spread of context-rich collaborative problem solving.

In total, the context-rich CCPS has been integrated into fourteen courses in five departments and is now been practiced by 28 faculty instructors, most of whom had not been using this RBIS before SIIP. While the spread of CCPS has been the most far reaching spread of RBIS, other RBIS are also spreading across the program. Classroom response systems (i.e., clickers) and peer instruction [4] are being used in 16 SIIP-affiliated courses, most of which had not been using clickers before SIIP. The use of an adaptive learning and testing platform is now being used in 10 SIIP-affiliated courses. The use of the Comprehensive Assessment of Team Member Effectiveness (CATME) is being used in 11 SIIP-affiliated courses.

By embedding leadership team members into innovation CoPs, we are also able to provide just-in-time faculty development. As we have previously discussed, many faculty have little or no prior experience with the rigorous evaluation of their teaching efforts. During weekly meetings, embedded leadership team members helped faculty develop student surveys, negotiate research-based course policies, and connect faculty with others who have previously successfully accomplished target innovations of the CoP.

Finally, in accordance with change theory, embedding EIFs into CoPs has created a greater sense of representation during decision making. This sense of representation was particularly critical when we changed policies to introduce mid-year project evaluations and pre-proposals. Existing innovation CoPs expressed significant concerns about the change in policies and fears about their ability to maintain funding under the new policies. We were able to allay these fears by positioning the embedded leadership team member as an advocate for the CoP during evaluations. The leadership team member helped guide each CoP through their self evaluations and helped the CoPs identify those practices which they had been doing well. Mid-year evaluations were positioned then as formative, collaborative endeavors to maximize performance rather than punitive or coercive structures designed for the leadership team to get its way.

Sustainable innovation despite decreasing funding

When first conceived, SIIP was going to be a three-year program with funding guaranteed only for those first three years. Consequently, the original expectation was that projects would stop being funded after the 2014-2015 school year. Because of the successes of SIIP, the college agreed to continue funding SIIP to enable a new set of SIIP projects to begin in the 2015-2016 school year, but reduced its budget by almost 50% (See Figure 4). This reduction in funding for individual projects as well as the program as a whole provides a test case for studying whether reforms are sustainable beyond the life of funding.

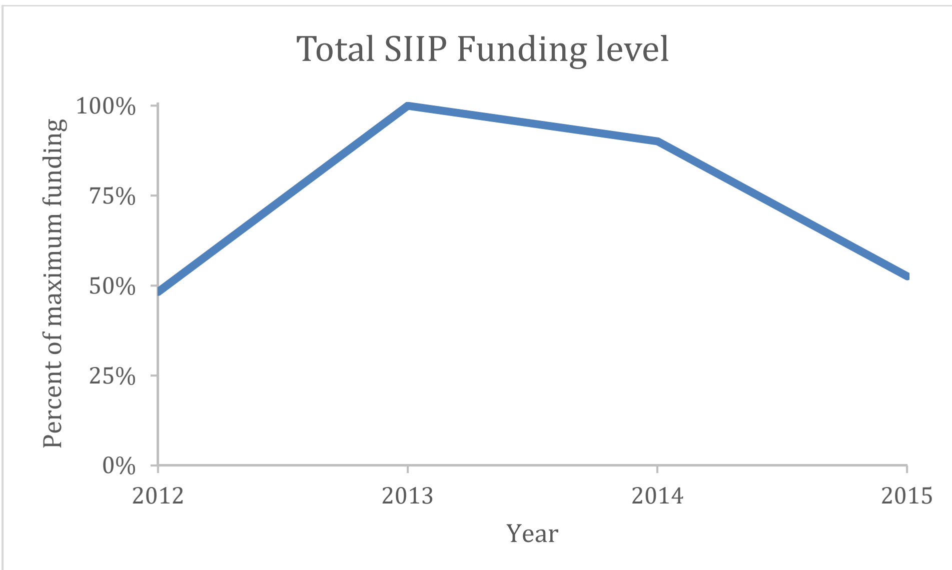

Figure 4: Level of funding for SIIP over its four years of operation

As intended, each of the five original SIIP projects (TAM 2XX, PHYS 211/212, ECE/CE, CS Scale, and CEE 201/202) are no longer funded by SIIP (See Figure 5). Two of these projects (TAM 2XX and PHYS 211/212) remain as full participants in the SIIP program even without funding. These CoPs still meet on a weekly basis, participate in mid-year and annual reviews of their projects and attend cross-SIIP team meetings. Two of the original projects (ECE/CE and CS Scale) are no longer full participants in SIIP, but have achieved varying degrees of sustainability. The CS Scale CoP project voluntarily relinquished funding, but requested to stay connected to the SIIP community. Consequently, a community of faculty in the Computer Science department continues to share practices and ideas for how to teach at scale and participate in cross-SIIP team meetings, but no longer have formal weekly meetings and do not participate in the review process. The ECE/CE team successfully redesigned their curriculum as proposed and many reforms have been institutionalized, but the faculty community no longer participates in SIIP in any official capacity. Only one project (CEE 201/202) never achieved their proposed reforms.

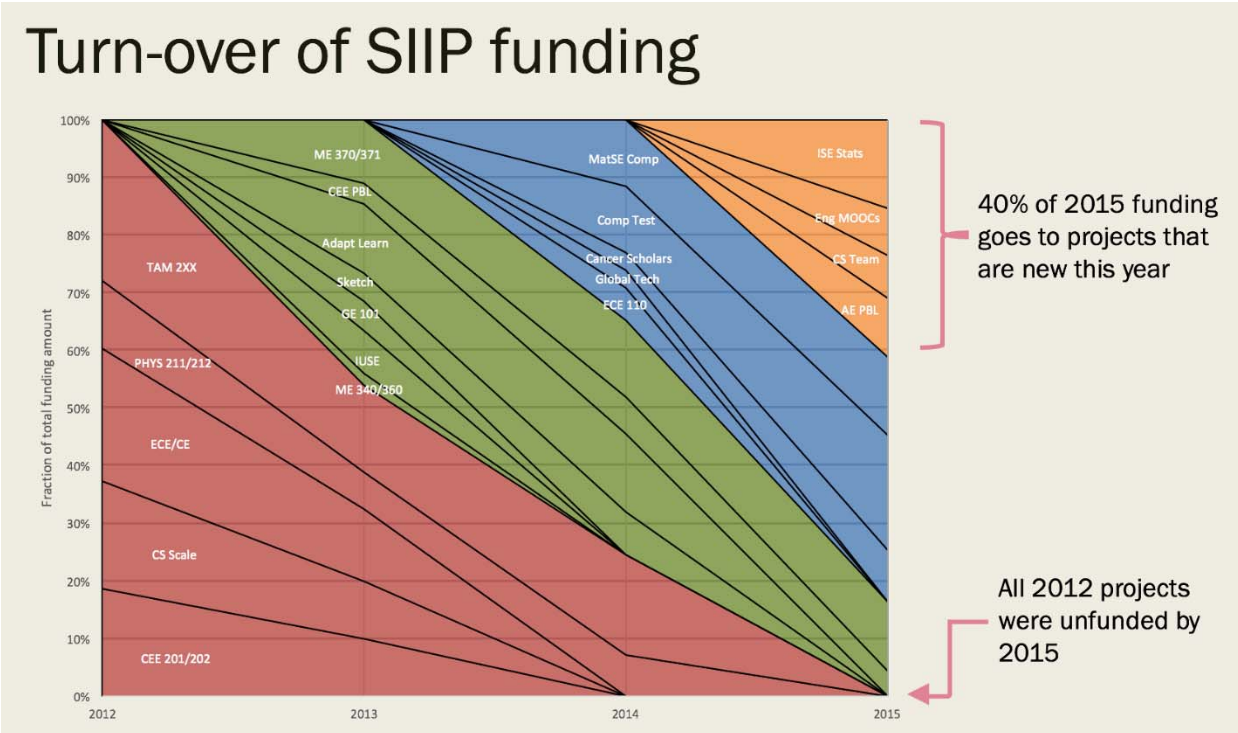

Figure 5: Percentage of SIIP budget allocated to each of the 21 projects.

Of the seven projects first funded in 2013-2014, three projects were denied continued funding because of their failure to create a functional CoP or commit to an innovate-evaluate development cycle. Two projects (Sketch and Adapt Learn) both voluntarily relinquished funding but remain as active participants in SIIP to varying degrees. The Sketch project has switched its focus to supporting context-collaborative problem solving activities without being part of the SIIP review process. The Adapt Learn project continues to support the use of their adaptive learning platform among various SIIP projects and remains a full participant in SIIP. Funding of CEE PBL and ME 370/371 continues, though, at reduced levels.

Of the five projects first funded in 2014-2015, two projects (ECE 110 and Global Tech) both voluntarily relinquished funding. ECE 110 remains a full participant in SIIP, participating in all aspects of the program. Global Tech is no longer a participant in SIIP, but the program developed through their efforts is still continuing. The remaining projects are entering their second year of funding.

Because existing projects have steadily been reducing their funding, we were able to fund an additional four SIIP projects in the 2015-2016 school year despite the drastic reduction in funding from the college.

Figure 6 shows which teams were funded each year and the status of their funding. Three teams teams were denied renewed funding and two teams opted to not reapply because of team functioning. Seven of the SIIP teams funded before the 2015-2016 school year continue to operate after SIIP funding, of which five opted to withdraw from SIIP funding before being required to relinquish funding.

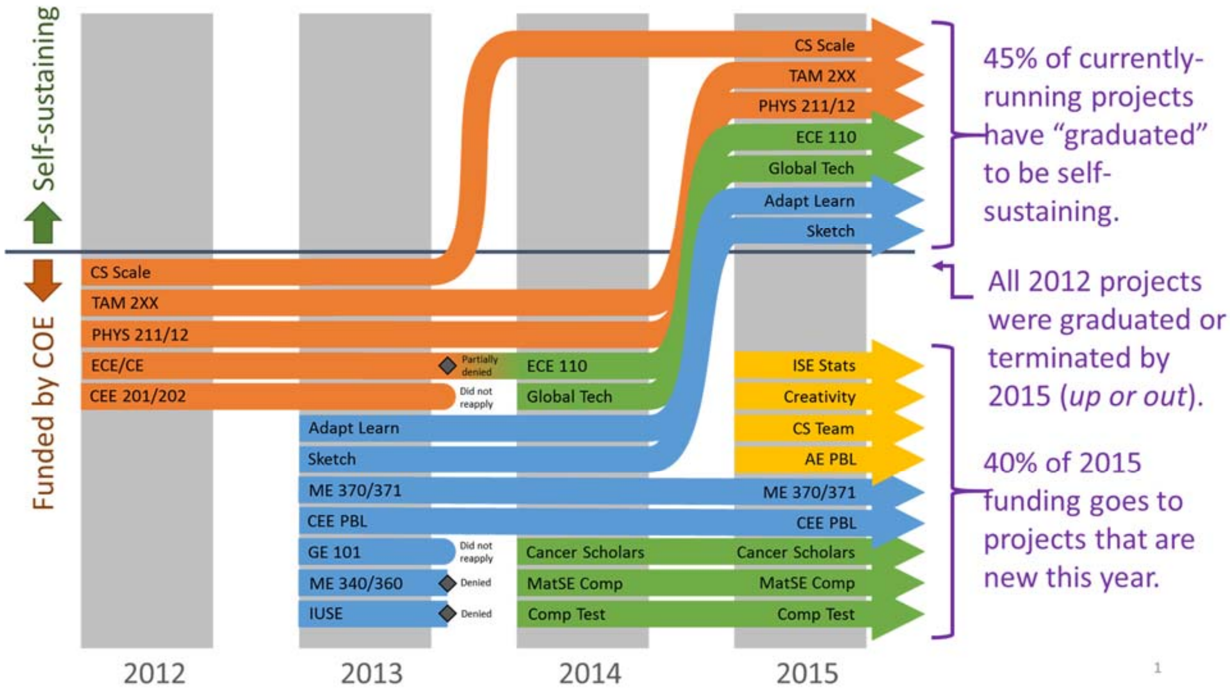

Figure 6: SIIP teams funded by year

Discussion and Conclusions

Over the past four years, SIIP has funded 21 projects, engaging 151 faculty and staff in the process of innovating and improving engineering education. The program has supported the rapid dissemination of RBIS across faculty, courses, and departments. We believe that by embedding members of the leadership team into each of the innovation CoPs, we were able to create a change model that provides just-in-time training in RBIS for faculty and spreads best practices across the broader program.

In 2013, the program supported 12 active projects. In 2015, the program is now supporting 13 projects with half the budget. Notably, many active projects have opted to continue as full participants in SIIP without continued funding and some projects have continued their efforts apart from the SIIP community. These decisions to continue participation in the program without funding is perhaps the strongest endorsement of our faculty in the program. This voluntary inclusion reveals that the sense of community, support, and vision provide a compelling reason for traditional, technical, research-focused faculty to have sustained engagement in improving engineering education.

As of yet, we have not been able to change tenure and promotion policies or any other college-based policies regarding teaching. So our faculty are continuing to engage in these reform efforts without any particular extrinsic reward, but because of intrinsically motivated desires to improve teaching. This sustained faculty engagement in the reform process provides preliminary evidence that faculty teaching behaviors and practices can be changed without long term monetary or career evaluation incentivizes by creating communities that support and sustain faculty motivation and learning.

Acknowledgements

This project was supported by the College of Engineering at the University of Illinois at Urbana-Champaign. This work was also supported by the National Science Foundation under grant DUE-1347722. The opinions, findings, and conclusions do not necessarily reflect the views of the National Science Foundation or the author's institution.

References

1 Beach, A., Henderson, C. & Finkelstein, N. Facilitating change in undergraduate STEM education: Implications from an analytic review of literature. *Change: The Magazine of Higher Learning* **44**, 52-59 (2012).

2 Borrego, M., Froyd, J. E., Henderson, C., Cutler, S. & Prince, M. Influence of engineering instructors' teaching and learning beliefs on pedagogies in engineering science courses. *International Journal of Engineering Education* **29**, 1456-1471 (2013).

3 Borrego, M. & Henderson, C. Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies. *Journal of Engineering Education* **103**, 220-252 (2014).

4 Borrego, M., Cutler, S., Prince, M., Henderson, C. & Froyd, J. E. Fidelity of implementation of Research-Based Instructional Strategies (RBIS) in Engineering Science Courses. *Journal of Engineering Education* **102**, 394-425 (2013).

5 Froyd, J., Borrego, M., Cutler, S., Henderson, C. & Prince, M. Estimates of Use of Research-Based Instructional Strategies in Core Electrical or Computer Engineering Courses. *IEEE Transactions on Education* **56**, 393-399 (2013).

6 Henderson, C., Dancy, M. & Niewiadomska-Bugaj, M. The use of research-based instructional strategies in introductory physics: Where do faculty leave the innovation-decision process? *Physical Review Special Topics – Physics Education Research* **8**, 020104 (2012).

7 Herman, G. L., Hahn, L. & West, M. Coordinating college-wide instructional change through faculty communities. in *Proceedings of the 2015 International Mechanical Engineering Congress & Exposition.*

8 Wenger, E. *Communities of Practice: Learning, Meaning, and Identity*. (Cambridge University Press, 1998).

9 Wenger, E., McDermott, R. & Snyder, W. M. *Cultivating Communities of Practice*. (Harvard Business Press, 2002).

10 Finelli, C. J. & Millunchick, J. M. The teaching circle for large engineering courses: Clearing the activation barrier. In *Proceedings of the 120th American Society for Engineering Education Annual Conference & Exposition* AC2013-6643 (Atlanta, GA, 2013).

11 Villachia, S. W., Marker, A. W., Plumlee, D., Huglin, L. & Chegash, A. The arrows in our backs: Lessons learned trying to change the engineering curriculum. in *Proceedings of the 120th American Society for Engineering Education Annual Conference & Exposition.* AC2013-6659.

12 Mezirow, J. Transformative learning: Theory to practice. *New Directions for Adult and Continuing Education* **74**, 5-12 (1997).

13 Siddiqui, J. A. & Adams, R. The challenge of change in engineering education: Is it the Diffusion of Innovations or Transformative Learning? in *120th American Society for Engineering Education Annual Conference & Exposition* AC2013-7574 (Atlanta, GA, 2013).
14 Mezirow, J. *Learning as Transformation*. (Jossey-Bass, 2000).
15 Hasweh, M. Z. Effects of science teachers' epistemological beliefs in teaching. *Journal of Research in Science Teaching* **33**, 47-64 (1996).
16 Yerrick, R., Parke, H. & Nugent, J. Struggling to promote deeply rooted change: The 'filtering effect' of teachers' beliefs on understanding transformational views of teaching science. *Science Education* **81**, 137-159 (1997).
17 Tsai, C. Nested epistemologies: Science teachers' beliefs of teaching, learning, and science. *International Journal of Science Education* **24**, 771-783 (2002).
18 Luft, J. A. & Roehrig, G. H. Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education* **11**, 38-63 (2007).
19 Kegan, R. & Lahey, L. L. *Immunity to Change: How to Overcome It and Unlock the Potential in Yourself and Your Organization*. (Harvard Business Review Press, 2009).
20 Brownell, S. & Tanner, K. Barriers to faculty pedagogical change: Lack of training, time, incentives, and tensions with professional identity. *CBE-Life Sciences Education* **11**, 339-346 (2012).
21 Blader, S. L. & Tyler, T. R. Testing and extending the group engagement model: linkages between social identity, procedural justice, economic outcomes, and extrarole behavior. *Journal of Applied Psychology* **94**, 445-464 (2009).
22 Colquitt, J. A. *et al.* Justice at the millennium, a decade later: a meta-analytic test of social exchange and affect-based perspectives. *Journal of Applied Psychology* **98**, 199-237 (2013).
23 Organ, D. W. & Konovsky, M. Cognitive versus affective determinants of organizational citizenship behavior. *Journal of Applied Psychology* **74**, 157-164 (1989).
24 West, M. & Herman, G. L. Mapping the spread of collaborative learning methods in gateway STEM courses via Communities of Practice. in *Proceedings of the 2015 American Society for Engineering Education Annual Conference and Exposition.*