

Pivotal Junctures in the Undergraduate Research Enterprise

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I am truly honored to have been selected as a CUR Fellow for 2012, and I thank the selection committee for this tremendous privilege. Since learning of this award, I've taken the opportunity to reflect on the many individuals, organizations, and circumstances that have supported me in my undergraduate research endeavors. In my mind, three factors have profoundly shaped my undergraduate research journey—my institution, Harvey Mudd College, with its strong culture of undergraduate research; my students over the years who have been passionate about their research; and my long and wonderful association with CUR. I'd like to share a few thoughts about the impact that each of these areas has had in my career.

Tracing the Roots of the Institutional Culture of Undergraduate Research at Harvey Mudd

Harvey Mudd College (HMC) is a young institution, founded in 1957 with a focus on science, engineering, and mathematics. Our founding president, Joseph B. Platt, was the true architect of our strong institutional culture of undergraduate research. In his memoirs looking back at the start of the college (Platt, 1994), he spoke of looking for faculty with strong interests in research and scholarship: "The college was planned as a teaching institution, not a research institute, but I knew from personal experience that research can assist teaching by keeping the faculty interested in new developments and by involving able students with problems for which the answers are not yet known. Hence, I hoped for teachers with continuing interests in research and scholarship." The faculty he selected did indeed have the determination to conduct research despite the lack of facilities, time, or money in the early days of the college.

If we fast-forward more than 50 years, how has the culture of undergraduate research progressed at the college? One measure of the pervasiveness of the research culture was recently revealed in an alumni survey (HMC Impact Project)

conducted in 2009-10 to answer the question: "Is HMC making an impact in the lives of its students?" One of the survey questions specifically asked, "Which skills gained at HMC are most valuable to you now?" Over 26 percent of our alumni responded to this open-ended question, and the responses were analyzed by the frequency of the particular response. The findings indicate that research was the number one skill gained at HMC that was viewed as most valuable to our alumni now (see Figure 1).

Figure 1. Responses to the alumni survey question, "Which skills gained at Harvey Mudd College are most valuable to you now?" with font size reflecting the relative frequency of response.



Clearly a great deal has transpired during those 50+ years to yield this result. Table 1 is a list of what I view as the top ten pivotal moments in the history of undergraduate research at HMC.

Table 1. Top Ten Pivotal Moments in the History of Undergraduate Research at HMC

YEAR	PIVOTAL MOMENT
1960	1. Continuous summer research program in chemistry started with NSF-URP funding (now NSF-REU funding)
1961	2. Senior research required for graduation in chemistry for all classes
1980	3. HMC represented in CUR with Professor Mitsuru Kubota as councilor in 2nd year of organization's existence
1983	4. Beckman Research Endowment received to enable faculty start-up packages and internal research awards
1987	5. College makes commitment to support summer student housing
1991	6. Faculty vote to celebrate student creativity with three-day event, "Presentation Days"
1994	7. Chemistry department starts sophomore spring-semester research program (and now also offers a research course for first-year students)
1998	8. Harvey Mudd College receives NSF Award for the Integration of Research and Education
1999	9. Harvey Mudd College joins CUR as an institutional member (and in 2009 elects enhanced membership)
1998-2008	10. Harvey Mudd College establishes Research Fellowship Programs in Engineering and receives Stauffer Challenge Grant in Chemistry to provide endowments for undergraduate research

The list could be sorted into three categories. The first category consists of various decisions that a committed faculty made to support undergraduate research (items #1, 2, 6, and 7). In 1960, as soon as we had a science building on campus, the chemistry faculty started a summer research program and that tradition continues today and now involves all departments at the college. With an undergraduate enrollment of 750, we typically have more than 200 students on campus in the summer conducting research in collaboration with faculty. In 1961, with the first senior class at the college, a senior research thesis was required in chemistry; now all graduating seniors in all departments conduct a year-long senior thesis project or participate in an industry-sponsored team clinic. In 1991 the faculty voted to cancel three days of classes at the end of the spring semester for what we call Presentation Days to celebrate students' research and cre-

ative activities. Nothing indicates faculty commitment more than the willingness to forego classes for a few days! Finally, formal efforts to involve students in research well before their senior year have been in place for nearly 20 years in the chemistry department, and this practice has expanded to other departments as well.

Two pivotal moments (#3 and #9) highlight our strong association with CUR: first, having Professor Mitsuru Kubota as one of the organization's early councilors, in the second year of CUR's history, and later, the decision to become an institutional member and now an enhanced institutional member.

Of course, some of the pivotal moments (#4, 5, 8, and 10) involve funding obtained to enhance research—particularly for faculty start-up funds, departmental endowments for research, and integrating research into the curriculum.

While every institution is unique, perhaps a take-home message from this walk through history might be a generalized list of key steps to building an undergraduate research culture on campus. I think many of our institutions would trace a similar path.

Following are seven key steps to building a campus undergraduate research culture:

- Start with a core group of committed individuals
- Align with your institutional mission statement
- Start with a small set of goals
- Build research into your curriculum
- Seek the advice and effective practices of others
- Design effective assessment measures
- Celebrate achievements and milestones

The culture of undergraduate research at my institution had a strong impact on my career. As I reflect on the various stages in my research career as a faculty member, I can select three key events that strongly shaped my research path. The first was arriving on campus to an empty laboratory with no start-up funds. That's something that we don't typically subject new faculty to these days! But what the situation taught me was the need to seek out grant funding, and I am extremely grateful for that early lesson. Looking back, I now recognize that the research culture at an institution

is the most critical element for faculty success. The second key event, my election as a CUR councilor nearly 20 years ago, had a profound influence on my career as I began to see the national landscape of undergraduate research and bring that perspective to my institution. Finally, while many of us change in our research directions over the years, the decision that I made to make a significant shift just as I had been promoted to full professor was one of the best decisions that I ever made. Indeed, professional development and renewal is essential at all faculty career stages.

Since research is central to CUR, let me provide a 30-second overview of my current work in laymen's terms. I investigate compounds primarily derived from the sugar glucose that can be used in a variety of applications that include facilitating drug delivery, enhancing the texture of chocolate, and encapsulating ink in inkjet printers. The reason for the variety of applications is that these compounds spontaneously assemble into a variety of three-dimensional structures when placed in water at various temperatures and concentrations. My students and I use two techniques to identify the aggregates formed. Our first approach is a unique method that employs a molecule known as a fluorescence probe to signal what aggregate might be present. We also confirm the variety of aggregates that might form using a second technique known as optical polarizing microscopy. Then we put all of that information into a figure known as a phase diagram to show the aggregates present at various compositions and temperatures. Our fluorescence approach is so sensitive compared to traditional techniques that the resulting phase diagram is more fully depicted (and therefore thermodynamically accurate). See for example, Karukstis, et. al. 2012.

Reflections from Former Students on Their Research Experience

As I noted, my research students over the years are one of the key factors in the development of my research career. In preparing this address, I wanted to further explore the findings of our alumni survey and wrote to my former senior research students to ask them what aspect of undergraduate research, if any, had an impact on their current professional or personal lives. I received a variety of responses and will share a few.

One of my students now in academia commented on the importance of project ownership and how it developed her

scientific creativity and confidence and how she tries to foster this ownership in her lab today:

I thought my entire research experience rocked. One aspect that was really important was the project ownership ... my opinion and ideas mattered. I think those feelings have helped me to develop my scientific creativity. ... I also see that, in my research lab now, the most successful undergraduate research students are the ones that have taken ownership of the project. ... So I try and foster this ownership in my lab.

Another former research student who is also a faculty member recalled my taking the group to a professional conference (we were working in the area of photosynthesis when I first started at Harvey Mudd). That event had such an impact on him that he strives to take his students to national meetings as well:

A memory that remains strong is the time you took us to a conference on photosynthesis. It was an exciting experience for me, the chance to learn about the latest advances, as well as a feeling of being part of a larger enterprise. This memory is probably why I have pushed the department at [my institution] to let me take our current students to national meetings.

Another one of my students who is now a pediatric dentist gained an appreciation for having an inquisitive mind. That attitude has helped her in her current profession, as well as with her own children:

There are many aspects of my undergraduate research experience that I find priceless. If I had to pick one, it would be the appreciation I gained for an inquisitive mind. ... My biggest reward is to be able to walk an anxious child through a successful dental procedure and also earn his/her trust. Whether it is at home or at work, I welcome questions from my children and my patients.

Another student experienced the excitement of basic research and that led to a change in major:

I went to HMC to be an engineer but left as a scientist, and I think that is mostly because of my undergraduate research experiences. ... I am still doing, and still love doing, basic research.

A recent research student pursued both a Pharm D and a medical degree and commented on how a basic understanding of research principles aids her in interpreting primary medical literature:

Understanding basic research principles helps me interpret primary medical literature. ... I feel confident in being able to deduce what type of conclusions and applications I can draw and what the limitations are of such studies.

Another one of my students who continued to medical school and is now a radiologist and a medical director of a hospital imaging department commented on the realization that research was hard work:

Summer research taught me that basic research is hard work indeed and big breakthroughs are not easy to come by.

Now, not all of my students have gone on in science. One of my projects a few years ago caught the special interest of a sophomore chemistry major because it involved investigations of the colorful properties of azo dyes. He was a highly creative scientist, but he soon realized that his passion was in an entirely different direction. He ended up completing an art major with a minor in chemistry—we have one or two students a year who take this route of completing a major at one of the other Claremont Colleges. This former student is now a professional artist, sculptor, and ceramicist. His chemistry roots are still apparent as he is fascinated by the material that he works with:

My main inspiration for my pieces is the material itself.

I also asked my research students to reflect on the less positive aspects of their undergraduate research experience. I received a few comments, including:

I would have benefited from more time writing up the work.

I wish I had had the depth of knowledge to dream, plan, and execute the whole research at that stage—the fantasy that kids have about “science” growing up.

The demands on my time from my course load constrained the amount of research that I could do during the academic year.

There are a lot of take-home messages from these comments. Each student valued a particular aspect of his or her research experience—we must keep in mind that they are individuals. I truly believe that, no matter what the skill level or level of interest, every student can make a contribution to a research project. Also, we as mentors must continue to help students understand the realities of research progress in their position as undergraduates. But, perhaps most importantly, on those days when we might wonder how significant a contribution we might be making to the scientific world, we should remind ourselves: “My research might not impact the world, but I can impact the world of my students.”

Reflections on My Involvement in CUR

Finally, let me offer just a few reflections on CUR and my involvement with this wonderful organization.

Each one of us might select different pivotal moments in CUR’s history to date. Certainly there are all of the “firsts”—the first directory of UR that launched the whole organization, the first gathering of councilors, the first national conference, the first institute, the first recruitment of individual members and then institutional members, etc. There is also CUR’s early involvement in the research funding arena with a proposal to the National Science Board in 1982 that led to the NSF-RUI program. Also important to the organization was the establishment of a national office and the eventual move of that office to Washington, D.C. As the organization has matured, it has also started to receive significant NSF funding to enlarge the scope of its work, including several major NSF Course, Curriculum, and Laboratory Improvement awards. All of these are key moments in CUR’s history.

There is no doubt that the movement to institutionalize undergraduate research has swept this country. One only needs to look at the growth in institutional members in CUR—now at its highest level in the history of CUR (see Figure 2)—and the growth in the number of institutions that have participated in one of CUR’s institutes or workshops on institutionalizing undergraduate research (Figure 3) to demonstrate this fact.

Figure 2.

Measures of Growing Interest in Institutionalizing Undergraduate Research

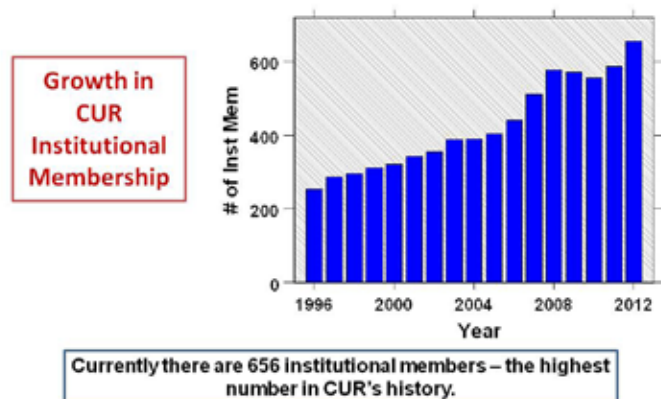
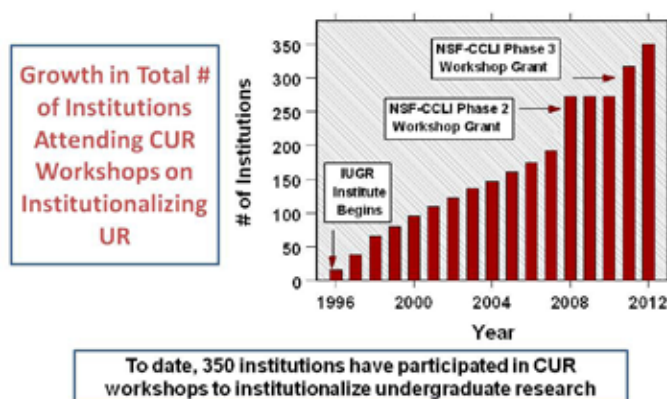


Figure 3.

Measures of Growing Interest in Institutionalizing Undergraduate Research



There are many tangible, successful outcomes from this institutionalization movement, including:

- Undergraduate research opportunities are available for students and faculty at a range of institutional types.
- When faculty members are hired, beginning with when the position is advertised, the expectations for undergraduate research involvement are clearly communicated.
- Many institutions now have a tradition of college-wide celebrations of undergraduate research.
- Research start-up funds for faculty are common.
- Student travel to professional conferences is valued and supported.
- While not all campuses can require undergraduate research of all students, it is possible for students to earn academic credit for their undergraduate research involvement on most campuses.
- Particularly because of the work of both Project Kaleidoscope and CUR, institutions recognize the importance of designing facilities with undergraduate research in mind.

The continuous struggle for research funding aside, some of the challenges that I see in the years ahead include:

- The need to give faculty teaching credit for mentoring undergraduate research students.
- The necessity to articulate in a more compelling manner how undergraduate research prepares students for non-research careers, in order to better argue for the student learning outcomes of undergraduate research.
- The need for many constituencies—including students, tenure and promotion committees, and funding agencies—to better appreciate the time needed for significant research progress when working with undergraduates.
- The necessity for all of us to work harder to disseminate students' work through publication, just as we have promoted student travel to professional meetings to present their work.
- The need to address the fact that while students typically receive a stipend for their summer work, many faculty members are poorly compensated or not compensated at all for mentoring summer research students.

Thus, CUR is still needed, perhaps now more than ever, as we continue to face these additional challenges.

I would like to conclude by thanking CUR for the impact that it has had on my professional and personal life. I am grateful that:

- I have made so many friends across all disciplines and at so many types of campuses.
- I have learned so much as a consequence of the incredible atmosphere of sharing within this organization.
- I've had the opportunity to develop some leadership skills, try my hand at editing books, and work on so many projects that have had a significant impact on individuals, institutions, and the undergraduate research landscape in general.
- I've gained a better appreciation for the federal funding process and how a strong, highly respected organization can have a voice.

I want to thank all of the individuals with whom I've worked closely on CUR initiatives over the years and those who have supported my undergraduate research ventures, including Nancy Hensel, Tom Wenzel, Jeff Osborn, Mitch Malachowski, Bridget Gourley, Diane Husic, Mike Castellani, Lori Bettison-Varga, Shontay Kincaid, Mary Boyd, Jodi Wesemann, Mel Druelinger, Silvia Ronco, Tim Elgren, John Gupton, Jerry Van Hecke, Robert Cave, Sam Tanenbaum, and Sheldon Wettack. I'd like to extend an enormous thank-you to the entire CUR National Office staff—past and present—for their professionalism and passion for supporting our undergraduate research endeavors. I especially thank Li-Cor Biosciences for its sponsorship of this award and for all that company does to enable faculty to engage undergraduates in research with state-of-the art instrumentation. Most importantly, I thank the many students for whom I've had the privilege of serving as a research mentor—they continue to inspire me as they thrive well beyond their days at Harvey Mudd College.

It has truly been a rewarding undergraduate research journey thus far, and I look forward to a continued strong collaboration with CUR in the years ahead.

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