

Students' Understanding of the Scientific Process: Transformation or Stagnation?

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Preface:

Transformation?

- Is it presumptuous to think that Undergraduate Research could be a *transformative* experience?
- What does such a transformation require, both of us and of our students?
- And what do we want the transformation to be?

Value and Gains

- **Experience:** Inspirational \leftrightarrow Practical
- **Skills:** Marketable \leftrightarrow “Cool”
- **Culture:** Induction \leftrightarrow Lingo
- **Learning:** Cognitive \leftrightarrow Affective

- Hunter, A.-B., Laursen, S. L., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education*, 91(1), 36-74.
- Kardash, C. M. (2000). Evaluation of an undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology*, 92(1), 191-201.
- Seymour, E., Hunter, A.-B., Laursen, S. L., & Deantoni, T. (2004). Establishing the Benefits of Research Experiences for Undergraduates in the Sciences: First Findings from a Three-Year Study. *Science Education*, 88(4), 493-534.

A counterexample?

So we arrive at the telescope last night. Only half of the students are excited at all: Me and [Bob]. We've been looking forward to this forever. One student has been before, and another just doesn't care. So we all sit down and wait for something to happen. And [Nate], the person who has been there before, gets to do something. He gets to determine the FWHM and something else that the professor who has taken us mumbled that it is important. And then the professor who took us does everything. Except [Nate's] job. He doesn't even tell us the stuff he's doing. Doesn't tell us what it means, why he's doing it, or even what we're observing for his student's project. He had remarked earlier that he'd been here 20-25 times and it just isn't as cool as it used to be. And now he won't even let us do anything.

After a little while, he encourages us students to go look at the not-very-light-polluted night sky. It is quite lovely. Three of us sit out there and talk about different aspects of astronomy, including astrobiology. It's really interesting stuff! That was the best part of the night.

So we went back inside and after 1 hour of sitting around trying to be involved in observing, I give up. ... [Later] it was me and Dr. [Inkley]. For about a half hour. And he was observing stuff, wheeling back and forth between two computers instead of asking me for help or to participate in this 'observing experience.' And after a while, he started getting ready to leave, announcing that he was going to go. ... I wake up to hear [him] say, "Maybe you guys should turn in for the night." So we all quickly pack up and leave to go to bed: The most productive thing we've done all night.

. . . So [f^&*] it. I don't want to be an astronomer anyway.

Best cases: Faculty goals

- **The “process of science”:** “How do we come up with ideas in the first place, and what is the process for chasing them down”
- Appreciation for science: “I want them to experience the joy of scientific discovery.”
- Valuable skills: “...learning how to design experiments or field work, working with groups when this occurs, developing oral and written communication skills.”
- Goals and future

Best cases: Student outcomes

- Self reports: Affective gains, positive experiences, new opportunities and credentials
- Views of Science: Information collecting, utilitarian, problem solving
- “What did you learn:” Specific problem solving, skills, collecting specific data:
“[A]fter isolating DNA from tissue, I performed molecular sequencing tests.”

Best cases summary

- Faculty suggest broad goals:
The scientific process and franchise
- Students see very specific gains:
Skills and experiences
- Is this a problem? What is it?

“The Rub”

- We want students to do something that is independent, original, self-directed ...
- But we have an inherent understanding of the discipline, the community, and the research itself.
- Is it really fair to expect a research experience to be “transformative”? Do we change our expectations, or do we change the experience?

Discussion Prompt

What are your goals for Undergraduate Research Experiences in the sciences?

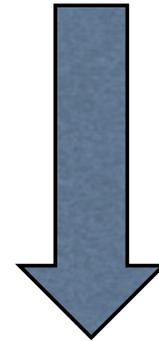
Individual Differences: Students

- Articulating UR goals is complicated by individual differences in student interests and talents.
- Dependent Profile: Student with extrinsic interest for status (grad school admission etc.) and limited knowledge or motivation for the particular research.
- Autonomous Profile: Student with intrinsic interest in and ability to run their own research study on the topic.

Student Profiles

- Laborer
- Technician
- Apprentice
- Learner

- Dependent

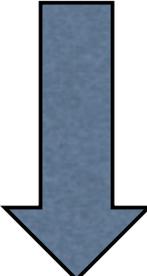


- Autonomous

Individual Differences: Faculty

- Articulating UR goals is also complicated by individual differences in faculty motivations and goals.
- Enhancing Dependence: Faculty who are more invested in the research than the students and strongly direct their activities
- Enhancing Autonomy: Faculty are as or more invested in students than research and gives students space to make research decisions.

Faculty Profiles

- Boss
 - Leader
 - Mentor
 - Advisor
- Enhancing Dependence
- 
- Enhancing Autonomy

Positive Interactions

- There are ways in which student and faculty background suit each other, resulting in positive outcomes.

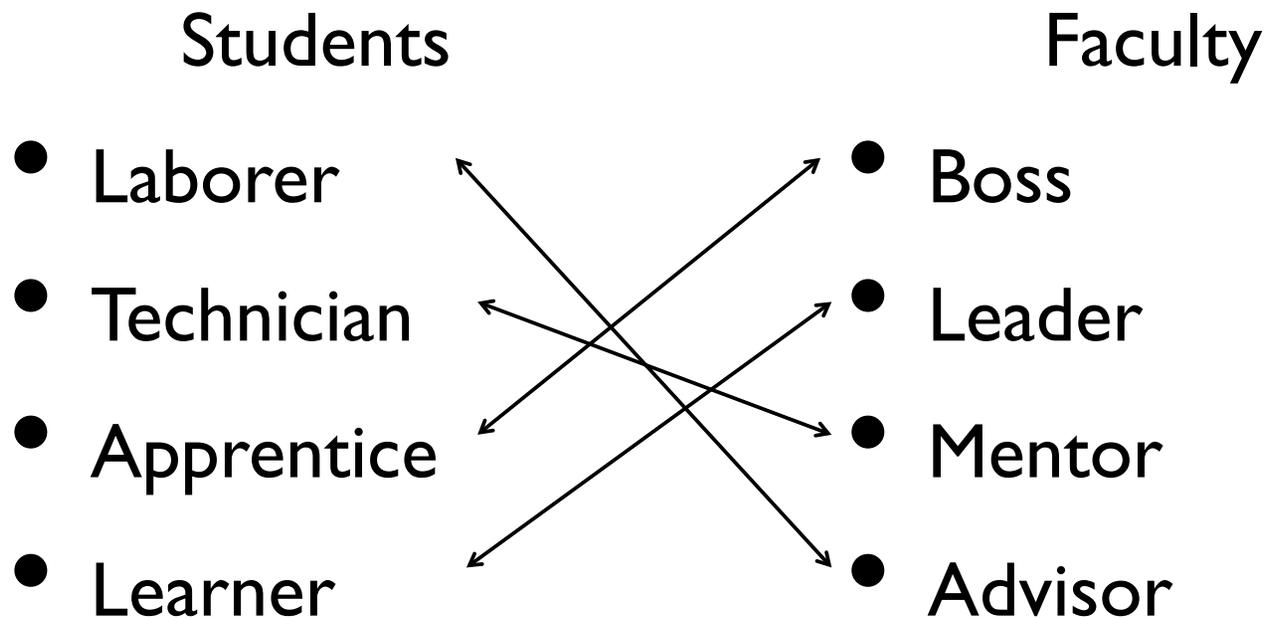
Students

Faculty

- | | | |
|--------------|----|-----------|
| ● Laborer | ←→ | ● Boss |
| ● Technician | ←→ | ● Leader |
| ● Apprentice | ←→ | ● Mentor |
| ● Learner | ←→ | ● Advisor |

Negative Interactions

- But mismatches can prove to be very difficult situations, leading to conflict and frustration for all concerned.



Authentic Science

- If URE is going to be transformative, it has to insure an **authentic scientific experience**, whatever faculty and student backgrounds.
- Account of how authentic science was defined and built into curriculum (PrePS).
- *Science refers to an attitude – an intellectual approach to viewing the natural world – with an investigative method of asking and answering questions and a willingness to entertain alternative explanations.*

Scientists-in-Waiting

- In PrePS, students are treated as *scientists-in-waiting* whose knowledge and curiosity is leveraged by faculty to help them grasp the scientific value of their activities.
- PrePS students learn about the nature and meaning of science by faculty who:
 - Guides their activities
 - Supports their reflection activities,
 - Leads to discover scientific value of their activities.

PrePS and URE

- PrePS is a preschool program and is a model for *Sid the Science Kid*.
- Preschoolers can discover how their activities connect to a socially-based inquiry process, but undergraduates can appreciate how their activities connect to the epistemological foundation of science.
- URE can be an opportunity to see how individual activities are related to the structure of scientific knowledge, its process of change, and its institutionalization.

Possible Solutions

- What can be done to create an URE that is scientifically authentic and transformative?
- **Nothing:** An authentic and transformative URE can not be orchestrated.
- **Contracts:** Create contracts which specify expectations for students and students.
- **Coordination:** Select and pair students and faculty to assure coordinated goals.
- **Instruction:** Course or seminar to guide students reflection on research experiences.

Instructional Solution

- We proposed an instructional solution which had 4 goals, which was piloted by Adam this past semester.
 - Challenging student researchers' misunderstandings and misconceptions about scientific inquiry
 - Scaffolding reflection on the scientific significance of their research activities
 - Encouraging discussions with advisors or supervisors about how their activities relate to scientific inquiry.
 - Promoting interactions among student researchers so to highlight the diversity of scientific endeavors and to better present scientific inquiry on a grander scale.

Discussion Prompt #2

- How can we shape UREs to overcome the challenges to make such experiences both scientifically authentic and transformative?
- What are the roles and responsibilities of the undergraduate researcher?
- What are the roles and responsibilities of the faculty?
- What are the roles and responsibilities of Academic Affairs, OUR and other administrative offices?