



## **Benefits and Costs of Undergraduate Research for Students and Faculty: Selected Findings from a US study**

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# Acknowledgements

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- The faculty and students at the four colleges for their generosity and openness in giving interviews.

We hope that they, and all who have enabled this work, will regard its findings as truthful, useful, and validating

# The US Context of Undergraduate Research

Undergraduate research (UR) in the sciences is a strong tradition, both at liberal arts colleges and research universities, largely as:

- **summer programs** (approx 10 weeks)  
(also traditionally offered by National Labs: Los Alamos, Fermi, NASA)
- **assistantships** during the academic year

These are **mentored** experiences of **authentic** research in which students work on aspects of their faculty advisors' research projects. (Students do not choose own projects)

In addition to organized “programs”:

- **informal** UR arrangements between faculty and students
- some science departments require **senior theses** in which students choose their own research topic.

# The traditional role of UR among science faculty

- Science faculty in undergraduate colleges have depended on undergraduate assistance to **further their own research**
- UR has played a critical role in **“replacing the profession.”** UR apprenticeships:
  - offer an opportunity to try out science as a possible career
  - encourage development of a scientific identity
  - introduction and bonding to the scientific community
- Science faculty take this professional responsibility very seriously

# Preparing young scientists: a balance of research and educational elements

## Students learn “how science is done”

- Work alongside their faculty mentor on some aspect of the faculty’s research
- Work with a small group of research peers
- Frequent discussion of project progress, problems, choices
- Develop responsibility for pieces of the project
- Learn how to discuss, present, explain their part in the project in formal presentations (end of summer, conferences with faculty, posters)

# The traditional balance of objectives for students

- Educational and professional **preparation** for those who are interested in **becoming scientists**
- An opportunity for **prospective scientists to clarify their career choices** in light of authentic experiences of research and professional life.
- **A good science education for others**

Where faculty place their emphasis on this **spectrum of objectives** has been a matter for individual or departmental choice

# The spread of three ideals are changing UR

1. **Access**: addressing under-representation in the sciences by gender and race/ethnicity
  2. **“Science for all”**: Making science accessible; part of a normal education for more/all undergraduates
  3. **Quality of undergraduate education**: includes integrating research into education
- social sciences, mathematics, engineering have begun to offer UR experiences
  - **research-enriched courses** have been developed in many disciplines
  - development of UR programs focused on **recruitment and support of targeted groups**
  - pressure to **structure more educational experiences** into UR programs (literature discussions, seminars, presentation of work, student conferences)

# Sources of pressure to offer UR to more students

- **Public and private foundations** see UR work as critical in producing future scientists. Funders (e.g., NSF, HHMI) support UR programs:
  - to promote science careers
  - to increase access for under-represented groups
  - to make research experiences part of normal science education

Funders also press faculty to evaluate their UR work

- **Institutions** promote their record in graduate school enrollment as UR-related and seek ways to offer UR experiences to more students
- More **undergraduates** seek UR experiences: aware that this enhances their graduate school applications



Our research group (E&ER) began a 5-year study of UR summer programs at 4 liberal arts colleges at a time when these pressures were becoming evident.

Faculty found little to guide their UR program evaluation efforts (increasingly required by funders) because of the lack of research data on which to ground them.

# What do we know about what students gain from UR?

When began our study (2000): **NOT MUCH:**

- We found 9 studies meeting accepted methodological standards (classified in 1<sup>st</sup> article: see handout title page)

Majority of literature largely claims-based by faculty practitioners offering:

- descriptive accounts
- promotional and discussion articles
- histories and reviews

These are important, but not evidence-based

Are now a number of research and evaluation studies that document UR student benefits (see Table 8 and references)

# E&ER Study Research Questions

- What gains do students make from doing UR by the end of their summer experience, and in the longer term?
- By what processes do these gains come about? How do peers, faculty and departments contribute?
- How are career outcomes affected by UR participation?
- What are the benefits and costs to faculty of doing UR?

# Study Design

Best case scenario:

**4 liberal arts colleges:** with long history of well-established UR programs based on the summer apprenticeship model

- biology, chemistry, physics, math and CS, engineering, biochemistry, psychology

*An intentional sample* (compete population of students):  
with cells for every salient group of informants

## **In-depth, semi-structured interviews**

Individual, live (later rounds by phone) 1.5 to 2.5 hours each.  
Exploratory, conversational, using prompts and recaps

Protocols drew upon research findings/descriptive accounts, ending with checklist of gains from the literature of “things faculty think students gain from UR”

# Longitudinal and Comparative Student Samples

Interview	UR Participants (including 12 REU students)	Comparative Groups <ul style="list-style-type: none"> <li>• Chose <i>not</i> to do UR</li> <li>• Did UR late (as senior)</li> <li>• Participated in alternative experience (i.e., internship)</li> <li>• Applied for, but did not get, UR placement</li> </ul>
1 <sup>st</sup> 2 <sup>nd</sup> 3 <sup>rd</sup>	<ul style="list-style-type: none"> <li>• <b>As rising seniors (n=76)</b></li> <li>• As graduating seniors (n=69)</li> <li>• Currently working or in graduate school (n=55)</li> </ul>	<ul style="list-style-type: none"> <li>• As graduating seniors (n=63)</li> <li>• Currently working or in graduate school (n=25)</li> </ul>
<b>Totals</b>	<b>200</b>	88

# Comparative Faculty Samples

UR Participants		Comparative Group
<b>55 faculty</b> with whom UR student participants were working	<b>9 administrators</b> (including college presidents, deans, department chairs and REU and UR program directors)	<b>16 faculty</b> who: <ul style="list-style-type: none"><li>• Never, rarely, or only occasionally participate in UR</li><li>• No longer do research with students</li><li>• Are taking “time out” from research with students</li></ul>
<b>Total = 80</b>		

**Total faculty and student sample = 368 interviews**

**This analysis: 76 student interviews + 80 faculty interviews  
=156 interviews**

# Qualitative Research Methods Used

- *Transcription*: verbatim (unedited), confidential, trained transcribers, quality control
- *Data entry and manipulation*: The Ethnograph (use N'Vivo for some studies)
- *Coding*: on line-numbered transcripts (paper or screen). Codes are labels. They reference particular observations by the coder. Code definitions are entered into a code book which represents the analysis at any point.
- *Thematic grouping of codes*: (collecting similar types of codes together) to build a conceptual tree of related ideas, including explanations
- *Frequencies* of codes or code groups run
- *Reading similarly grouped segments* to check emergent themes, labeling, explanations, variations, subtleties
- Use of *verbatim quotations* to illustrate concepts.

# A Metaphor for Thematic coding



Taking necklaces (single files) apart to sort beads (coded elements) into patterns by their color, shape, size, and frequency, whether common or rare





The intention is to generate hypotheses rather than to test them

Findings help determine nature, range and relative weighting of the issues.

Findings are descriptive. They are not subjected to tests of statistical significance.

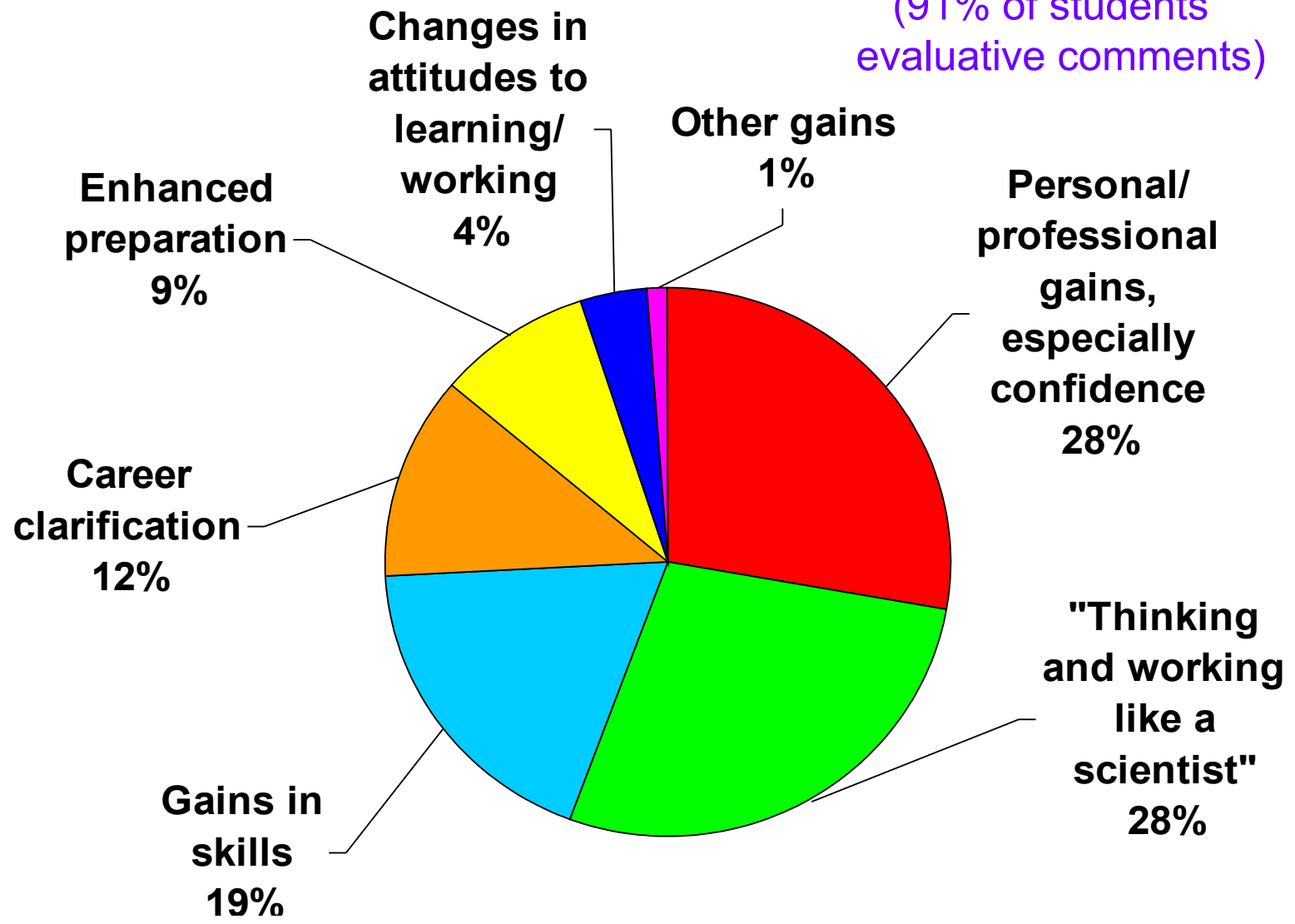
**Benefits of Participating  
in Undergraduate  
Research in Science:  
A Comparative Analysis of  
Student And Faculty Perceptions**

Seymour, E., Hunter, A-B, Laursen, S., and 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

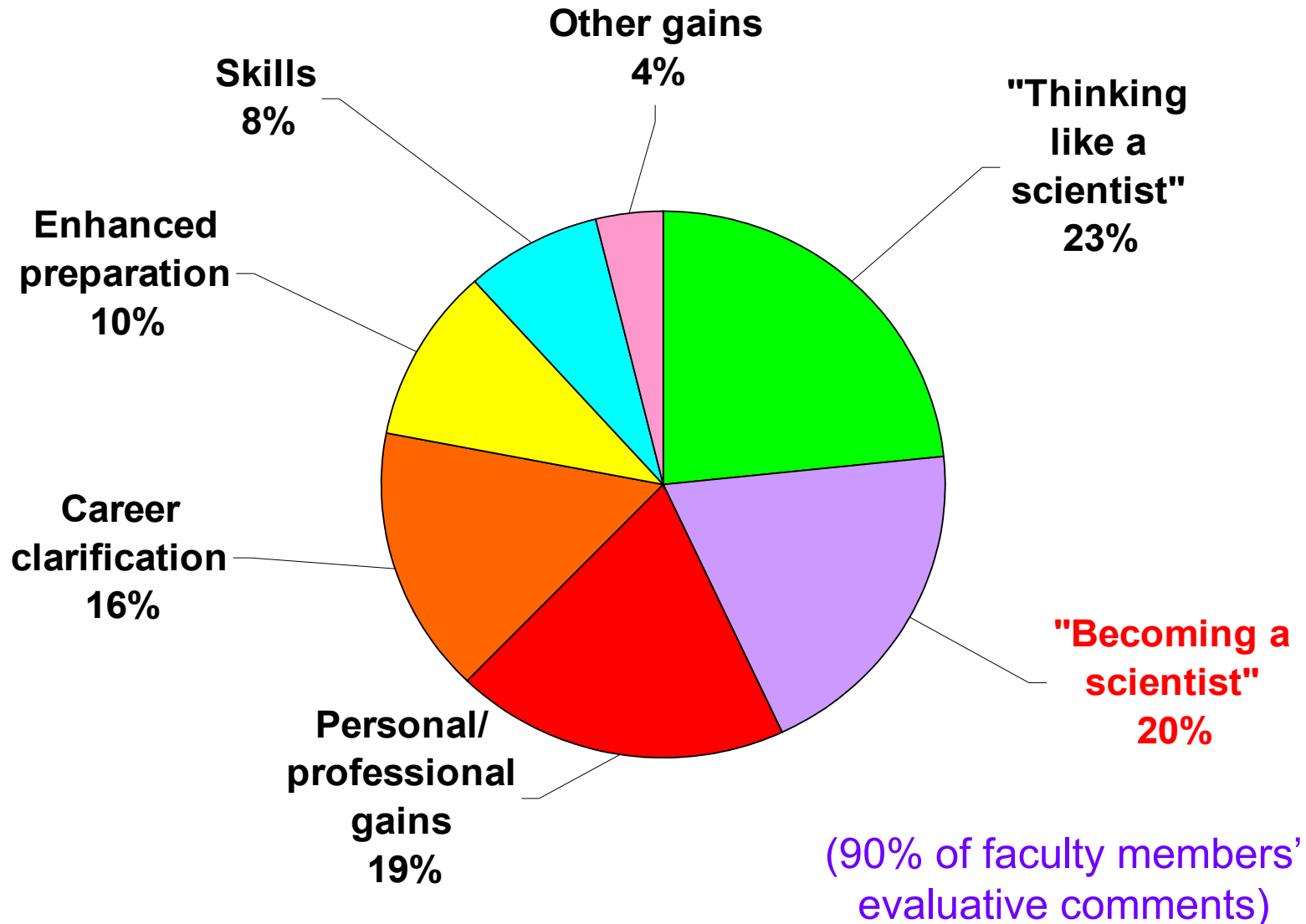
Hunter, A-B., Laursen, S., and Seymour, E. (2006) “Becoming a scientist:” The role of undergraduate research in students’ cognitive, personal, and professional development. (2006) Science Education, Forthcoming

# Students' Positive Observations on Gains from UR (N=1122)

(91% of students' evaluative comments)



## Faculty's Positive Observations on Student Gains From UR (N=2243)



# “Becoming a scientist”

**Faculty advisors** provided insight into how UR supports process of “becoming a scientist” — professional socialization into the role of scientist.

**They note when students:**

**Demonstrate an understanding of:**

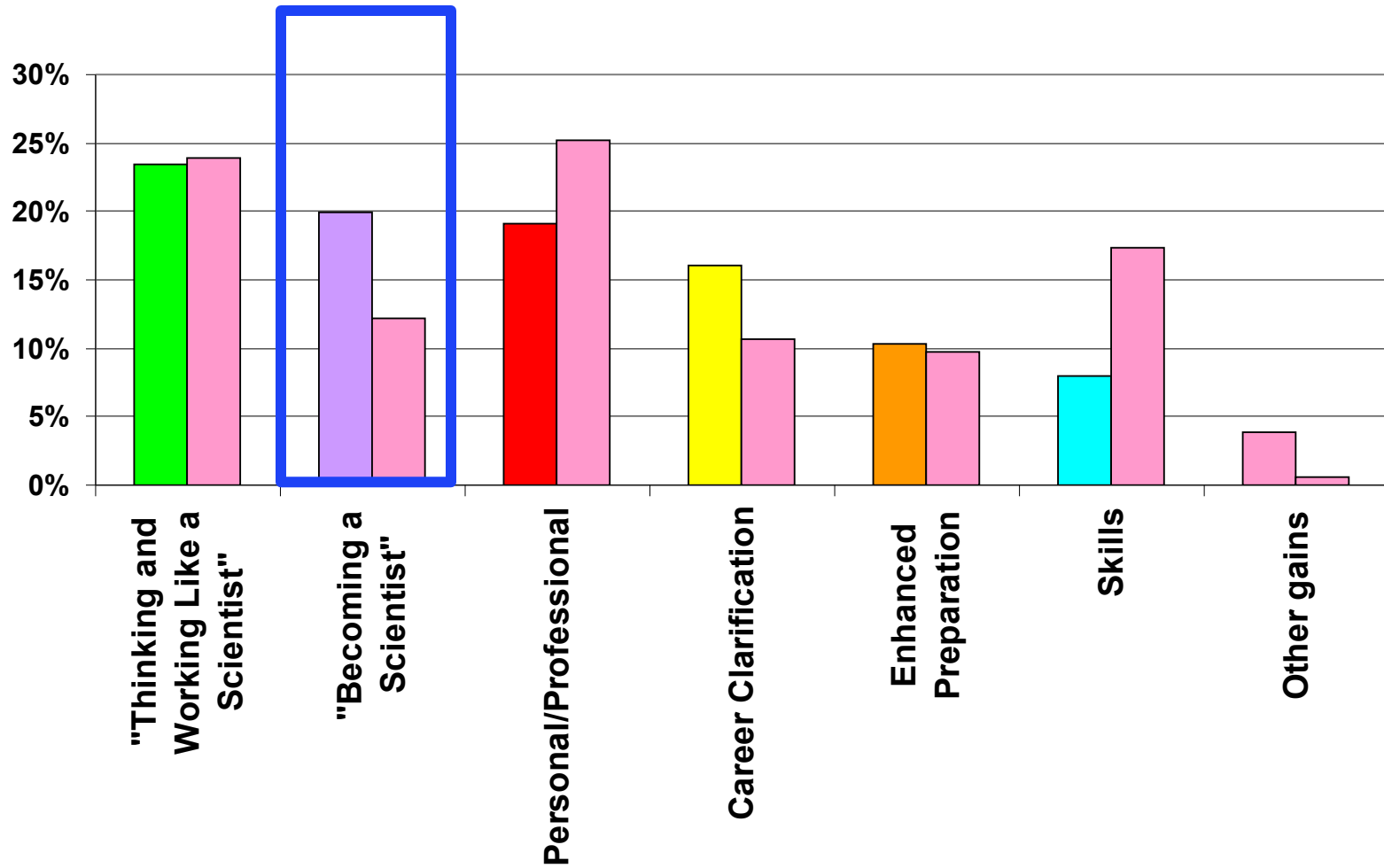
- the nature of research work
- how scientists practice their profession

**Demonstrate the attitudes, behavior, and temperament needed to be effective researchers**

**Begin to develop an identification with the profession (students describe this as “feeling like a scientist”)**

**Students do not frame these benefits in the same way as faculty, nor ascribe the same significance to them, but they *do* report the same elements.**

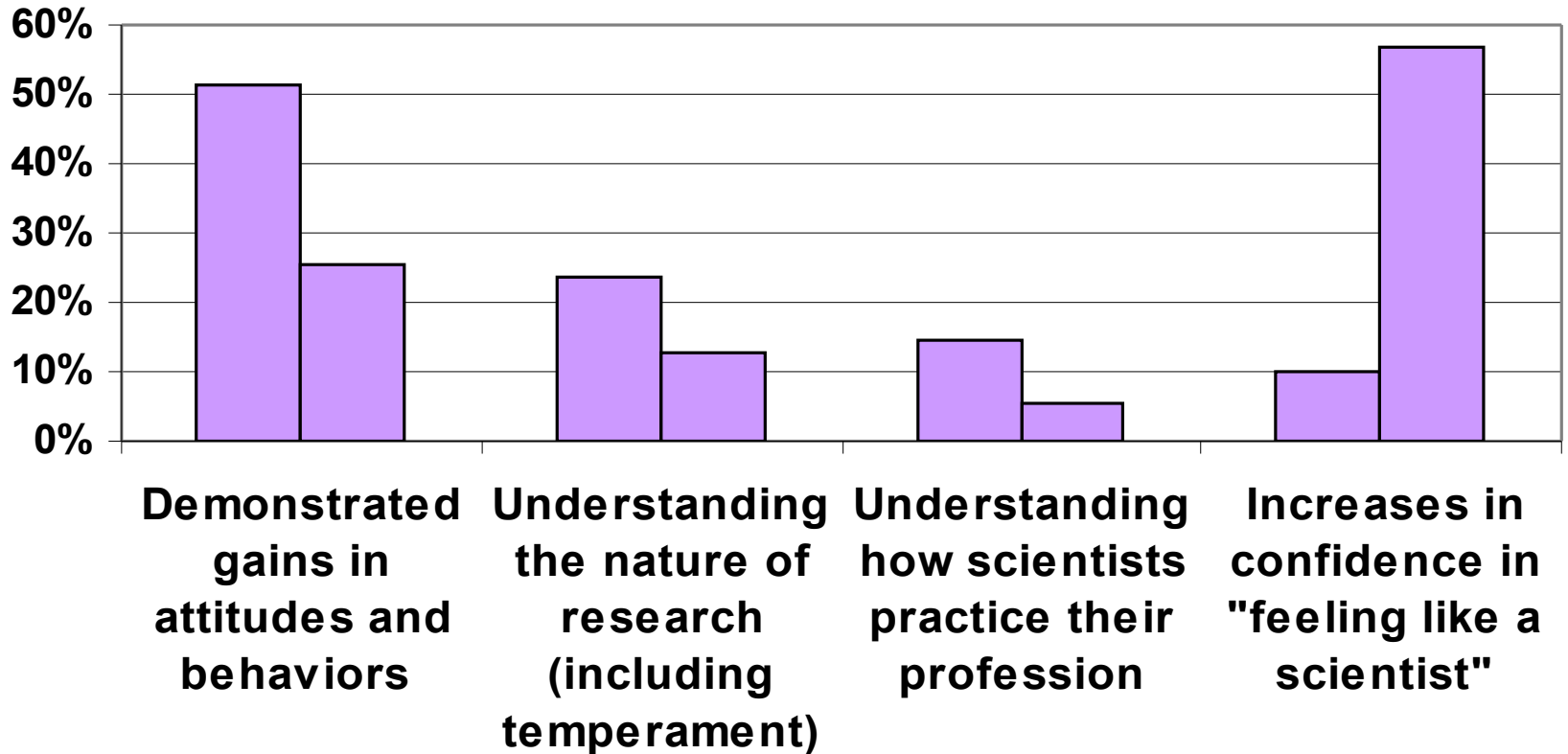
# Comparison of Faculty and Student Positive Observations on Gains from UR



■ Faculty observed gains (n=2243)

■ Student observed gains (n=1230)

**Table 2**  
**“Becoming a scientist”**



■ Faculty observed gains (n=450)

■ Student observed gains (n=150)



# “Becoming a scientist”

## ***Demonstrated gains in attitudes and attributes***

### **Faculty observation: Taking “Ownership” of the project/intellectual engagement:**

“What I look for, and to me, the mark of success in this kind of endeavor is ownership....It’s fun to see....There’s some transformation that occurs, where it suddenly becomes *their* project. And you see that.”

### **Student observation: Greater intellectual engagement/thinking and working independently:**

“Just being able to sit down and concentrate on one thing and figure it out and understand.... We work with protein-DNA interactions. And so just for me to look at that and really, really understand it rather than just getting the big overview. And then, actually thinking about the problem critically and creatively and being, ‘Okay. Now what can I change to have this effect and to have this outcome?’ That’s a whole new experience for me.”

# “Becoming a scientist”

***Understanding the nature of science/that research requires particular temperament***

## **Faculty observation:**

“I think they learn that science is really boring (laughs). And that’s the key. If they can know that science is boring and still do it, and still stick with it, then they have the makings of a really good scientist.”

## **Student observation:**

“You can’t get too emotionally distraught over something... I have a tendency, especially when it’s my own dumb mistake that’s caused me to lose several hours of work.... You have to just step back and deal with the facts as they are and say, “Okay. I’ve messed up. I need to correct this. It’ll take a few hours, but then we’ll move on.”

# “Becoming a scientist”

## ***Initial identification with the profession***

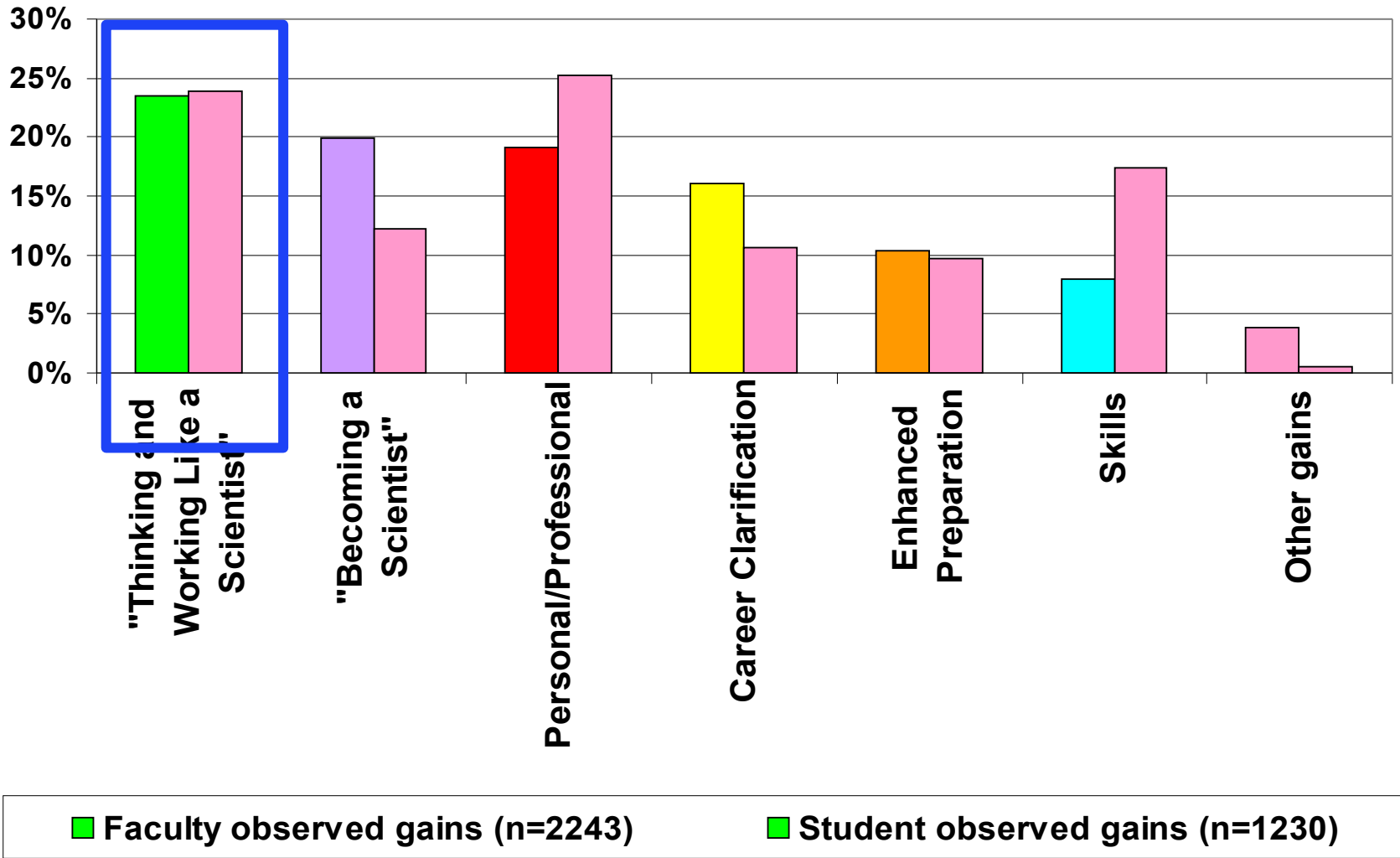
### **Faculty observation:**

“The number one thing I see, and the thing they perhaps talk about the most, is self-confidence....To be able to get into the laboratory, posing some questions, using sophisticated techniques to try and address, or answer those questions. Being able to interpret what the results are of their work. That they did it....They feel so good about it.”

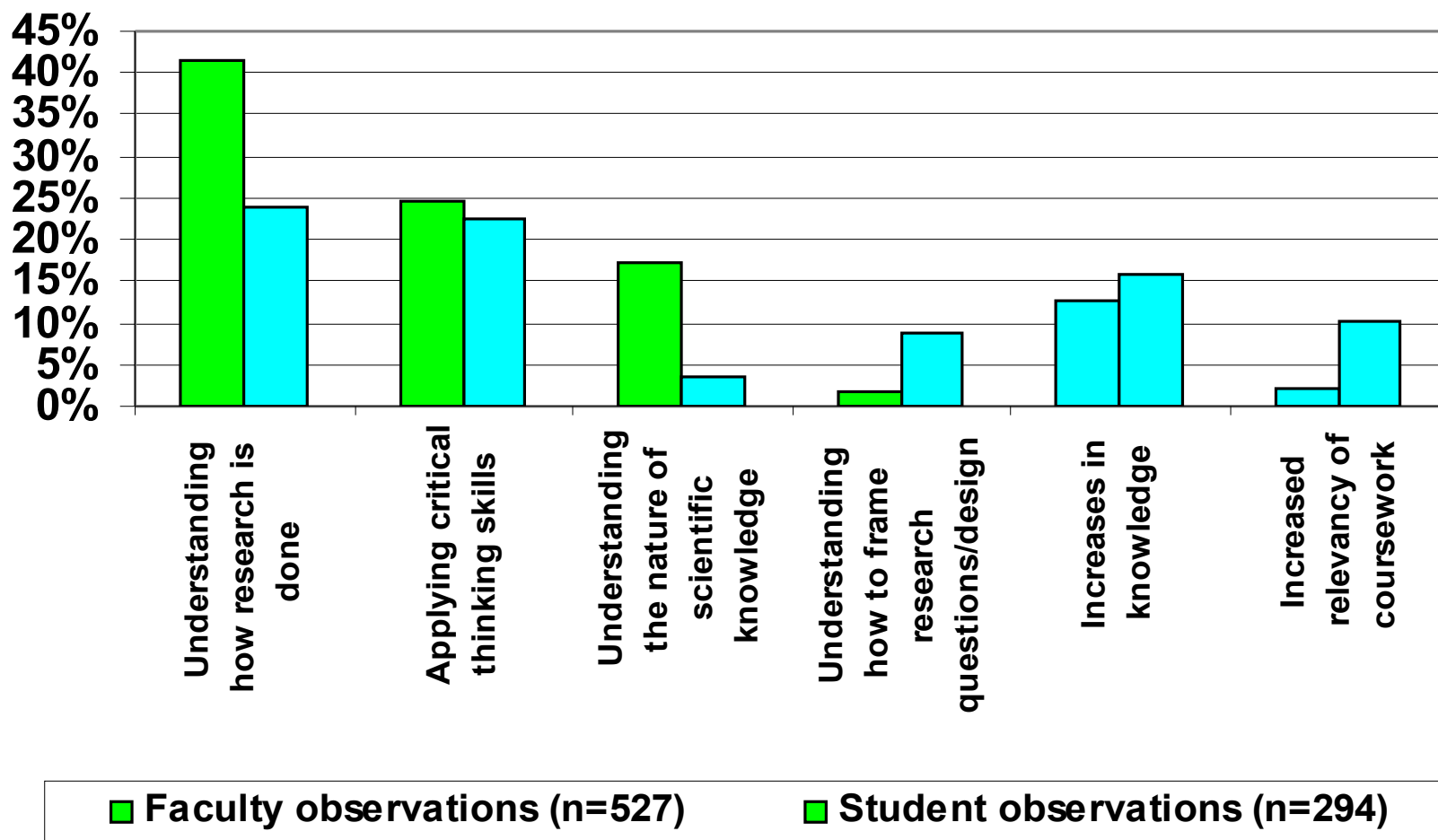
### **Student observation:**

“The summer’s research was sort of the first step in becoming a true biologist. The nature of the research is such that there are long periods of waiting before we can obtain data. And so some days were particularly trying, but as a whole, I look back on it fondly. I feel like I’m really learning what it’s like to be a scientist.”

# Comparison of Faculty and Student Positive Observations on Gains from UR



**Table 3**  
**“Thinking and Working Like a Scientist”**



# “Thinking and Working Like a Scientist”

Faculty emphasize more than do students their gains in:

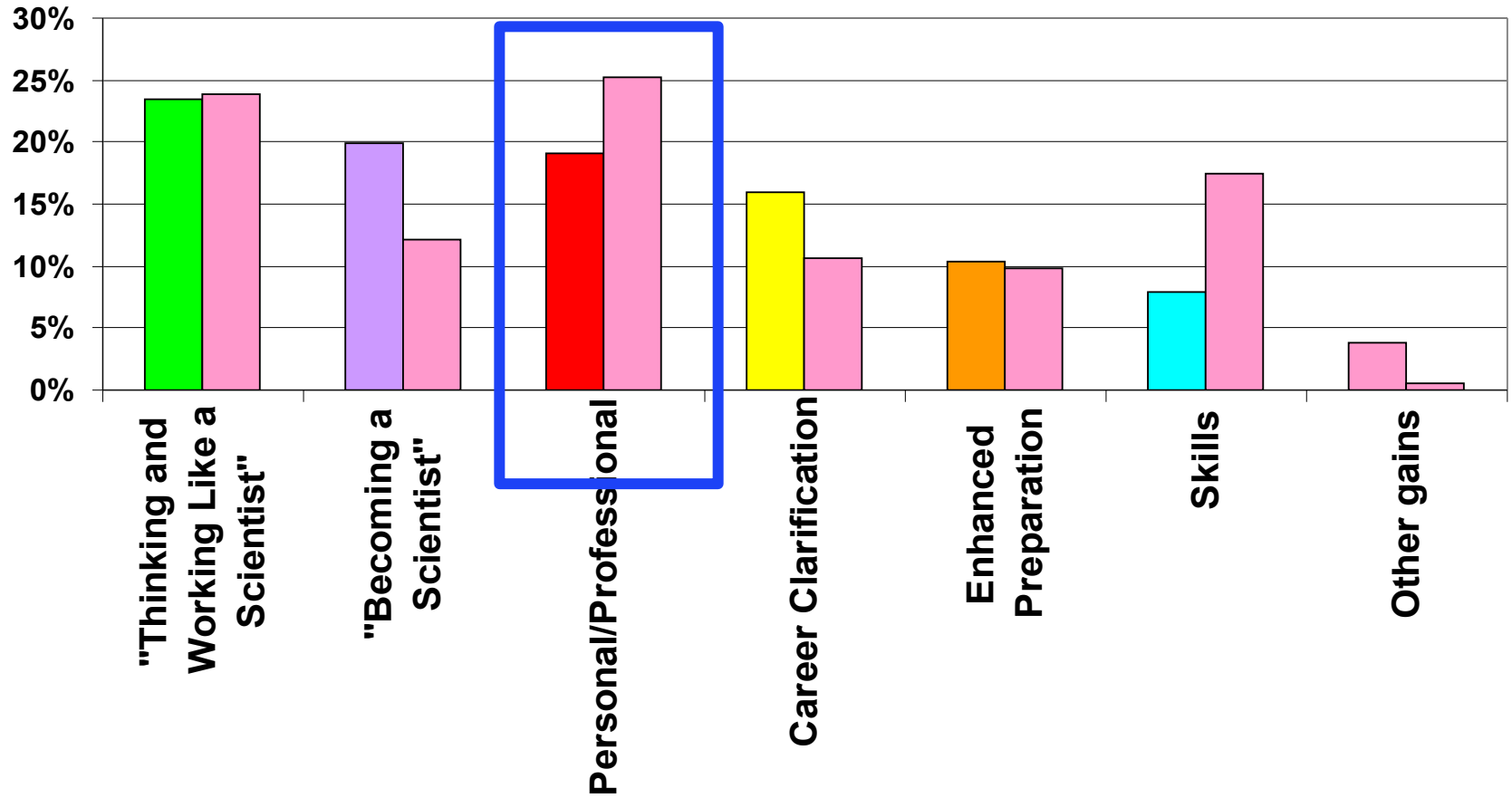
- understanding science research
- understanding the nature of science

Students emphasize more than faculty gains in:

- Increases in their knowledge
- Appreciating the relevancy of their coursework

Student claims in gaining increased understanding of how to frame research questions/develop research design are NOT matched by faculty observations of student gains in this area

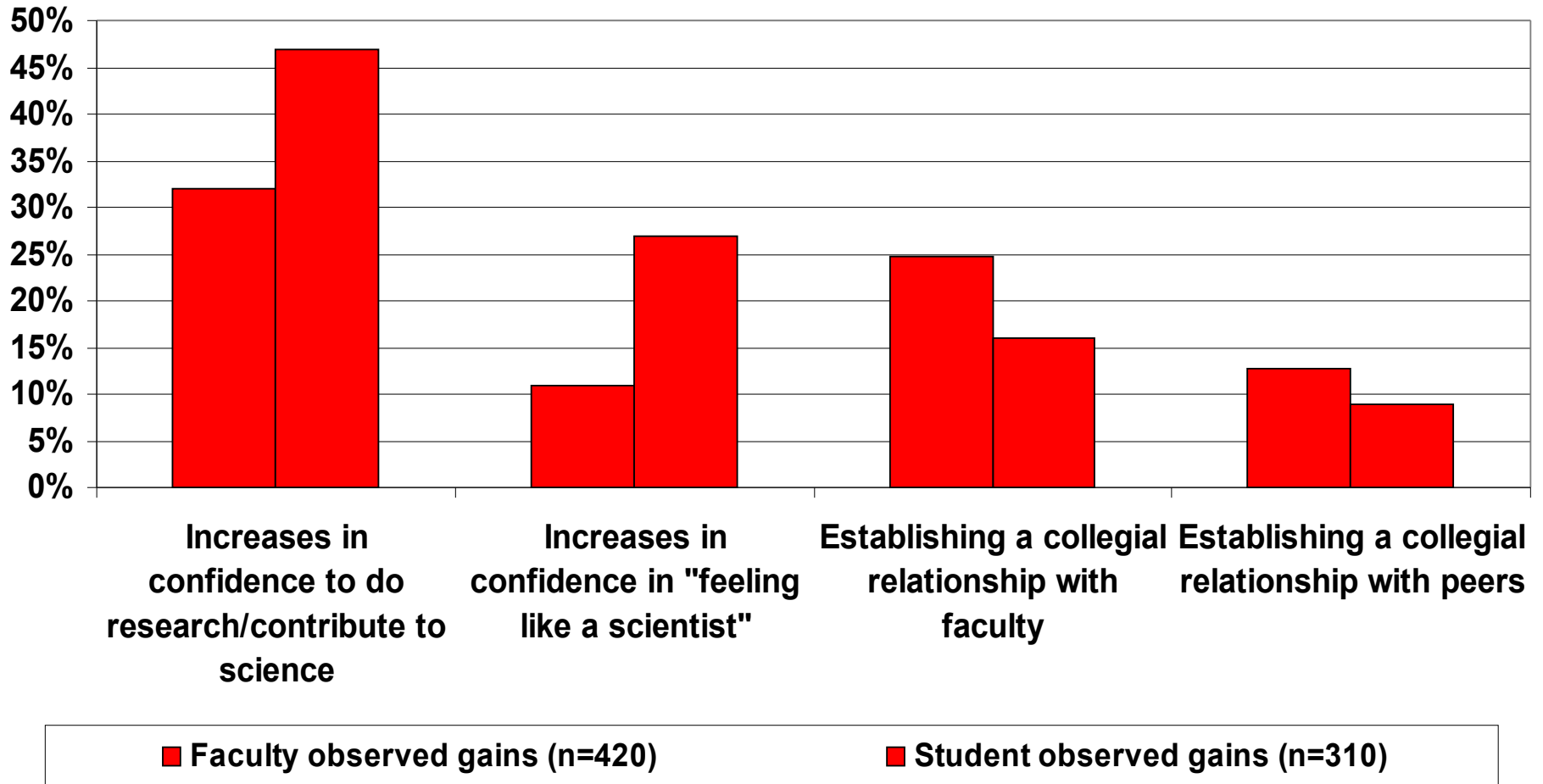
# Comparison of Faculty and Student Positive Observations on Gains from UR



■ Faculty observed gains (n=2243)

■ Student observed gains (n=1230)

**Table 4**  
**Personal-professional Gains**





# Personal-professional gains

## *Gains in confidence to do science*

### **Faculty observation:**

“You can see it a mile away. When they approach a new piece of equipment, it’s more, “Well, where’s the manual?” (Laughs) “Don’t waste my time teaching me this. Just tell me how to turn it on and I’ll figure it out.”  
Self-confidence, maturity.”

### **Student observation:**

“At the beginning, I asked a lot of questions to get a good basis and a good idea when I didn’t really know what I was doing. But by the end of the summer, I didn’t speak to my advisor much, because I would just do it.”

# Summary:

## Personal-professional gains

Students emphasize more than faculty gains in confidence:

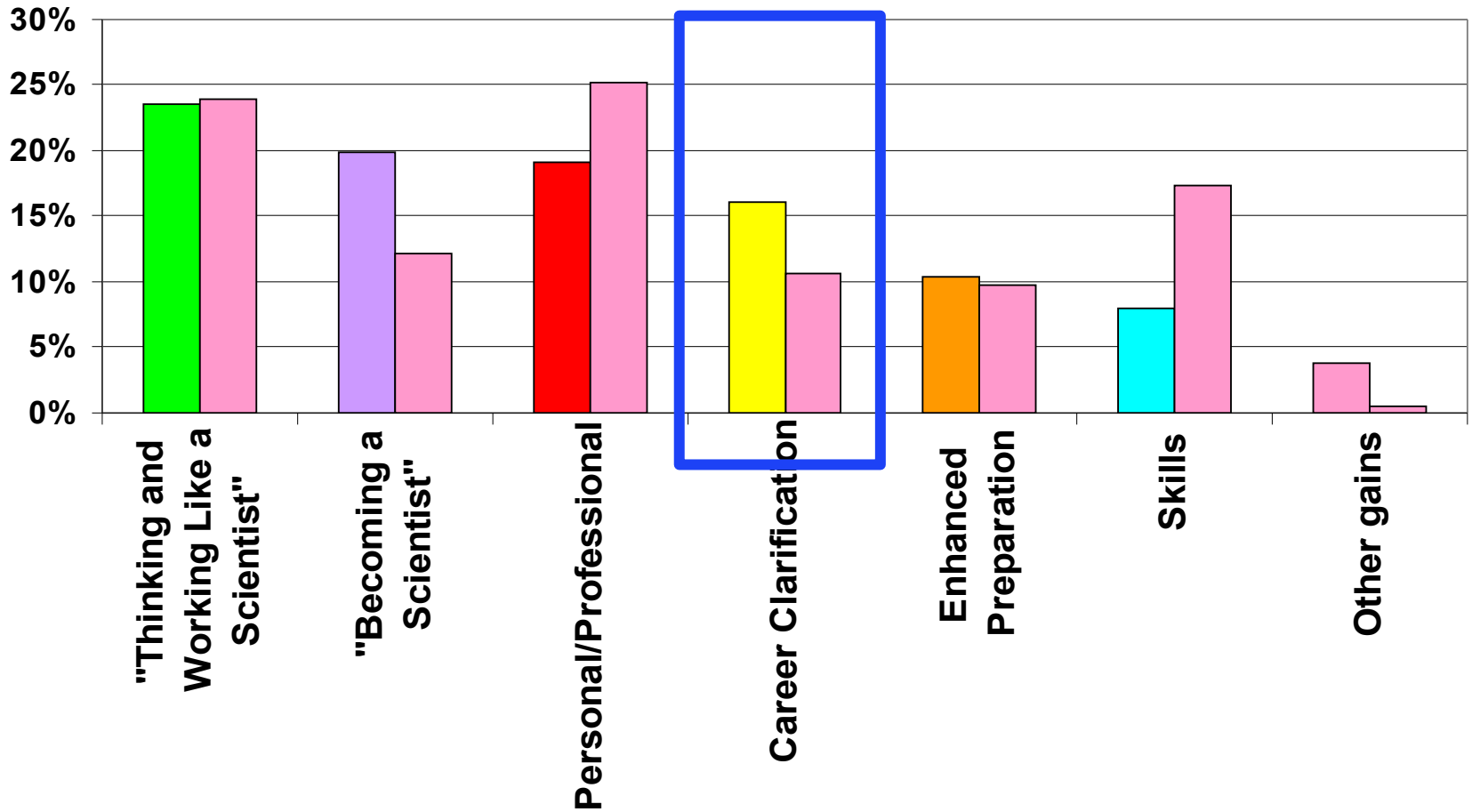
- to do research
- to contribute to science
- in “feeling like a scientist”

Students experience the force of these affective gains for themselves

Faculty emphasize more than students gains in establishing a collegial relationship

Faculty have longer-term evidence of the importance of these relationships (for themselves and for their students)

# Comparison of Faculty and Student Positive Observations on Gains from UR

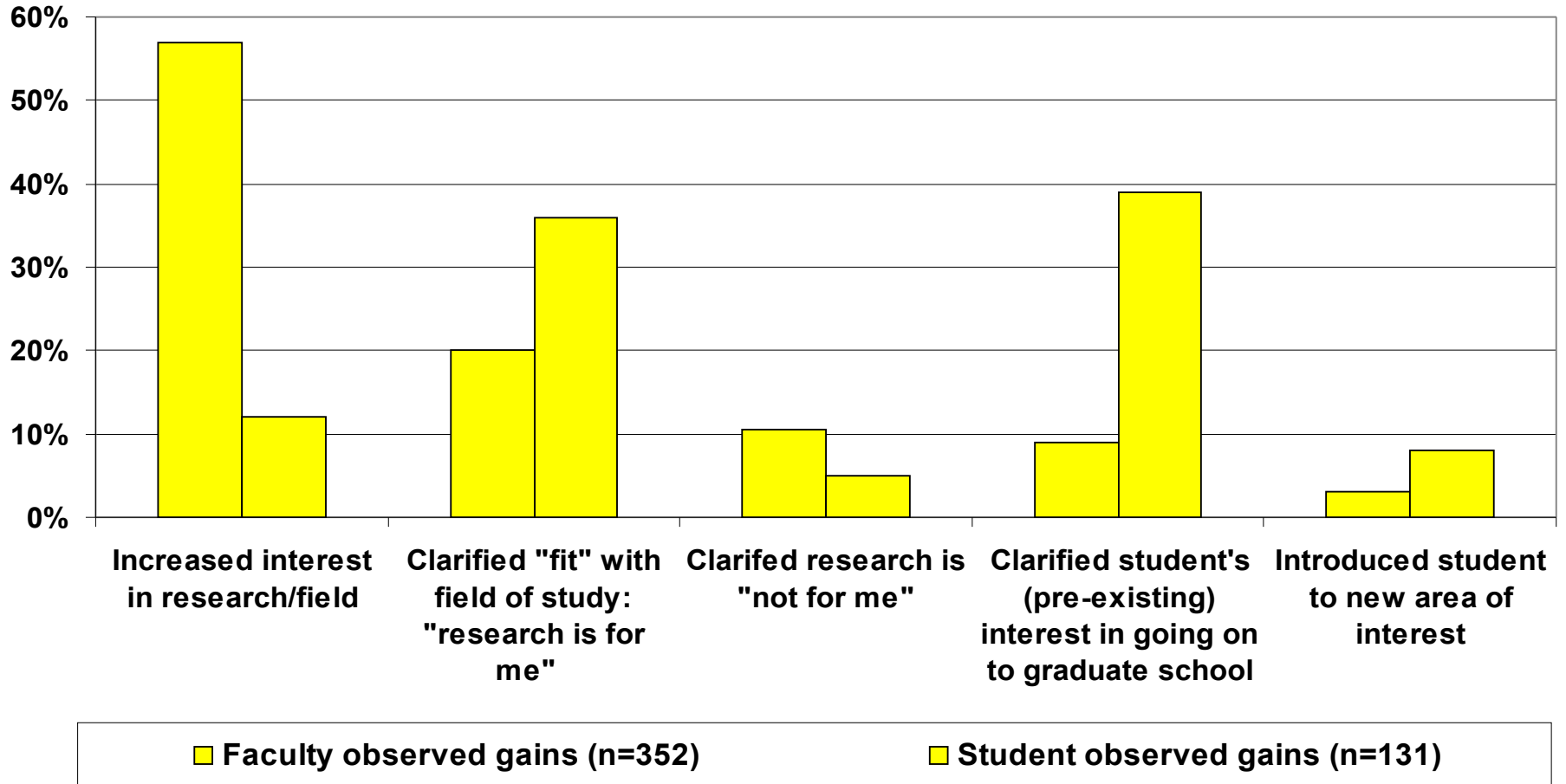


■ Faculty observed gains (n=2243)

■ Student observed gains (n=1230)

# Table 5

## Clarification/confirmation of Career/Graduate School Intentions



# Clarification/Confirmation of Career/Graduate School Intentions

## Faculty observation:

“It’s certainly nice to see them learn over the course of the summer, to see them doing more thinking for themselves, more autonomy, making good choices, making good decisions. It’s nice to see them gain confidence in their role as research collaborators. It’s nice to see them get to a point where they clarify what they do and don’t want to do, because that really *does* often happen. ...It’s nice to see them clarify, ‘Yeah, that was interesting, but it’s not my cup of tea,’ or, ‘Oh, I loved it and this is what I want to do!’”

## Student observation:

“I’ve always been thinking and wanting to go to grad school, ever since I can remember, wanting to get a doctorate, but I actually truly decided, it was this summer when I said, ‘Yes, I’m going to go to grad school. It’s what I want to do.’”

## **Clarification/Confirmation of Career/Graduate School Intentions**

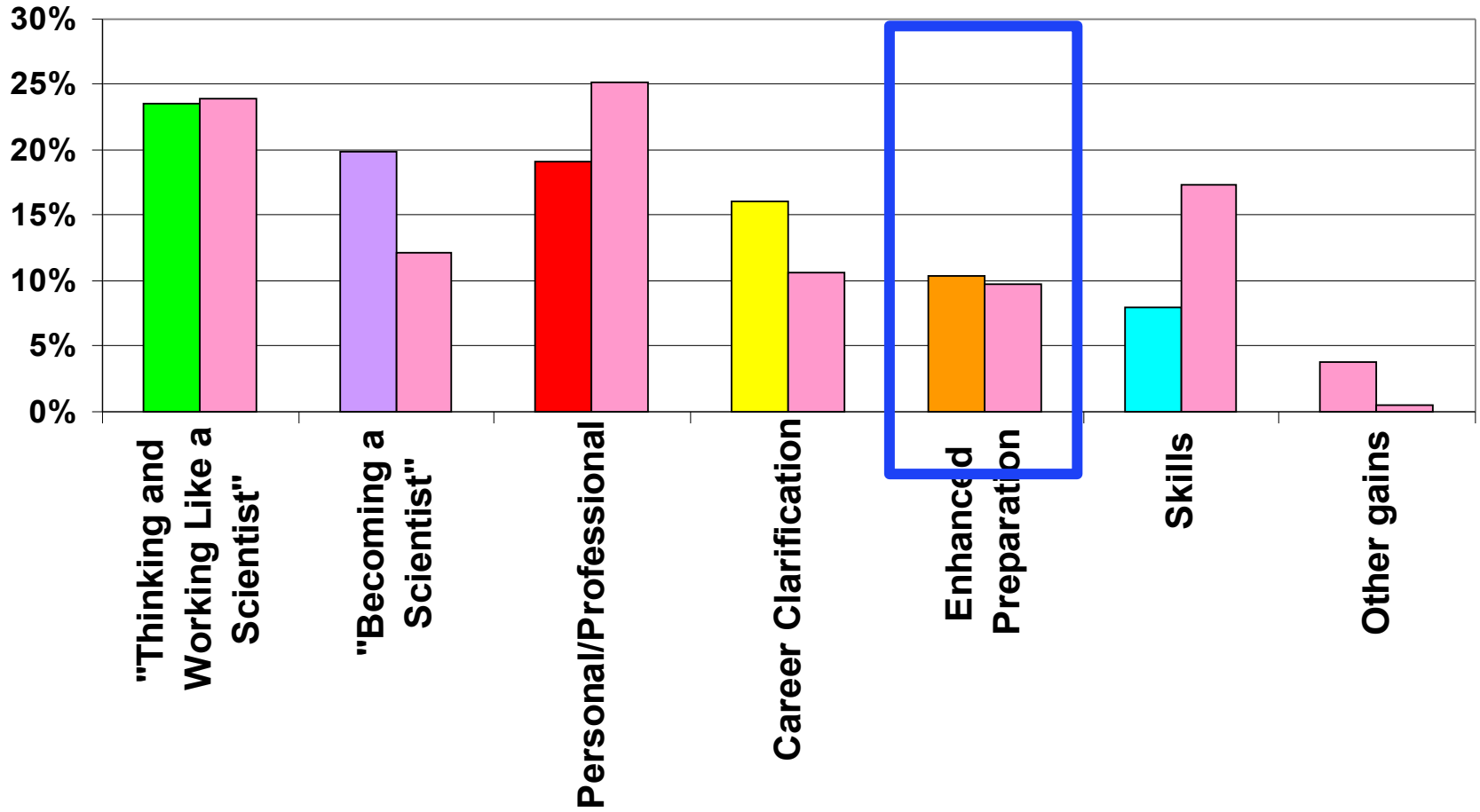
### **Students emphasize gains in:**

- Assessing “fit” between interests and field of study “research is for me”
- Clarifying, refining and confirming previous career/graduate school intentions

### **Faculty emphasize student gains in:**

- Increased interest

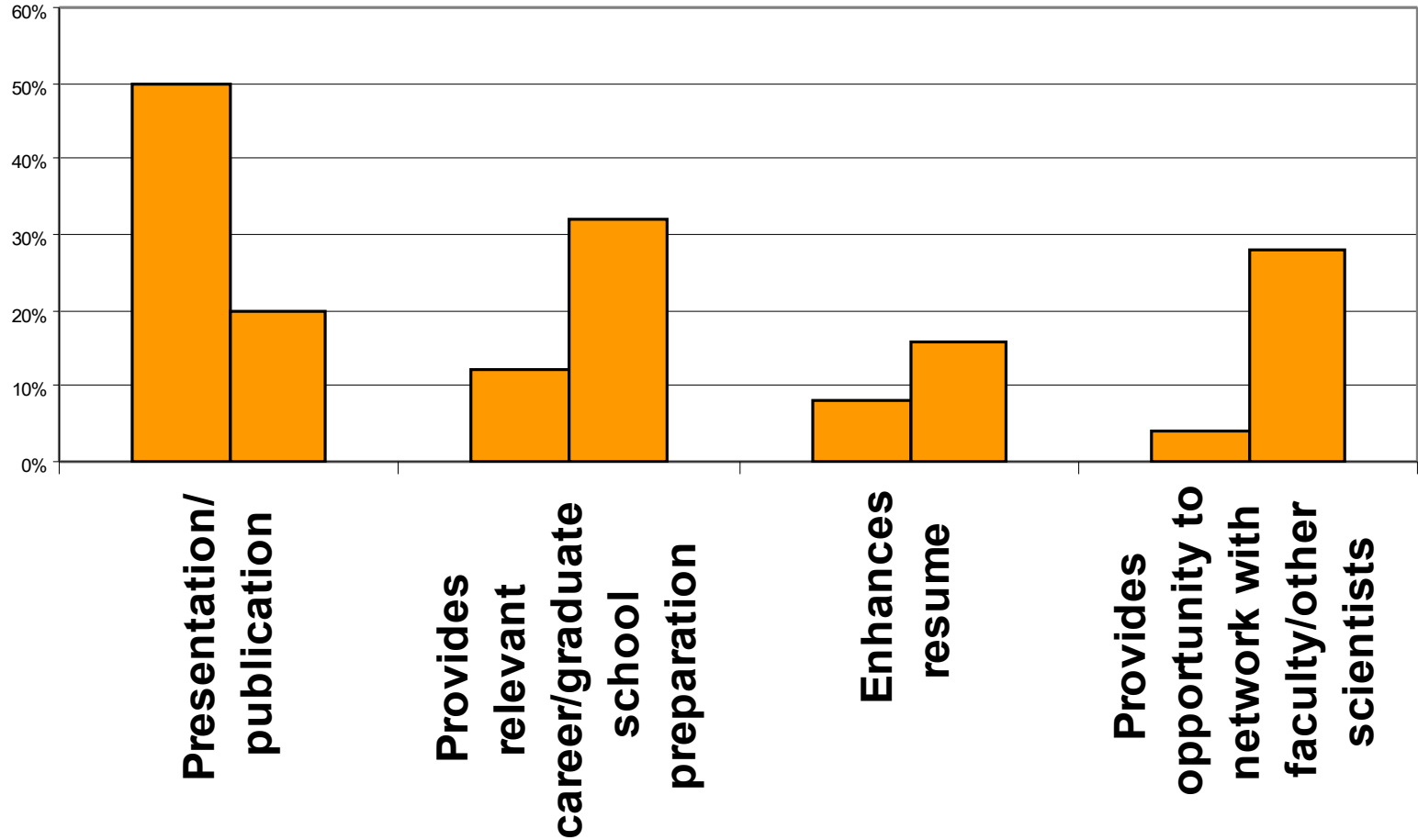
# Comparison of Faculty and Student Positive Observations on Gains from UR



■ Faculty observed gains (n=2243)      ■ Student observed gains (n=1230)

**Table 6**

**Enhanced Career/Graduate School Preparation**



■ Faculty observed gains (n=228)

■ Student observed gains (n=120)



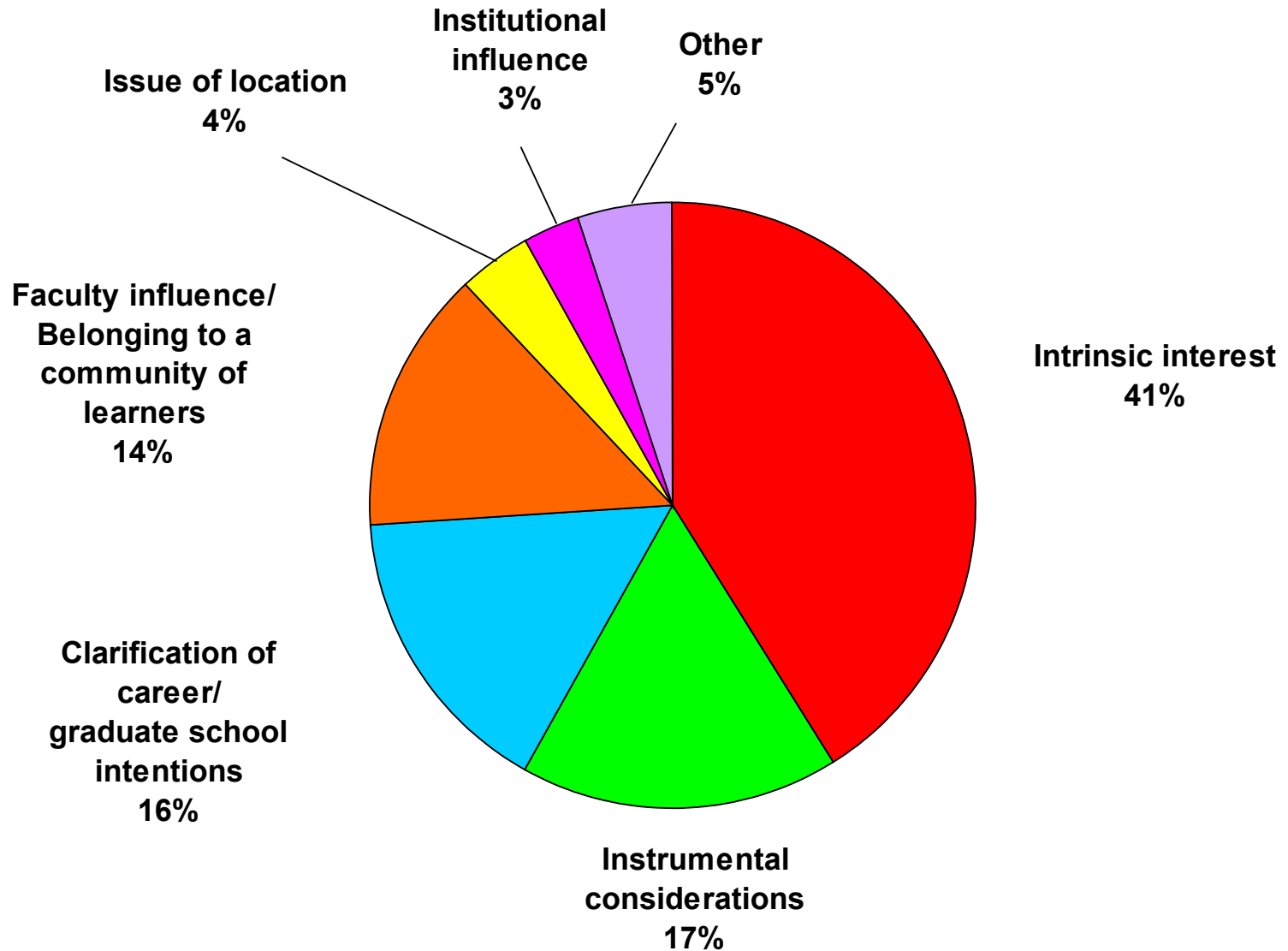
# Enhanced Career/Graduate School Preparation

The larger number of student comments for all types of observations highlights students position as graduating seniors and their preoccupation with “what comes next”

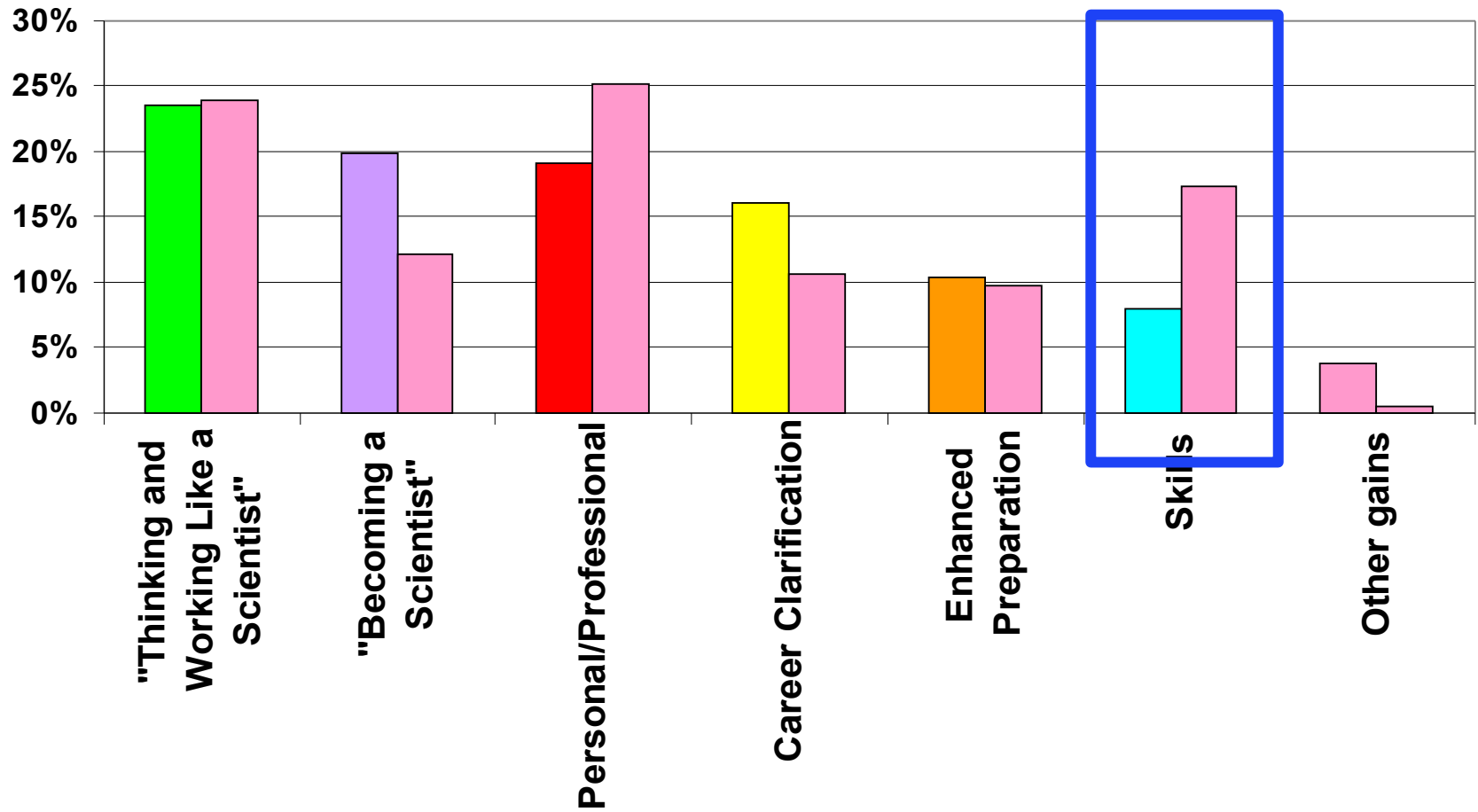
Faculty comments highlight the importance of UR to their own careers: “bean counting” numbers of students, articles, presentations, etc.

In a separate analysis of reasons why students undertook UR experiences, we confirmed that intrinsic interest rather than resume building was the dominant motivation.

# Student Motivations for Doing Undergraduate Research (N = 236)



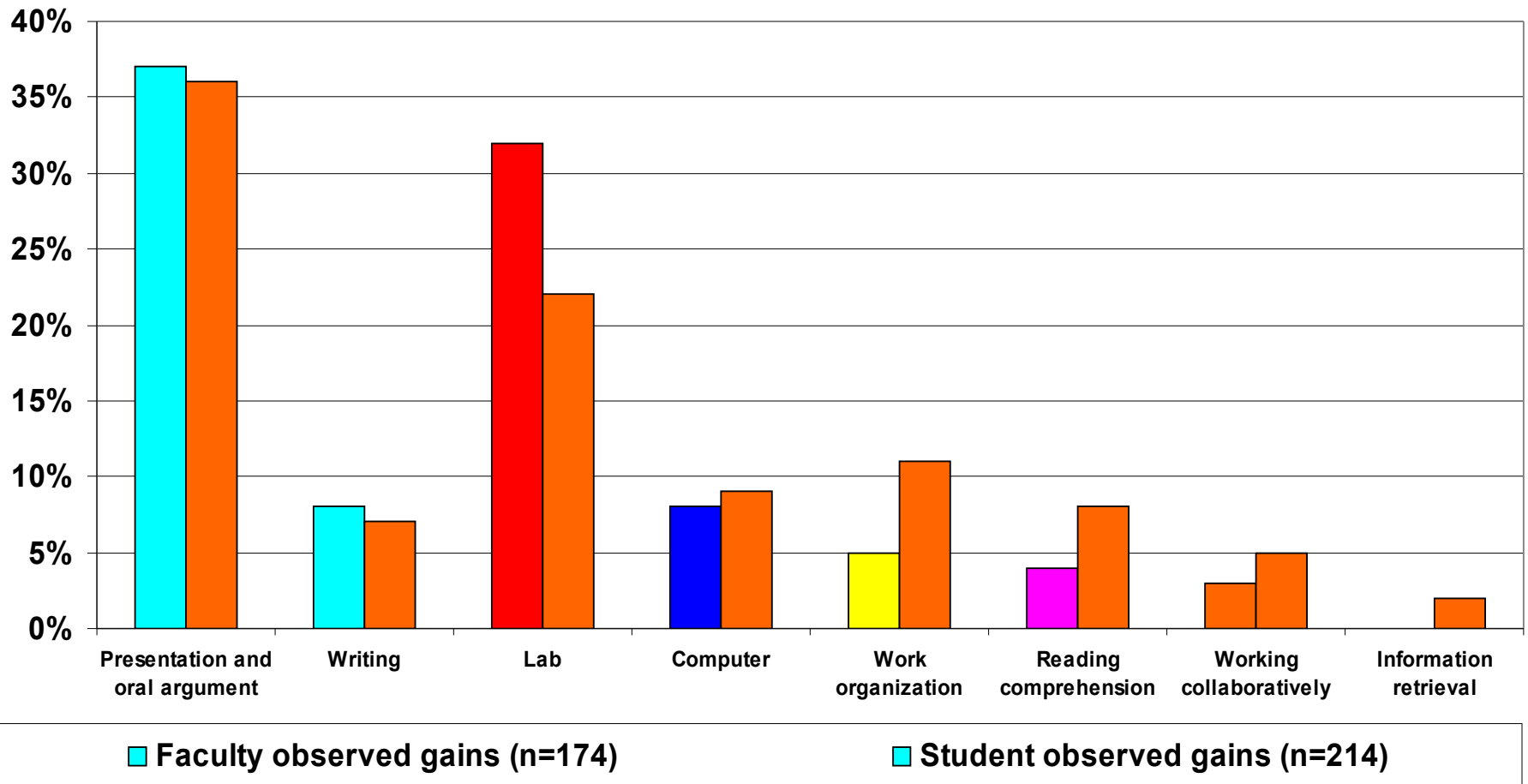
# Comparison of Faculty and Student Positive Observations on UR Gains



■ Faculty observed gains (n=2243)

■ Student observed gains (n=1230)

**Table 7**  
**Skills**



# Skills

## *Presentation skills*

### **Faculty observation:**

“We just watched students give presentations today.... One of them was a student I taught and, at the time I taught her, I couldn't have imagined that she would stand up and do the things she did today. The way they just become sort of professionals. I think for a lot of them, it's one of the first experiences they've had where they can walk into a room full of peers and really know more than everyone in the room about a certain topic and know it from experience, “This is how we do this. This is how this works.” And that's a big growth experience, I think.”

### **Student observation:**

“They give us lots of practice with presenting. And I'm really glad of that. I mean, I certainly have learned a lot better how to present.”

# Summary: Skills

Faculty and student observations are well aligned. Both agree greatest gains are in:

- Presentation skills
- Lab skills

Higher ranking of skills for students (3<sup>rd</sup>) than for faculty (6<sup>th</sup>) indicate their greater importance to students:

- Reflect the steep learning curve of UR: learning new instrumentation at the beginning; meeting the challenges of learning to present at the end
- Transferable to other areas in life and as important to future careers or graduate school

# Conclusions

**Different observations on the same types of gains reveals how each group sees and values the gains of undergraduate research differently**

Factors evident in students' observations:

- had just finished their 10-week UR experience: very intensive
- were about to start senior year, were uncertain/concerned about future plans
- as yet, do not recognize in themselves the development of professional traits that faculty see.

Factors evident in faculty members' observations:

- an encompassing view of student gains derived from long experience leading UR
- bring own perspective as educators and professional scientists (particularly noting gains in students seen as necessary if students are going to go on to replace the science profession)

- 1) **90% of faculty observations and 92% of student observations discuss gains**
- 2) **Students and faculty report observations on the same range of gains** (though observations are framed differently)
- 3) **High degree of agreement between faculty and student observations:** faculty and student data corroborate each other on the impact of gains and why
- 4) No evidence to suggest that undergraduate research plays a significant role in students' (at LACs) decisions to go to graduate school; rather, UR allows students to **confirm, refine or clarify pre-existing ideas/intentions** about careers and graduate school.
- 5) Taken together, "Thinking and Working like a Scientist," "Becoming a Scientist," and "Personal/Professional Gains," comprise 62% of all gains observations, both for faculty and for students: **strength of observations emphasize intellectual, personal and professional growth that students experience** in the process of learning science research hands-on and with the guidance of faculty.



# The Benefits and Costs of Faculty Engagement in Undergraduate Research

**Total Faculty sample (80 interviews) yielded  
5,509 codewords, 13,991 observations**

**Faculty “student gains” analysis:**

**689 codewords, 2243 observations**

**Benefits to faculty of UR: (Table 1)**

**210 codewords, 661 observations**

**Costs to faculty of UR: (Tables 2 & 3)**

**656 codewords, 1883 observations**

**“Processes” analysis:**

**~ 840 codewords, ~2150 observations  
(plus student data)**

# Overview of Table 1

## Faculty Descriptions of the Benefits Gained from Directing Research with Undergraduates

1. Faculty career gains attributed to their UR work. n=287 (43%)
3. Pleasures of working side-by-side with students as research colleagues. n=171 (26%)
5. Intellectual and professional growth (as a researcher or teacher) from UR engagement. n=83 (13%)
7. Satisfaction in signs that some students are “becoming scientists” n=65 (10%)
5. Satisfaction (for a wider range of students) of seeing them develop intellectually, in maturity, and skills, and in helping them find their place in the world. n=55 (8%)

# Overview of Table 2

## The Inherent Difficulties of Doing Authentic Research with Undergraduates at Liberal Arts Colleges

1. **Strains between education and faculty research objectives  
n=464 (34%)**
2. **Time and effort issues of research work with undergraduates  
n=161 (12%)**
3. **Problems of balancing UR work with other professional commitments and priorities, and with other aspects of life  
n=311 (23%)**
4. **Gender and family issues n=21 (2%)**
5. **Lowered research productivity and its consequences for faculty n=310 (23%)**
6. **Management issues n=49 (4%)**
7. **Resources for UR at LACs n=30 (2%)**

## **Table 2 Issues**

### **The Inherent Difficulties of Doing Authentic Research with Undergraduates at Liberal Arts Colleges**

#### **1. Strains between education and faculty research objectives. n=464 (34%)**

- **Statements of the problem (n=110)**
- **Finding authentic research projects to which undergraduates can make meaningful contributions is difficult; it also prompts compromises with faculty research agendas (n=175)**
- **Finding UR-appropriate projects is more difficult in some types of research, some disciplines, some disciplinary specialties (n=102)**
- **Because these UR projects are authentic, faculty cannot guarantee that students will have an experience that is both educational and produces good research results (n=125)**

## **Table 2 Issues (continued)**

- 1. Time and effort issues of research work with undergraduates. n=161 (12%)**
  - UR summer programs: time constraints and additional time demands (n=119)**
  - Time problems of UR during the academic year (n=42)**

## Table 2 Issues (continued)

### 3. **Problems of balancing UR work with other professional commitments and priorities, and with other aspects of life. n=311 (23%)**

- **UR creates a huge amount of work;**
- **the “teaching” aspects of UR often overwhelm the research;**
- **UR takes time away from other professional priorities;**
- **Negative impact on personal, family, social and vacation time;**
- **Heavy costs to families: summer UR is especially hard on mothers, although fathers are also torn between “their children and other people’s.”**
- **UR faculty never get any “time out”**

**Faculty reactions: Some drop out temporarily; some quit participating in UR permanently**

## **Table 2 Issues (continued)**

### **4. Gender and family issues. n=21 (2%)**

**(in addition to balance of work and life issues)**

- Persistence of male science work norms that mothers as super-efficient research time managers may still not overcome;**
- Encounter collegial prejudice; loss of status as “serious scientists” by having children;**
- Find few satisfactory role models;**
- Experience problems with some male students**

**Female undergraduate researchers comment on how their women UR advisors juggle work and family lives, and how male colleagues treat faculty with children. Their observations have a powerful effect in their own career thinking.**



## Table 2 Issues (continued)

- 5. Lowered research productivity and its consequences for faculty. n=310 (23%)**
- **High risk that faculty will not be as productive in their research with undergraduates as they would be otherwise (n=141)**
  - **Slow progress/under-productivity of doing research with undergraduates creates problems for younger faculty in achieving tenure and for senior faculty seeking promotion (n=74)**
  - **Lack of/loss of prestige among disciplinary colleagues (n=20)**

## **Table 2 Issues (continued)**

- 6. Management issues: faculty have little education in how to direct and manage UR. Flaws in project management makes a difficult task more difficult. n=49 (4%)**
- 7. Resources for UR are more limited and unreliable than at universities. n=30 (2%)**

# How do we explain these findings?

Recap:

**STEM LAC faculty have traditionally balanced UR's educational experiences in ways that are intended to offer:**

- **Educational and professional preparation to those who are interested in becoming scientists**
- **A good science education for others**
- **An opportunity for prospective scientists to clarify their career choices in light of authentic experiences of research and professional life.**

**Where faculty place their emphasis on this spectrum of objectives has been a matter for individual or departmental choice.**

# Balancing Research and Education

- Undergraduate assistance has been necessary to LAC faculty to be **productive as researchers**.
- UR is also critical to the educational and professional **preparation and placement of young scientists**. Central to this objective are:
  - The authenticity of the research
  - Limiting students' choice of projects
- Faculty also embrace idea of providing a good **science education for a wider group**.
  - Must balance this with their need for research productivity and their responsibility to prepare the next generation of scientists.

## **A Changing Situation**

### **STEM faculty who have always undertaken UR:**

- **As an expected part of their job**
- **To meet their own research needs**
- **As a responsibility to their students, their profession, science, their colleagues, departments, and institutions**
- **As their contribution to increasing both the numbers of scientists, and science access for under-represented groups**
- **Out of a strong belief in UR's educational benefits**
- **Because they enjoy its intrinsic pleasures**

### **. . . Are increasingly faced with demands:**

- **that they cater to larger numbers of students--perhaps beyond their collective capacity to meet these**
- **that they dilute (in their view) the duration and quality of the UR experience to make it available to more students**

# Faculty Stresses and Imperatives

UR faculty **experience** these growing demands as:

- competing obligations
- overload
- as a shift from voluntary professional practice to formal institutional expectations.

They also feel **strong moral obligations** that keep them trying to meet growing demands out of their time and effort.

## Faculty express a sense of duty:

- to their students: both their science education and their placement in the world
- to provide a valid science education to young scientists and to students more broadly
- to be a productive researcher and contribute to their field
- to their college, department and colleagues to do their job properly, pull their weight
- to their discipline/science at large to nurture, prepare and introduce promising young scientists to the profession

Moral commitment to their UR work makes it difficult for STEM faculty to say “No” to increasing demands that touch on any of these felt imperatives.

# Is UR a Voluntary or Compensated Professional Activity?

- The implied understanding that UR is a voluntary professional activity may be implicitly questioned by increasing demands from departments, institutions, funders, or students.
- This raises for STEM faculty (perhaps for the first time) issues of compensation and work credits; comparisons with work loads and expectations of non-STEM faculty



# Other Pressures on Faculty

- Expectations for tenure and promotion productivity and for **bringing in outside grants** appear to be increasing.
- The **tenure process** itself has become more strongly **codified**
- Extending the scope of UR increases pressures on **pre-tenure faculty**
- **Balance of life** issues (professional, social, personal) are raised especially for faculty with children.

There is less tolerance of these strains than in the past among younger men as well as women: partly the impact of the feminist movement.

## Consequences of these strains

**The intersection of changing expectations of STEM faculty with externally-imposed definitions of the objectives of UR programs**

- conflicts with faculty's own understanding of their own UR objectives,**
- strains their sense of moral obligation and**
- undermines their intrinsic pleasure in UR work**

**These are evident in our data, especially in one LAC where an institutional effort was underway to give all students a short (5 week) summer experience that combined some hands-on work with professional development (e.g., building scientific writing and presentation skills).**

## Table 3

### A Case-Study of **Added Stresses and Costs when Institutions Seek to Widen UR's Scope**

- **Strains between institutionalization of UR and organic evolution of UR for scholarly research. n=128. (24%)**
- **Difficulties arise when institutions or departments require students to do UR. n=187 (35%)**
- **Problems of rewarding STEM faculty for their additional work as UR advisors. n=222 (41%)**

# Benefits vs Processes

Because of the current search for ways to offer elements of authentic research experiences to more students, researchers need to shift from outcomes to processes.

- What elements are essential and which are optional for a good UR recipe?
- How should they be offered?

One of our upcoming analyses, therefore, is in terms of the processes whereby good outcomes arise or are promoted.

(For preliminary analysis: see matrix in handout.)