Establishing the Value of Undergraduate Research: Engaging Students in Real Science

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Acknowledgments

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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

Defining Undergraduate Research: a Spectrum of Experiences

"Inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline"

Council on Undergraduate Research (CUR)

The apprenticeship model: Intensive, multi-week, authentic research experiences, involving student mentoring, and collaboration with faculty or other experienced researchers.

Common UR Types in the sciences:
Faculty-led and Structured Programs

Common features of both types

- A well-defined research project designated to the student or student team, connected to an ongoing effort in the research group, or an area of scholarly interest to the supervising researcher
- Multi-week immersion—often, full-time for ten weeks during the summer, and/or during the academic year
- Individual guidance from an experienced scientist.

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History of UR in USA

- 1940's-1970's: Grassroots growth of UR in the sciences, esp. in predominantly undergraduate institutions where UR is critical to faculty scholarship.
- 1980s: funding agencies & professional organizations began to recognize UR as important to faculty scholarship & as high-quality science education.
- 1st NSF & private foundation UR programs
- CUR and NCUR founded

- 1990s UR funded was stimulated by several national reports (notably Boyer Commission, 1998) citing UR as:
  - improving undergraduate science education,
  - moving students from didactic to inquiry-based learning, and
  - reducing the dichotomy between teaching and research.
- Increase in UR programs focused on recruiting and retaining students from groups that are under-represented in STEM disciplines

- 2000s: After decades of blind faith in the benefits of UR, researchers and evaluators have begun to:
  - identify its outcomes
  - assess their prevalence
  - examine how they come about

See handout for our categorization of work on student outcomes to date

This Study: Research Questions

- What gains do students make from doing UR - immediately following the experience, and in the longer term?
- Can gains be realized through other experiences, such as internships or classes?
- By what processes do these gains come about?
- How are gains assessed?
- How are career outcomes affected by UR participation?
- What are the lasting benefits of UR participation?
- What are the benefits and costs to faculty of doing UR?

A “best case” study of the apprenticeship UR model

4 liberal arts colleges: well-established UR summer programs (often departmental)

Disciplines: biology, chemistry, physics, math and CS, engineering, biochemistry, psychology

Comparative and Longitudinal student samples:

- all (76) rising seniors doing UR;
- comparative sample (63),

interviewed (1) end-of summer, (2) pre-graduation, and (3) two years later

3 Rounds of in-depth, semi-structured interviews

Individual, initially live, rounds 2 &3 by phone. (1-1.5 hours). Exploratory, conversational, with prompts and recap checks

Protocols drew upon published accounts, ending with gains checklist of “things faculty think students gain from UR”

Comparative Faculty Samples

UR Participants		Comparative Group
55 faculty with whom UR student participants were working	**9** UR administrators (including college presidents, deans, department chairs and REU and UR program directors	**16** faculty in same departments who: • Never, rarely, or only occasionally participate in UR • No longer do research with students • Are taking "time out" from research with students
Total = 80		

All live interviews 1.5-2.5 hours.
Total faculty and student sample = 368 interviews

Qualitative Research Methods

- *Transcription:* verbatim (unedited), confidential, trained transcribers, quality control
- *Data entry and manipulation*: QDA software (The Ethnograph; use N'Vivo for some studies)
- *Coding*: on line-numbered transcripts (paper or screen). Codes are labels. Codes reference particular observations by the coder. Code definitions entered into code book: 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 are generated
- *Reading similarly grouped segments* to check emergent themes, labeling, explanations, variations, subtleties
- Use of *verbatim quotations* to illustrate concepts.

The intention: to generate rather than test hypotheses

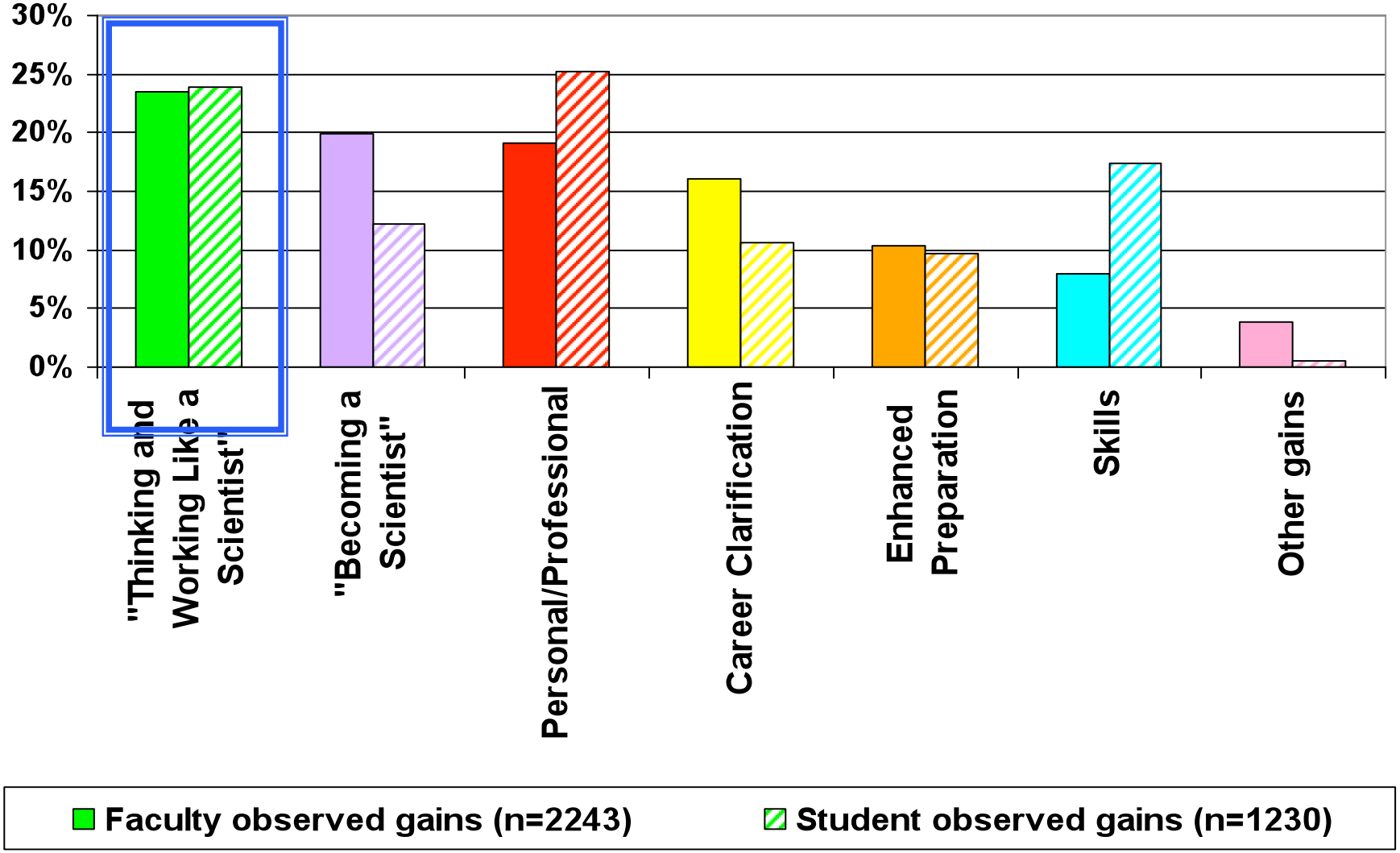
Findings in this study:

- indicate nature, range and relative weighting of issues; answer why and how questions.
- are descriptive (i.e., not subjected to tests of statistical significance).
- are strong, consistent across disciplines and study sites,
- show good triangulation between samples and over time (e.g., faculty & students, students & alumni).

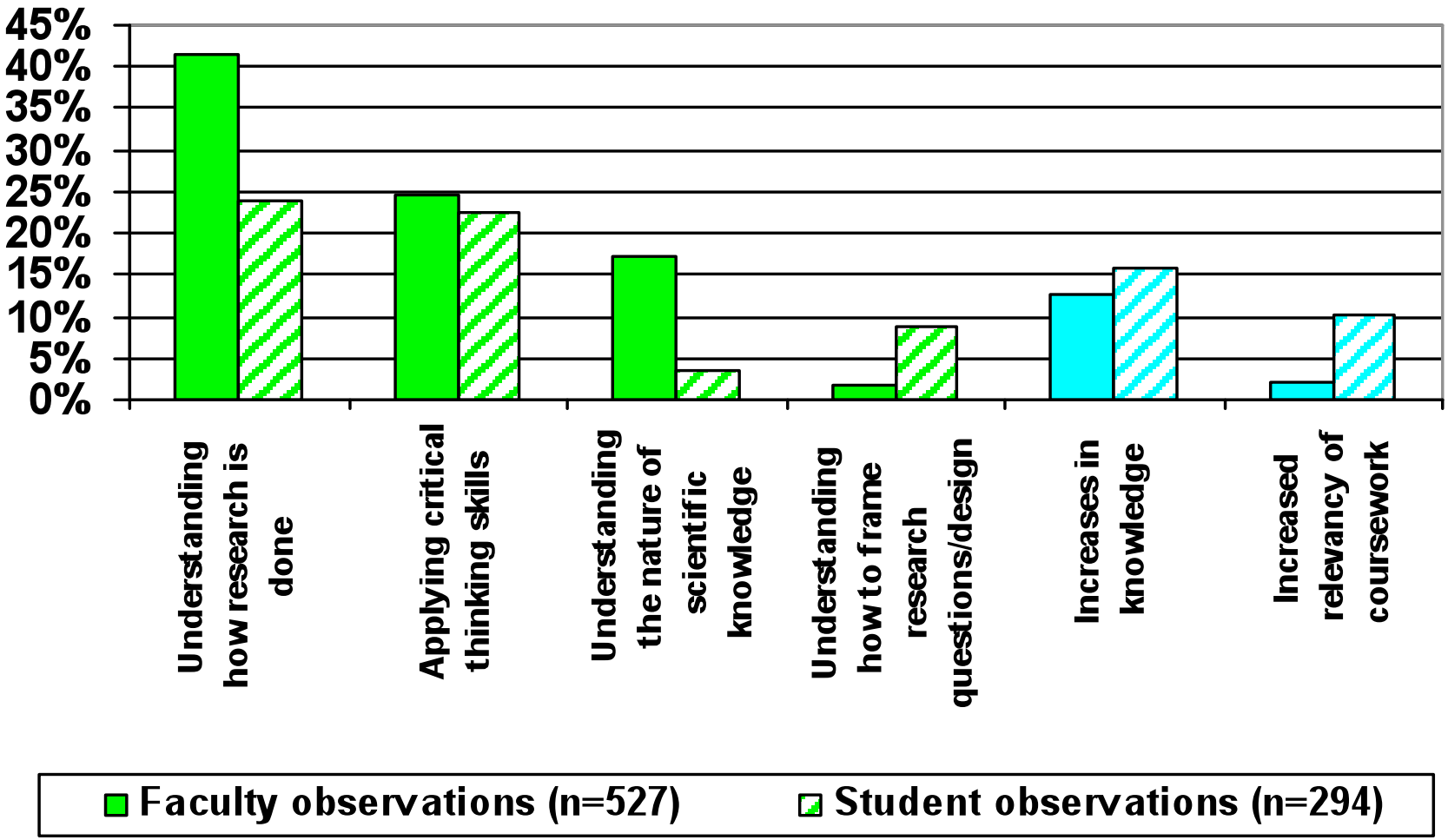
Categories of Gains

- Becoming a Scientist: Gains in attitudes and behaviors necessary to become a professional (e.g. independence, intellectual engagement, professional identity)
- Thinking and Working Like a Scientist: Gains in application of skills and knowledge, understanding the nature of scientific knowledge and the processes of research
- Personal/Professional: Gains in confidence, “feeling like a scientist,” establishing collegial relationships with faculty and peers
- Career Clarification: Validation of interest in field; clarification or confirmation of career choice
- Enhanced Career Preparation: Greater readiness for graduate school/professional work, “real world” experience, networking
- Skills: Gains in communication, presentation and argument, writing, organizational, laboratory skills

Comparison of Faculty and Student Positive Observations on Gains from UR



“Thinking and Working Like a Scientist”



"Thinking and Working Like a Scientist"

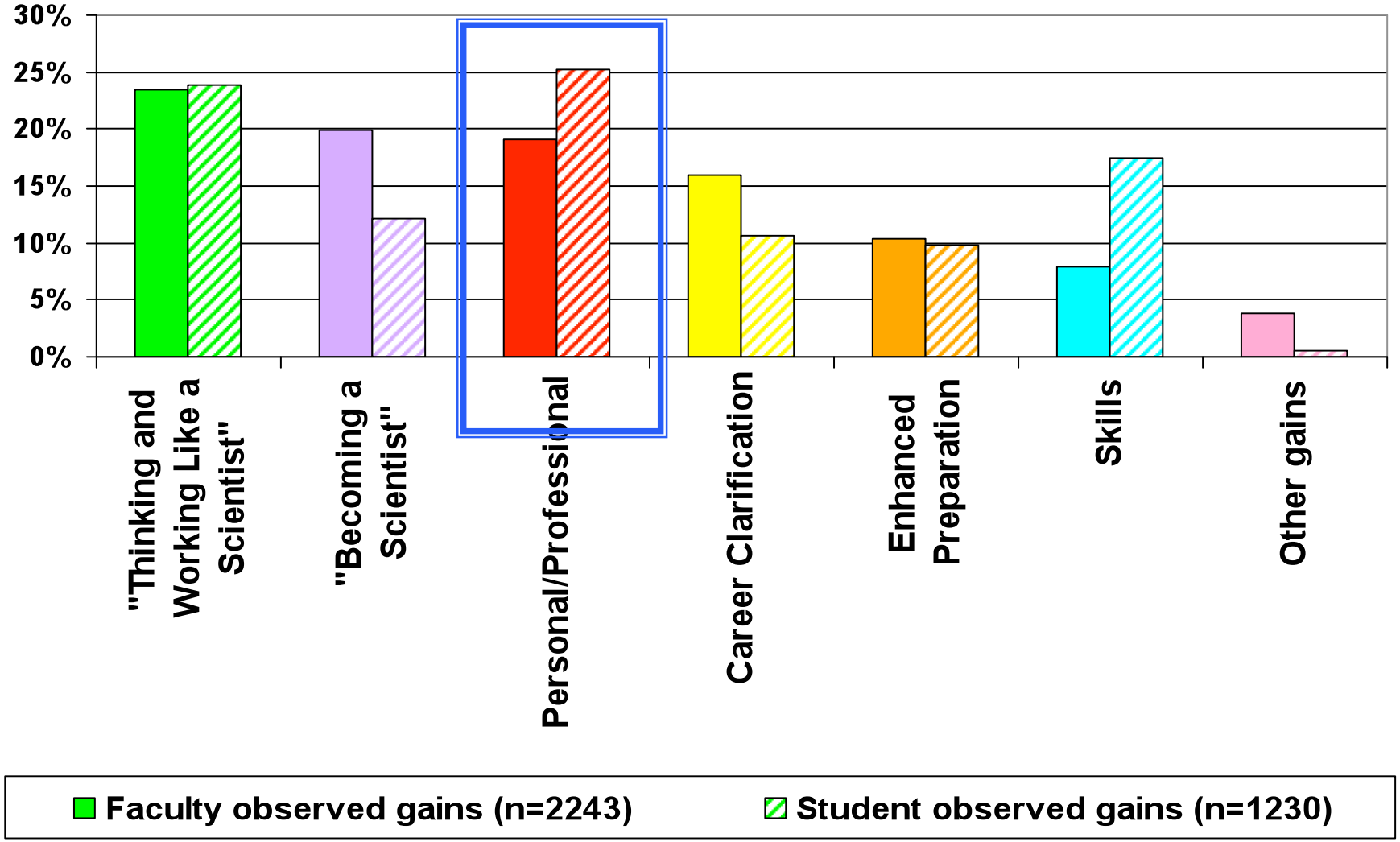
Faculty emphasize more than do students their gains in:

- understanding the intellectual processes of science research
- understanding the nature of science

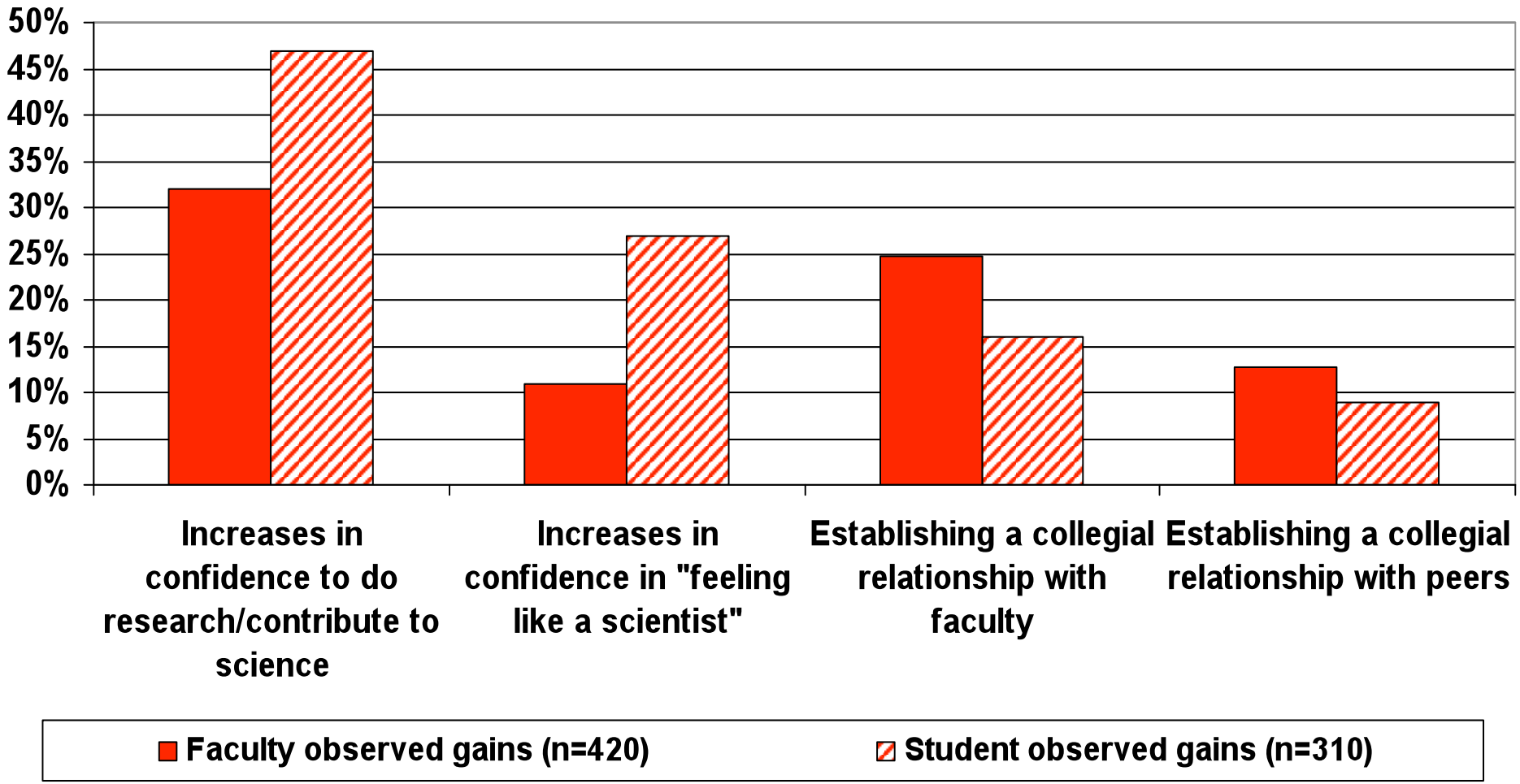
Students emphasize more than faculty gains in:

- Increases in their knowledge
- Making connections: understanding the relevance of their coursework

Comparison of Faculty and Student Positive Observations on Gains from UR



Personal-professional Gains



Personal-professional gains

Gains in confidence to do science/research

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?" (laughing) "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:

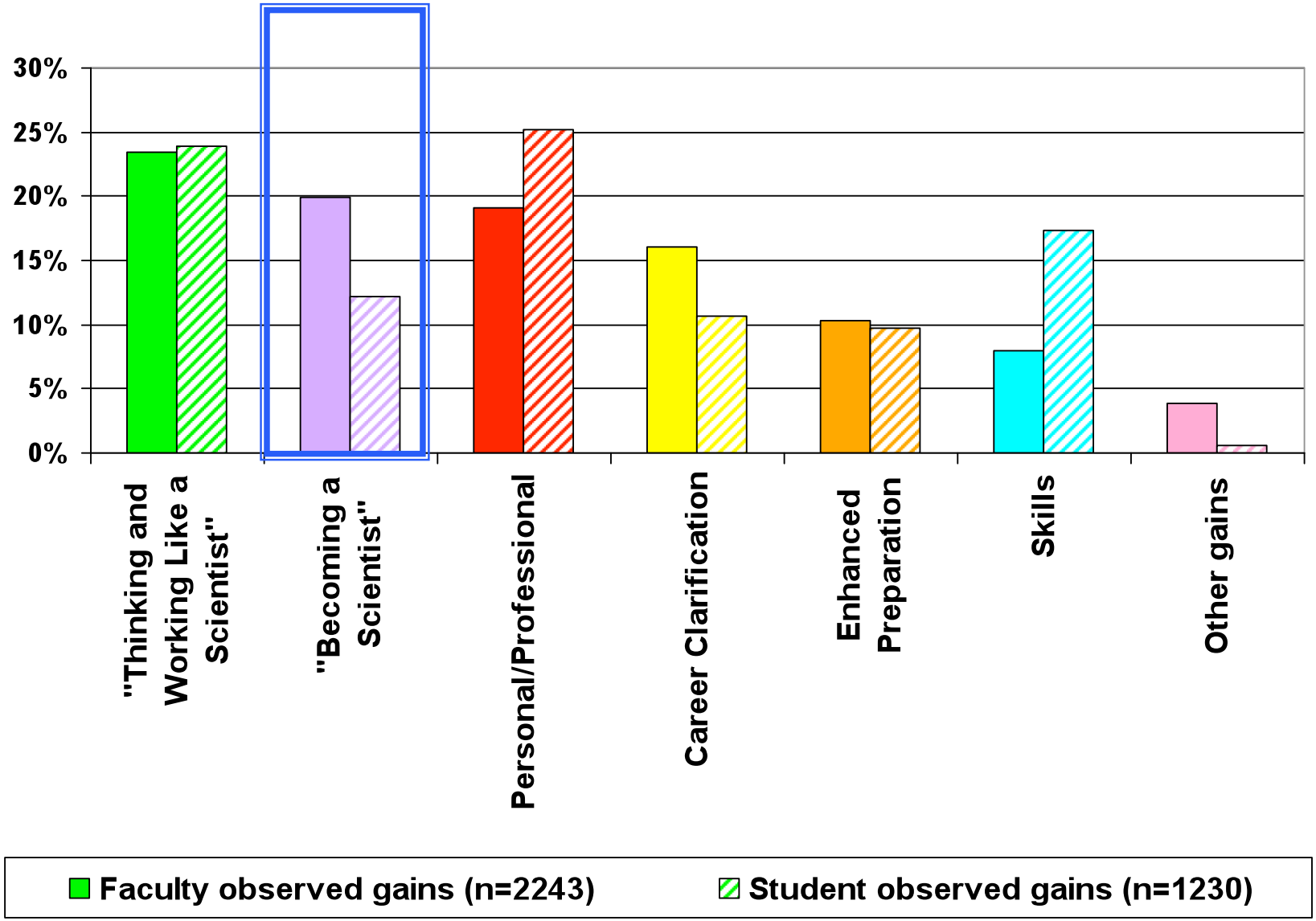
"At the beginning, I asked a lot of questions to get a good basis and a good idea when I didn't really know what I was doing. But by the end of the summer, I didn't speak to my advisor much, because I would just do it."

Summary: Personal-professional gains

Students emphasize more than faculty gains in confidence to do research, approach intellectual and technical challenges, present, defend and argue, make a contribution. See these as personal-with-professional growth

Faculty emphasize more than students gains in establishing collegial relationships: faculty know from experience the importance of these relationships. Developing collegiality is an important aspect of mentoring.

Comparison of Faculty and Student Positive Observations on Gains from UR



Students demonstrate:

- ownership of their project, responsibility for the work
- intellectual engagement, independent thinking and working
- initiative, willingness to take risks
- creative and independent approach to research decisions
- tolerance for set-backs, tedium, long hours, slow progress
- are beginning to understand nature of professional practice
- identification with and bonding to science as a profession
- confidence that are making an authentic contribution: claiming the status of scientist

"Becoming a scientist"

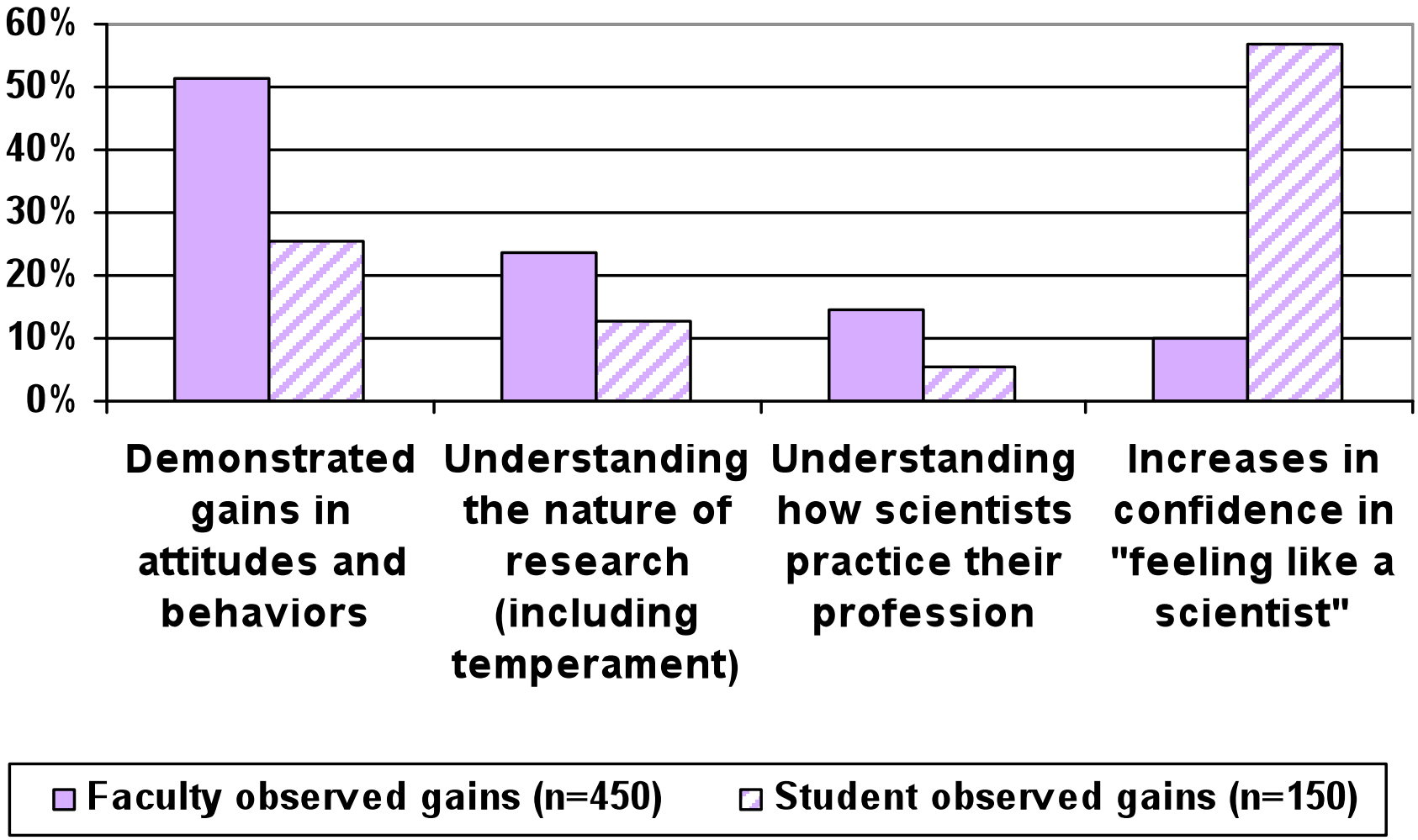
Faculty advisors provided insight into how UR supports process of professional socialization into the role of scientist.

They note when students demonstrate an understanding of

- The nature of research work and how scientists practice their profession
- Attitudes, behavior, and temperament needed to be effective researchers
- Begin to identify with the profession and see a place for themselves within it (claiming a new status)

Students do not frame these benefits in the same ways as their advisors, nor give them the same significance. Student sees many of these gains in personal and future professional terms. Faculty see them as essential steps in becoming scientists.

“Becoming a scientist”



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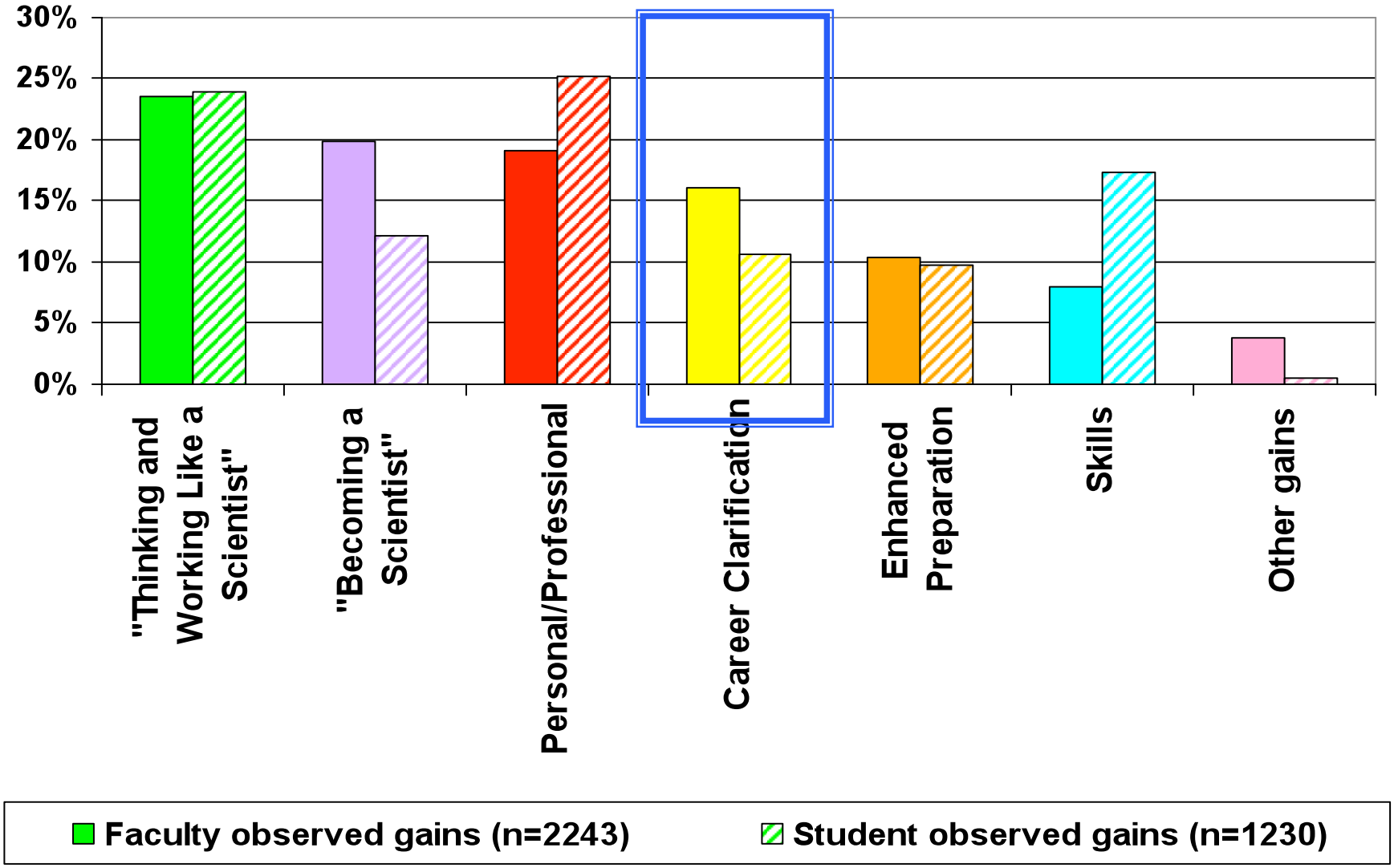
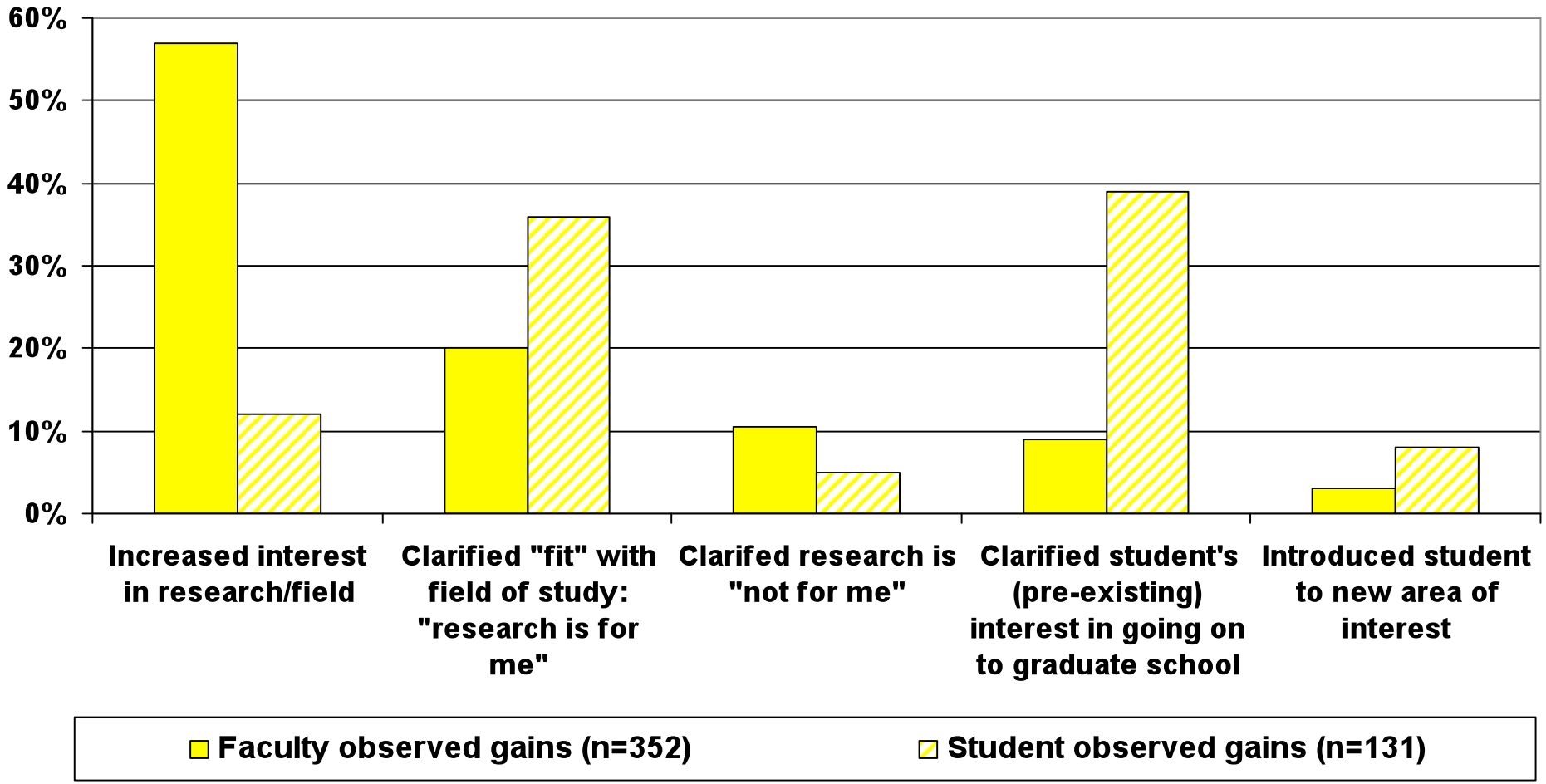


Clarification/confirmation of Career/Graduate School Intentions



Clarification/Confirmation of Career/ Graduate School Intentions

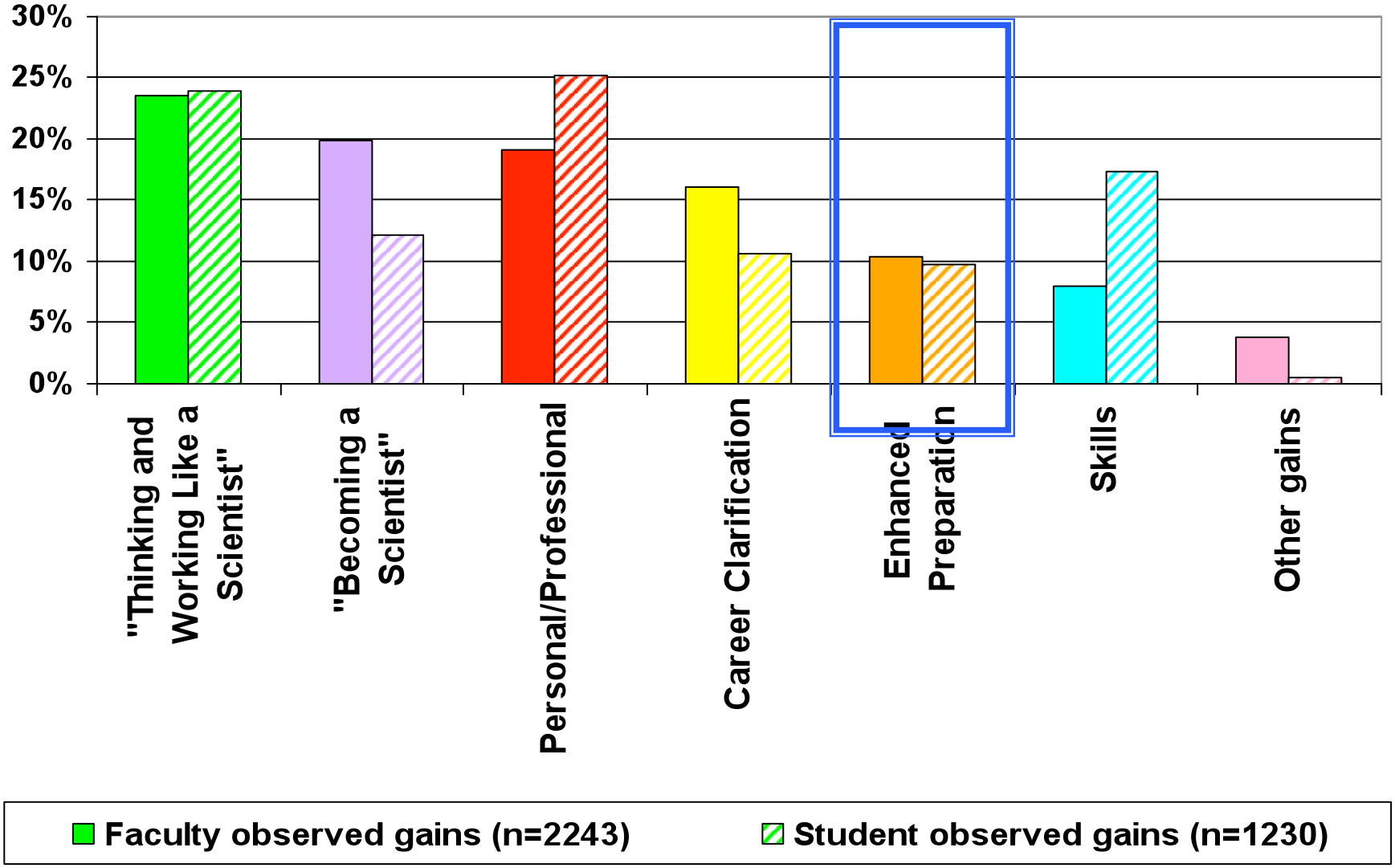
Students emphasize gains in:

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

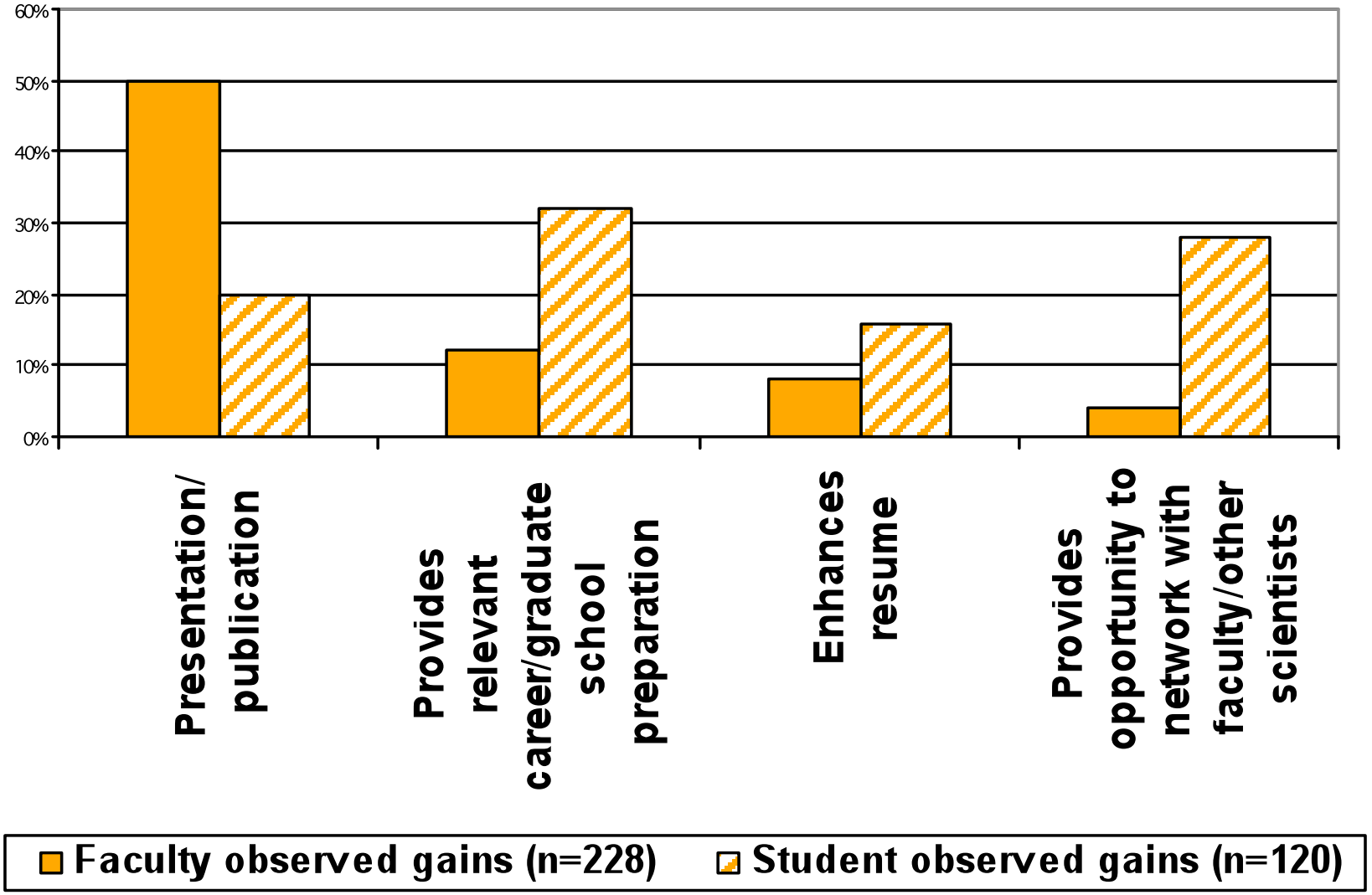
Faculty emphasize student gains in:

- Increased interest in research or particular field

Comparison of Faculty and Student Positive Observations on Gains from UR



Enhanced Career/Graduate School Preparation



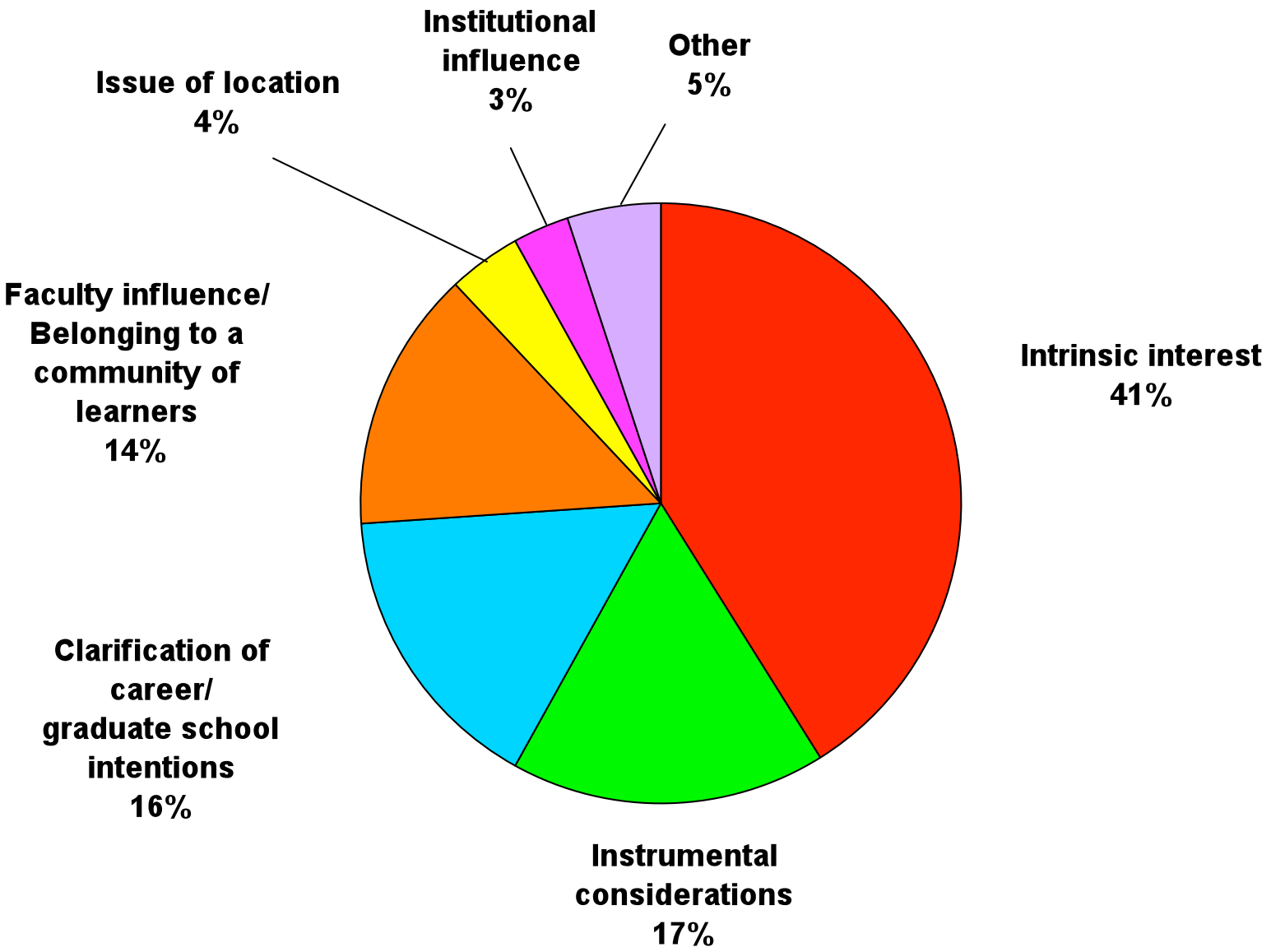
Enhanced Career/Graduate School Preparation

Students highlight gains in graduate school and other career preparation reflects graduating seniors' preoccupation with "what comes next?"

Faculty highlight the importance of UR to their own careers: recount numbers of students, articles, presentations.

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

Student Motivations for Doing Undergraduate Research (N = 236)



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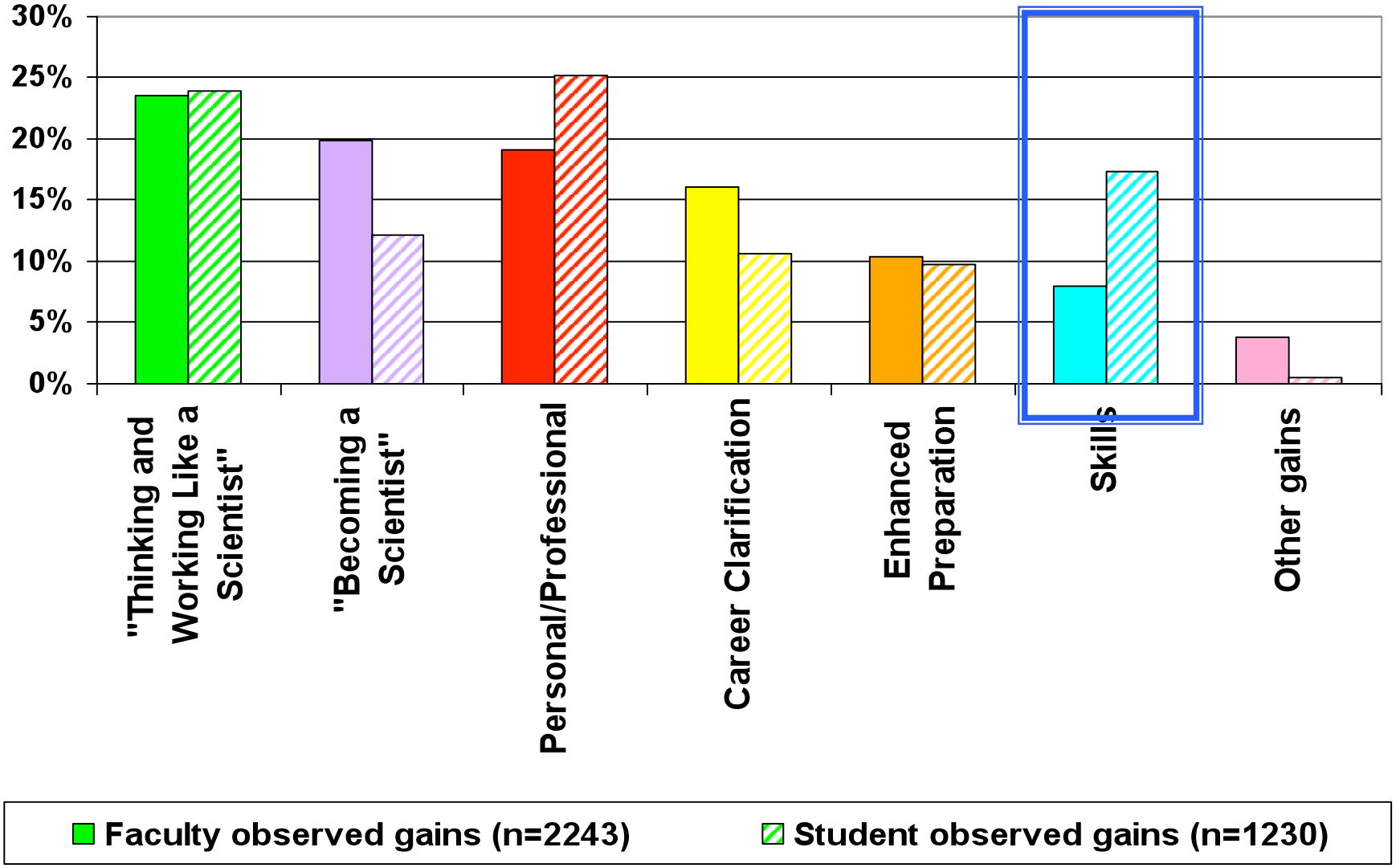
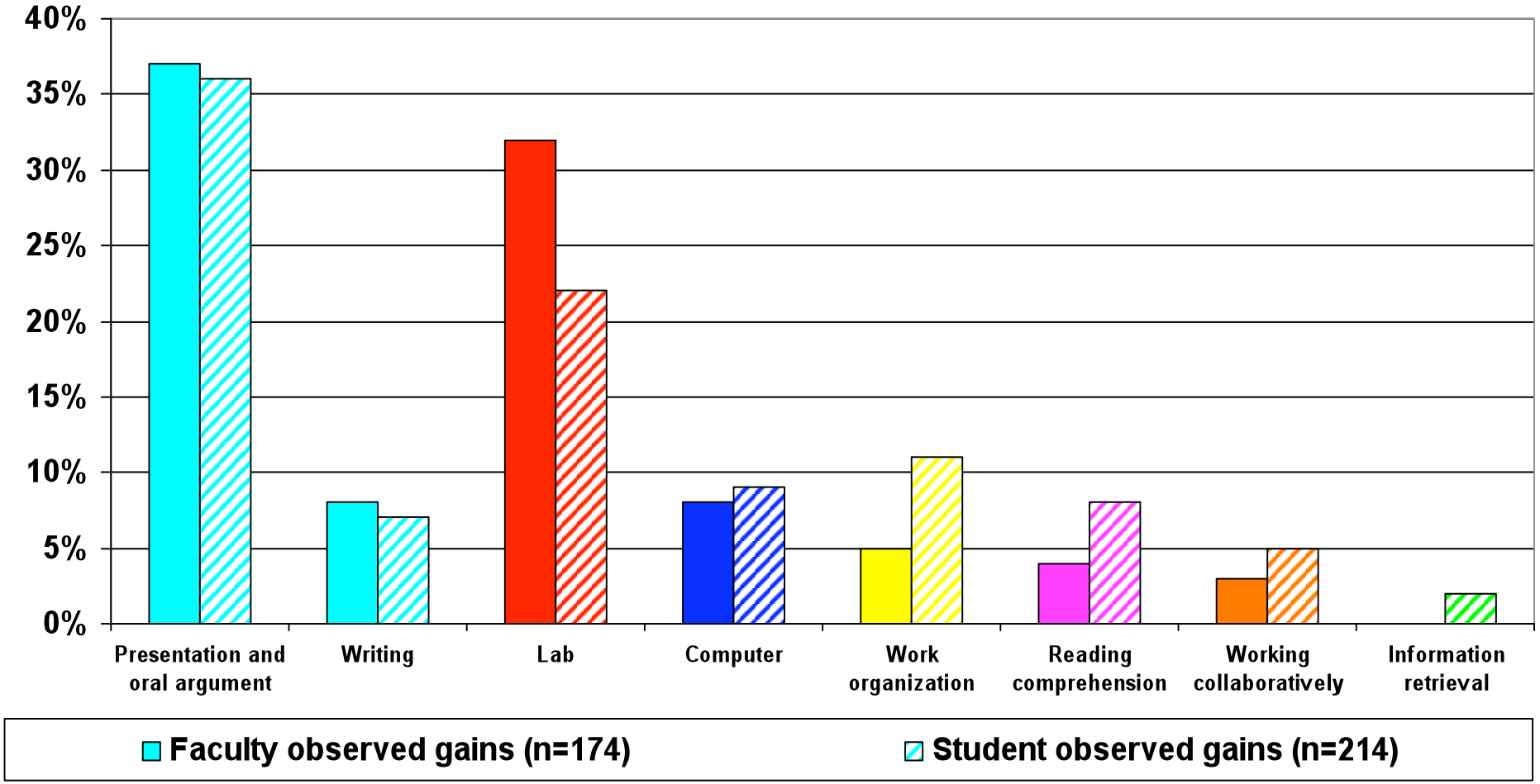


Skills


40%
35%
30%
25%
20%
15%
10%
5%
0%
Presentation and oral argument
Writing
Lab
Computer
Work organization
Reading comprehension
Working collaboratively
Information retrieval
Faculty observed gains (n=174)
Student observed gains (n=214)

Summary: Skills

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

- Presentation skills
- Lab skills

Higher ranking of all types of skills by students indicates 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

- Seen as transferable to other areas in life and as important to future careers or graduate school

URSSA

Undergraduate Research Student Self-Assessment

A tool for assessing student outcomes of undergraduate research

Sandra Laursen, Anne-Barrie Hunter, Heather Thiry.

Ethnography & Evaluation Research

and Tim Weston , ATLAS Research Center

University of Colorado at Boulder

Rationale for Developing URSSA

- A research basis has established the outcomes of UR for students in terms of real learning (not just student satisfaction)
- UR programs on campuses need a tool for assessing these known outcomes, that is reliable, simple to use, and cheap
- Self-report is the best way to learn about some types of student gains
- A standardized tool allows comparison over time, across programs or sites

Intellectual basis for URSSA: our own studies

Qualitative interview research and evaluation work on UR:

- 8-year study of undergraduate research at four liberal arts colleges, > 350 interviews, multiple disciplines
- evaluation studies of UR programs at two research universities and 1 national lab, > 350 interviews & > 150 survey responses
- literature review aligning all well-designed, published research and evaluation studies of UR

Structure of URSSA

Multiple choice and open-ended items

Core items: students' gains from UR

- skills, e.g. lab work and communication
- conceptual knowledge and linkages in their field
- understanding of the intellectual and practical work of science
- growth in confidence, adoption of an identity as scientist
- preparation for a career or graduate school in science
- clarity in career or educational choices

Core items: critical aspects of engagement in research

(e.g., taking responsibility, presenting work)

Optional items:

- motivation to do research, program info, satisfaction, career plans
- added program elements (housing, ethics training, career seminars)

Where Located: Student Assessment of their Learning (SALG) Web-site

Online instrument for *classroom* assessment of learning gains. In widespread use for more than a decade

Exclusive focus on what students gain from specific aspects of the course and pedagogy

Free, adaptable, offers statistical analysis, and data storage.

Site still developing. Adding departmental and evaluation sites, QDA function.

Also gains-focused program evaluation instruments (e.g., pre-post options, and URSSA).

Access URSSA for free via the SALG platform, www.salgsite.org

For more information

http://spot.colorado.edu/~laursen/accessURSSA.html

Hunter, A.-B., Laursen, S., Thiry, H., & Weston, T. (2009). *CUR Quarterly,* spring 2009.

Research Advisors' Markers of Student Progress

Advisors had developed a distinctive and widely-shared set of practical assessment indicators by which they judged a student's progress in attaining particular learning objectives, or their set of objectives overall.

Advisors were articulate in describing the signs that they looked for in students, and the significance that they accorded to them, but had no collective term for these progress indicators, which we have labeled assessment "markers."

Assumption: All student growth and its indicators derive from the authentic nature of the research experience.

- Core pedagogy: Using naturally-occurring conceptual and technical problems to stimulate intellectual growth and the temperamental and behavioral attributes needed to become a good researcher.
- Assessment: How students responded to problems (inc. stress, risk, and uncertainty) were tests of aptitude for research-based careers.
- Achieving these markers was as a necessary prelude to readiness for a research career.

Advisors saw intellectual growth as most dependent upon authenticity.

- "Critical thinking" glossed an array of distinct but related signs of intellectual development.
- These markers looked for:
  - In individual and group discussions of research issues
  - Observed in action as students worked to resolve problems.
- Advisors placed great emphasis on signs that students were intellectually engaged in their research work.
- Critical thinking and intellectual engagement markers strongly influenced an advisor's willingness to spend time and energy working with any student.

Assessing Overall Effectiveness

Advisors used four particular markers to gauge the overall effectiveness of their teaching and mentoring work.

These markers were taken as signs that a student was "becoming a scientist":

- confidence in her ability to do science,
- ownership of a project,
- expressing a sense of belonging within science,
- identifying herself as a scientist.

Each was seen as multi-causal, cumulative over time, and advisors needed to see all four to be certain that a student aspiring to a research career had chosen it appropriately.

Lasting Changes from Authentic UR Experiences

- How does UR influence students' post-baccalaureate choices about careers and graduate education?
- What benefits of undergraduate research experience continue to hold value for students beyond college?

Analysis of interview data from 56 UR alumni (74%) and 25 comparison alumni (40%)

Career Consequences

Context matters: Findings confirm our original hunch that for largely middle-class, white students at US liberal arts colleges, UR is **not** a deciding factor in their career choices.

UR participation helped to **confirm, clarify, and refine** a strong pre-existing interest in graduate school and a research career in a STEM field—the interest that led them to try UR in the first place.

Comparison sample alumni were also following particular career paths well before this summer.

Other Career Consequences:

- Although most students did not pursue UR for instrumental reasons, two thirds of UR alumni reported that UR experience had benefitted them in job or graduate school searches.
- Comparison alumni also cited job placement benefits (particularly from alternative research and internships) that directly contributed to success in securing employment or grad. school admission.

Finding a good fit

- Most-cited motivation for both groups was “trying out” the “fit” between their field interests and their temperament.
- UR alumni: 82% found they enjoyed research, were good at it, wanted to do more, had discovered “what research is about” and that the lifestyle “suited me.”
- Similar findings for comparative alumni with research experiences only.

UR enabled students to understand the meaning of their choices

- In both positive and negative accounts, UR alumni had learned “what they would be getting into” by pursuing graduate study or a research career. That direct knowledge had helped them make wise choices.
- Other professional experiences also influenced decision-making among comparative alumni, but only research experiences influenced their thinking about graduate study.

Career Preparation: Transferable Skills facilitated a smooth transition

- UR and some comparative alumni found they had relevant skills that some colleagues did not, and were able to apply these skills in new settings.
- The most transferable skills were the most general:
  - communicating complex ideas to varied audiences,
  - finding and understanding scientific literature,
  - writing computer programs; analyzing data,
  - working collaboratively.

Other Lasting Gains: Overall

How did other benefits that students originally cited play out in the longer term? Which gains became more or less important over time?

- Both UR and comparison alumni confirmed their initial assessments: there was little change in the overall distribution of gains observations across the six main categories.
- Although the immediacy and intensity of their experiences had faded with time, the same gains they reported as students remained important to alumni.

However, specific subcategories of gains stood out

- Alumni had come to understand the significance of aspects of their UR experiences that they had not appreciated earlier.
- As graduate students or working professionals, they could now see more subtle influences on their development that had ongoing personal and professional value.

Specific gains of long-term importance included:

- greater sophistication in their intellectual understanding of science;
- clearer understanding of how scientists work day-to-day and why these practices matter;
- adoption of work norms and socialization into the profession;
- new appreciation of ways in which collegial relationships with their advisors had modeled professional practice and informed their understanding of how science works as a profession.

Thinking and Working Like a Scientist: a critical change

A common goal of undergraduate science education, and a specific goal of UR faculty advisors:

> to develop students' understanding of the nature of science and scientific knowledge.

We found that these sophisticated ideas were grasped by relatively few students, even after a summer of intensive research.

First round findings. UR participants:

- Largely focused on their increased ability to apply knowledge and problem-solving skills to real research questions: 84% reported these gains.
- 25% could generalize from their hands-on experience to generate and frame a research problem that could be investigated scientifically.
- Only 12% described a higher level of abstraction--a clearer understanding of how scientific knowledge is constructed.

A “pyramid”—This progression of increasingly abstract ideas was achieved by increasingly fewer undergraduates

This picture changed with the alumni:

- The lowest level of intellectual gain remained widely cited: 54 of 56 (96%)
- However, alumni gains in the upper levels of the pyramid increased markedly; they credited their UR experiences with beginning this process:

  45% felt able to develop productive research investigations—to “dive in,” “figure out what we want to study;” select appropriate methods: “theoretical or experimental, or both?”

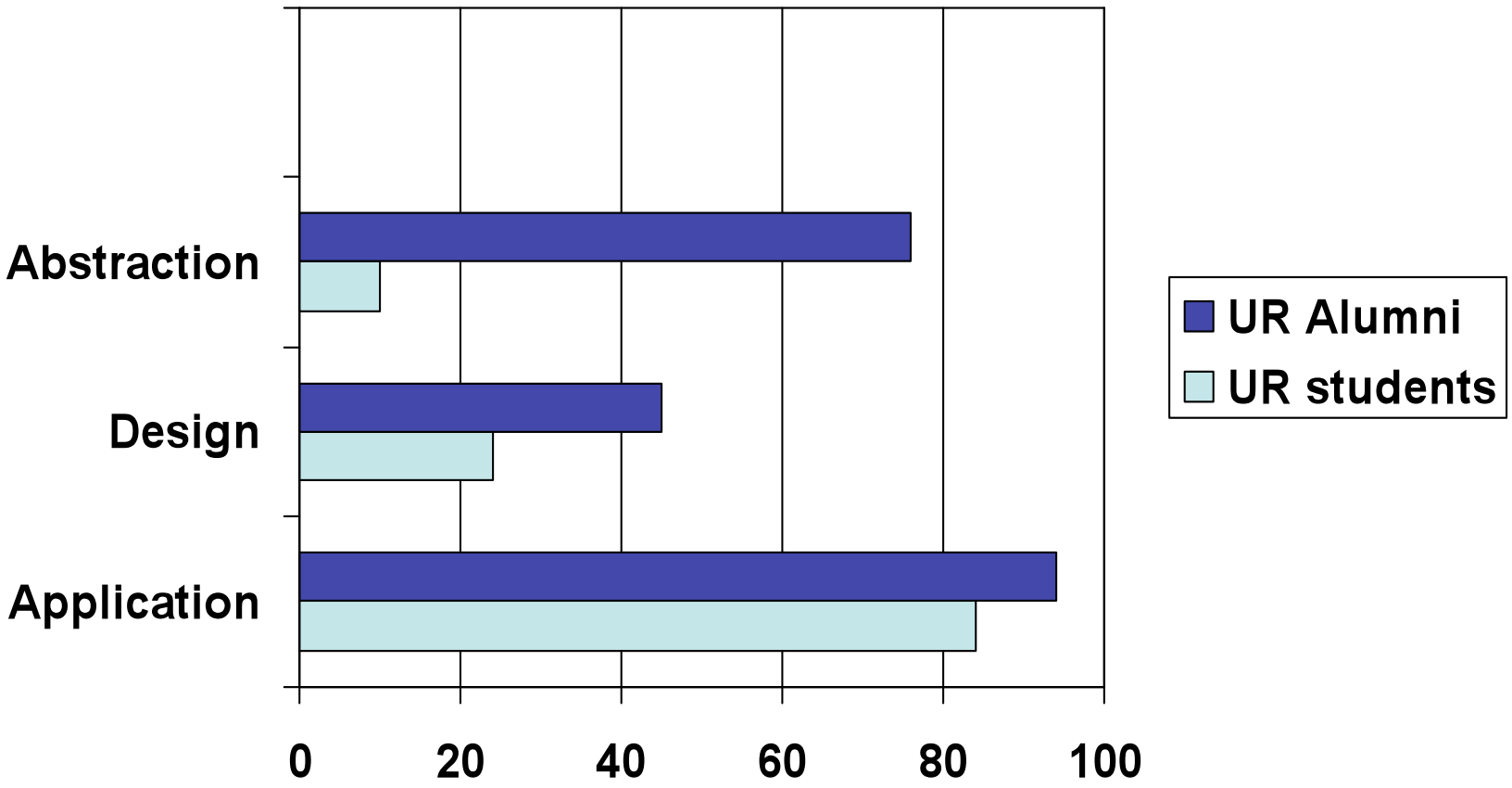
At the top of the pyramid, the strength of alumni reports was even more surprising

75% UR alumni described a clearer understanding of the nature of scientific knowledge.

At the end of their UR summer, they were not conscious of changes in their epistemological views. (Most had difficulty comprehending the interviewer's questions).

However, UR had began their process of understanding the role of research in knowledge construction, and the open-ended, provisional and fallible of scientific knowledge.

The pyramid disappears over time



Among comparison students: similar findings

A sophisticated understanding of the nature of science and construction of knowledge was rare initially, but became more common among alumni who had participated in alternative research.

Many consolidated an understanding of the nature of science only *after* they had encountered additional examples of the research process in their senior year or in graduate school, and then realized that they had met these ideas before.

Conclusions: UR participation offers the potential for students to move through a sequence of intellectual gains—from application to design to abstraction.

Few move through this sequence in a first experience. These gains are only realized after further research experiences illuminate general principles.

While UR helps to develop a more sophisticated understanding of the nature of science, it takes a long time for such understanding to become explicit.

Becoming a Scientist

Alumni also reported a deeper understanding of how scientists work.

Both alumni groups stressed this more than any other enduring gain.

They saw how engaging in research taught the practical importance of particular work practices that they now modeled as professional standards in context.

These enduring UR benefits thus shaped their own current work practices.

Linkage and merging of hitherto discreet gains

UR alumni now made linkages between increased understanding of professional practice and their understanding of *how* knowledge is constructed.

Everyday scientific habits were no longer mere procedures, but shaped the *nature* of the knowledge that was thus derived.

Examples:

- Recognizing the critical role of good laboratory record-keeping to making progress in original work.
- Working closely with an advisor had benefits not understood as a student: learning how scientific knowledge was shaped by professional norms (e.g., acknowledging the intellectual contributions of others, and laying one's own work open to scrutiny).

Collegial interactions with advisors, peers, and other scientists were a powerful source of these new understandings.

Alumni cited (as a long-term benefit) learning the value of collaborative work: the benefits of constructive criticism, input on novel ideas, modeling the professional culture and the workings of research.

Practices that had seemed idiosyncratic as students were now appreciated as essential.

Comparison alumni who had participated in alternative UR and internships

- Also reported lasting value from participating in the day-to-day practicalities of research and other professional work.
- They too had learned how professionals do their work, and had absorbed professional ethics, values, and norms. They now saw more clearly how their research mentors had modeled the profession for them.
- Over time, collegial relationships had became more important for them also.