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

Elaine Seymour

and

Members of Ethnography & Evaluation Research

University of Colorado at Boulder, USA

Sources:

Forthcoming book "Undergraduate Research in the Sciences: Engaging Students in Real Science, to be published by Jossey-Bass, January 2010

Articles include:

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.

Hunter, A.-B., Laursen, S. L., & Seymour, E. (2008). Benefits of participating in undergraduate research in science: Comparing student and faculty perceptions. In R. Taraban & R. L. Blanton (Eds.), *Creating effective undergraduate research programs in science: The transformation from student to scientist* (pp. 135-171). New York: Teachers College Press.

Hunter, A-B., Weston, T. J., Laursen, S. L., & Thiry, H. (2009). URSSA: Evaluating student gains from undergraduate research in science education. *Council on Undergraduate Research Quarterly, 29(3)* 1-519.

Laursen, S. L., Hunter, A.-B., Seymour, E., DeAntoni, T., De Welde, K., & Thiry. H. (2006). Undergraduate research in science: Not just for scientists any more. In J. J. Mintzes and W. Leonard (Eds.), *Handbook of college science teaching* (pp. 55-66). Arlington, VA: NSTA Press.

Seymour, E., Hunter, A.-B., Laursen, S., & DeAntoni, T. (2004). Establishing the benefits of research experiences for undergraduates: First findings from a three-year study. *Science Education, 88(4)*, 493-534. doi: 10.1002/sce.10131

Undergraduate Research in the Sciences: Engaging Students in Real Science: TABLE OF CONTENTS

Table 2.1. Comparison of findings on student benefits from UR from published research and evaluation studies.

The italicized numbers across the top of the table identify particular studies and correspond to references listed in the legend. Complete citations are listed in the references. U.S. research institutions are all classified as "high" or "very high" research institutions by the 2007 Carnegie Classification (Carnegie Foundation for the Advancement of Teaching, 2007).

	British univ.	Studies Conducted at Research Institutions															Multi-institution Studies								Laboratory	TOTALS
Type of student gain	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Includes findings on students from underrepresented groups				*	*	*	*		*		*					*							*	*	*	
Personal/professional gains																										
Increased confidence			S,F	S	S	S			S	S	S,F	S-	S					S	S	S+,F		S			U	**14**
Establishing collegial relationships with advisors			S,F		S	S	S				S		S	F		S		S	S	S,F			U		U	**13**
Establishing collegial relationships with peers			S,F		S	S					S							S	S	S,F					U+	**8**
Seeing that scientists are real people	S				S															S,F						**3**
Feeling like a scientist																				S, F					U	**2**
Thinking and working like a scientist																										
Deepened knowledge in field; making conceptual connections			S		S			S+,F-			F		S+				S,F-	S	S	S,F			U			**10**
Appreciating relevance of coursework					S						S								S	S,F-					U	**5**
Improved critical thinking and problem-solving; ability to analyze & interpret results					S			S+,F+					S+	F+	S+			S	S	S,F					U	**9**
Understanding research through hands-on experience	S		S,F		S			S+,F+			S				S+		S,F	S+	S+	S+,F+		S	U		U	**13**
Understanding how to pose and investigate research questions		S						S-,F-												S,F-		S				**4**
Understanding how knowledge is constructed	S									S		S-						S	S	S,F		S				**7**

Becoming a scientist																									
Working independently			S					S+, F+				S	S	F	S+		S,F	S	S	S,F					**10**
Approaching problems creatively, thinking synthetically												S		F				S	S	S,F					**5**
Increased understanding of the nature of research work	S				S												S			S,F	S			U	**6**
Demonstrated gains: increased tolerance and perseverance												S			S			S	S	S,F				U	**6**
Understanding professional practice: working collaboratively			S									S		F						S,F	S			U+	**6**
Understanding professional practice: presenting and publishing; importance of communication skills, including writing			S		S															S,F				U	**4**
Increased intrinsic interest in learning, intellectual curiosity												S		F+	S+				S	S,F					**5**
Skills																									
Technical skills		S										S+					S,F	S+	S+	S,F	S	U			**8**
Communication skills: presenting, argument					S			S+, F+				S-	S		S			S-	S-	S,F	S			U	**10**
Communications skills: writing		S						S-,F-							S+			S-	S-	S,F				U	**7**
Computer skills													S+							S,F				U	**3**
Reading & critiquing literature		S						S,F-							S			S	S	S,F					**6**
Information searching & retrieval													S+		S+					S,F					**3**
Collaborative work																				S,F				U	**2**
Time management, organization																				S,F				U	**2**
Enhanced career preparation																									
UR provides good preparation for work or graduate school					S										S					S,F	S			U	**5**
Provides opportunity to network with peers, faculty, scientists																				S+,F		U		U	**3**

Career clarification																									
Clarified, confirmed, refined career interests & goals (including graduate school)		S		S	S					S			S	F	S		S	S-	S-	S,F		U		U	**13**
Gained insight into profession or graduate school; assessment of "fit"			S,F	S	S							S					S			S,F	S	U		U	**9**
Increased likelihood of post-graduate education		S	S	S	S		S,U		S		S		S		S		S	S	S	S,F	S	U		U	**16**
Increased interest in science			S	S	S						S						S			S,F+					**6**
Introduced new field of study			S	S																S,F					**3**
Research is *not* for me			S								S					S		S	S	S,F					**6**
UR experience *prompted* choice, is a causal factor in decision to enroll in graduate school				U	U		U				U					U		S	S	U	U			U	**10**
Career outcomes																									
Retention to graduation				S,U		U	S,U		U		U					U						U	U	U	**9**
High rates of students going to graduate school				S,U	U		S,U		U		U		S			U			S	S	S	U	U	U	**13**
High rates of students earning advanced degrees in STEM fields or medicine					U				U						S							U	U	U	**6**

Legend

S = Student gain reported (by students or alumni)

F = Faculty-rated student gain

U = Gain for students from underrepresented groups

S+ = Highest student-rated gain

F+ = Highest faculty-rated student gains

S- = Lowest student-rated gain

F- = Lowest faculty-rated student gains

Index to research and evaluation studies referenced in Table 2.1

	Author and date	Study location
1	Ryder, Leach & Driver, 1999	University of Leeds, Great Britain
2	Kremer & Bringle, 1990	Indiana University
3	Alexander, Lyons, Pasch & Patterson, 1996	University of Wisconsin-Madison
4	Foertsch, Alexander & Penberthy, 1997	University of Wisconsin-Madison
5	Alexander, Foertsch & Daffinrud, 1998	Rice University
6	Nagda, Gregerman, Jonides, von Hippel & Lerner, 1998	University of Michigan
7	Hathaway, Nagda & Gregerman, 2002	University of Michigan
8	Kardash, 2000	Midwestern, Carnegie Research University
9	Maton, Hrabowski, & Schmitt, 2000	University of Maryland, Baltimore County
10	Rauckhorst, Czaja & Baxter Magolda, 2001	Miami University
11	Adhikari, Givant & Nolan, 2002	University of California, Berkeley
12	Ward, Bennett & Bauer, 2002	University of Delaware
13	Zydney, Bennett, Shahid & Bauer, 2002b	University of Delaware
14	Zydney, Bennett, Shahid & Bauer , 2002a	University of Delaware
15	Bauer & Bennett, 2003	University of Delaware
16	Barlow & Villarejo, 2004	University of California, Davis
17	Fitzsimmons, Carlson, Kerpelman & Stoner, 1990	Multi-institution
18	Lopatto, 2004	Multi-institution
19	Lopatto, 2007	Multi-institution
20	Hunter, Laursen & Seymour, 2007; see also Seymour, Hunter, Laursen & DeAntoni, 2004	Multi-institution
21	THIS PUBLICATION (four-college study)	Multi-institution
22	Russell, 2005; see also Russell, Hancock & McCullough, 2007	Multi-institution
23	National Research Council, 2005	Multi-institution
24	Clewell, de Cohen, Deterding & Tsui, 2006	Multi-institution
25	THIS PUBLICATION (SOARS case study); see also Pandya, Henderson, Anthes & Johnson, 2007	National Center for Atmospheric Research

Table 3.1. Student gains from undergraduate research, as reported by UR students, UR alumni, and research advisors.

"Parent" category: Group of gains-related codes	UR students	UR alumni	Advisors
Individuals interviewed	76	56	80
	Number of observations		
Personal/professional	310	428	335
Non-comparable subcategories	-	59	85
Category total as % of all positive gains	*25%*	*21%*	*19%*
Thinking and working like a scientist	248	386	527
Non-comparable subcategories	46	-	-
Category total as % of all positive gains	*24%*	*16%*	*23%*
Becoming a scientist	151	327	450
Category total as % of all positive gains	*12%*	*14%*	*20%*
Skills	214	404	169
Non-comparable subcategories	-	2	5
Category total as % of all positive gains	*17%*	*17%*	*8%*
Career clarification, confirmation, and refinement of career & education paths	131	245	348
Non-comparable subcategories	-	-	4
Category total as % of all positive gains	*11%*	*10%*	*16%*
Enhanced preparation for career & graduate school	90	356	169
Non-comparable subcategories	30	160	59
Category total as % of all positive gains	*10%*	*22%*	*10%*
Miscellaneous and general gains	11	13	92
Category total as % of all positive gains	1%	1%	4%
Subtotal, comparable gains only	1144	2146	2151
Total, all positive gains observations	**1231** *(100%)*	**2380** *(100%)*	**2243** *(100%)*

Negative gains observations	51	257	140
Mixed, partial, or uncertain gains observations	54	88	112

Table 8.1. Intellectual, affective, and behavioral markers of student progress, as reported by research advisors.

Markers of intellectual growth

1. **"Critical thinking"**

- Showing openness to different ways of approaching research objectives and tasks
- Starting to ask critical questions
- Thinking for themselves
- Developing skepticism; not taking ideas as given
- Showing understanding of why they are doing any task
- Showing creativity in response to problems
- Making connections; understanding relationships among ideas
- Applying prior learning to their research
- Making sense of their data, understanding what their results mean

2. **Understanding the conceptual framework for their work**

- Gaining insight into their discipline
- Showing a grasp of the research process
- Developing a more sophisticated understanding of the nature of science and the construction of knowledge

3. **Intellectual and affective engagement**

- Showing intellectual engagement in their research work
- Showing commitment to the work, excitement about what they are doing, interest and enthusiasm for research and the discipline

Markers of change in approach to science

1. **Learning through problem-solving**

- Persevering in face of difficulties by applying methodical problem-solving and trying new directions
- Taking initiative to discuss problems, using collegial networks to make progress
- Showing willingness to work hard, putting in effort to finish a task

2. **Dealing with risk and uncertainty**

- Showing willingness to wrestle with problems and take risks
- Treating setbacks as normal, becoming comfortable in dealing with them
- Tolerating uncertainty and frustration

3. **Developing independence**

- Beginning to work independently; consulting, seeking critique or confirmation after making a decision
- "Getting on with their work" in a careful and responsible manner
- Using ingenuity to resolve problems; marshaling resources and taking initiative to seek assistance or advice
- Showing confidence in decision-making; enjoying thinking and acting for themselves
- Becoming self-directed

Markers of gains in skills

- Showing confidence in using and applying new technical skills
- Planning, organizing and documenting their own work

Markers of gains related to professional communication

1. **In discussing and presenting their own work**

- Discussing difficulties openly and revising ideas with others
- Explaining, making arguments, fielding questions about their work
- Giving, taking and responding to collegial critique comfortably

2. **From attending professional meetings**

- Recognizing their contributions as valuable
- Starting to take themselves seriously as scientists
- Making connections between their own work and the field
- Starting to build professional networks

Markers for collegiality and collaboration

- Working actively with peers as colleagues
- Behaving respectfully with peers regardless of differences of view
- Starting to develop and use scholarly collaborations

Markers of career readiness

- Realizing that research is or is not what they want to do
- Gaining a sense of what career directions and working life styles are right for them
- Expressing self-knowledge and confidence
- Demonstrating intellect, temperament, and skills that ready them for graduate work

Markers of overall UR effectiveness

1. **Developing confidence in their ability to do science**

- Taking on an intellectual or technical challenge, trying to figure it out
- Taking risks
- Thinking and acting independently
- Persisting, seeing a task through
- Working comfortably and appropriately with other researchers

2. **Taking ownership of their work**

- Showing motivation to meet the demands of the work
- Talking about their work with enthusiasm and interest
- Being serious and creative about their own ideas and vested in their outcomes
- Taking the initiative, offering ideas and proposals, making plans
- Seeking input and finding intellectual stimulation in collegial work
- Assuming responsibility, taking decisions, seeking validation later
- Expressing pride or sense of accomplishment in their own work

3. **Adopting the status of belonging within science**

- Realizing the value of their work and extent of their knowledge
- Claiming the status and having this claim validated by their advisor and other scientists

4. **Recognizing that they have "become a scientist"**

- Claiming the identity of "scientist" and having this identity validated by their advisor