Twenty-One Learning Benefits of Undergraduate Research

David Lopatto

Grinnell College

The Survey of Undergraduate Research Experiences (SURE) and the Classroom Undergraduate Research Experience (CURE) survey share items that students evaluate numerically. Two sets of items, those for self-evaluated learning gains course elements, have evoked interest in validity. In the following notes I present various attempts to query these sections for their validity.

Reported learning gains and overall evaluation of the undergraduate research experience.

Twenty-one evaluative questions on specific learning gains are presented to the respondents (Table 1). These are common to the SURE and CURE surveys. The similarity is deliberate. In some analyses, learning gains from the CURE are compared to those of the SURE in support of the assertion that the CURE does capture aspects of an authentic research experience (Jordan, et al., 2014; Lopatto, et al., 2008). The information below resulted from an analysis of the items following administration of the SURE or CURE. The inter-item reliability of the 21 items is routinely tested with every year's data collection. The reliability statistic, Cronbach's alpha, is without exception between .92 and .95.

Table 1. The 21 learning gains evaluated by the student respondent. The scale is 1 (no gain, etc.) to 5 (very large gain).

	No gain or very small gain	**Small gain**	**Moderate gain**	**Large gain**	**Very large gain**	**N.A./ Prefer not to answer**
Clarification of a career path	❍	❍	❍	❍	❍	❍
Skill in the interpretation of results	❍	❍	❍	❍	❍	❍
Tolerance for obstacles faced in the research process	❍	❍	❍	❍	❍	❍
Readiness for more demanding research	❍	❍	❍	❍	❍	❍
Understanding how knowledge is constructed	❍	❍	❍	❍	❍	❍
Understanding of the research process in your field	❍	❍	❍	❍	❍	❍
Ability to integrate theory and practice	❍	❍	❍	❍	❍	❍
Understanding of how scientists work on real problems	❍	❍	❍	❍	❍	❍
Understanding that scientific assertions require supporting evidence	❍	❍	❍	❍	❍	❍
Ability to analyze data and other information	❍	❍	❍	❍	❍	❍
Understanding science	❍	❍	❍	❍	❍	❍
Learning ethical conduct in your field	❍	❍	❍	❍	❍	❍
Learning laboratory techniques	❍	❍	❍	❍	❍	❍
Ability to read and understand primary literature	❍	❍	❍	❍	❍	❍
Skill in how to give an effective oral presentation	❍	❍	❍	❍	❍	❍
Skill in science writing	❍	❍	❍	❍	❍	❍
Self-confidence	❍	❍	❍	❍	❍	❍
Understanding of how scientists think	❍	❍	❍	❍	❍	❍
Learning to work independently	❍	❍	❍	❍	❍	❍
Becoming part of a learning community	❍	❍	❍	❍	❍	❍
Confidence in my potential to be a teacher of science	❍	❍	❍	❍	❍	❍

The origin of the items

An early version of a taxonomy of the benefits of undergraduate research in the sciences was the result of a collaboration between the author and Dr. Elaine Seymour and her research group (See Lopatto, 2010, for a review of the history). While Dr. Seymour pursued a qualitative research program, I created the original ROLE survey (Research On Learning and Education, a name borrowed from the NSF grant program that funded the work). The survey posed 45 potential benefits for student researchers to evaluate. A factor analysis of the results was consilient with the coded qualitative information gleaned from Seymour's work (see Figure 3-1 in Lopatto, 2010). Forty five items to be evaluated, however, seemed excessive, so key items from the survey, including key items from each of the factors, were extracted to create a more compact list of 21 items[1]. One implication of this truncated list is that the SURE/CURE list is has a more clinimetric value than a value as an instrument for uncovering any new latent variable in the assessment of undergraduate research programs[2].

Sensitivity of the items to differences in student experience

Because the benefit items in the CURE are identical to those in the SURE, we can look at relations between variables in the SURE to analyze the features of the 21 items. In the SURE, the student rating of his or her direct supervisor was related to the student's evaluation of learning gains. A summary of the 21 learning gains was obtained by computing the average gain for each respondent. Figure 1 shows the mean composite learning gains for students classified by

[1] Concurrently, the original ROLE survey evolved to be available to nonscience as well as science disciplines. The list of 26 learning benefits in the current ROLE survey is not identical with the original list or with the SURE.

[2] See Lopatto (2017) and my working paper on ROLE survey statistics, this website.

their evaluation of their supervisor (SURE data, 2015-2016; N = 3,953)[3]. Students with outstanding supervisors reported the highest learning gains. Students with above average supervisors reported the second highest learning gains. Students with below average or poor supervisors reported the lowest learning gains.

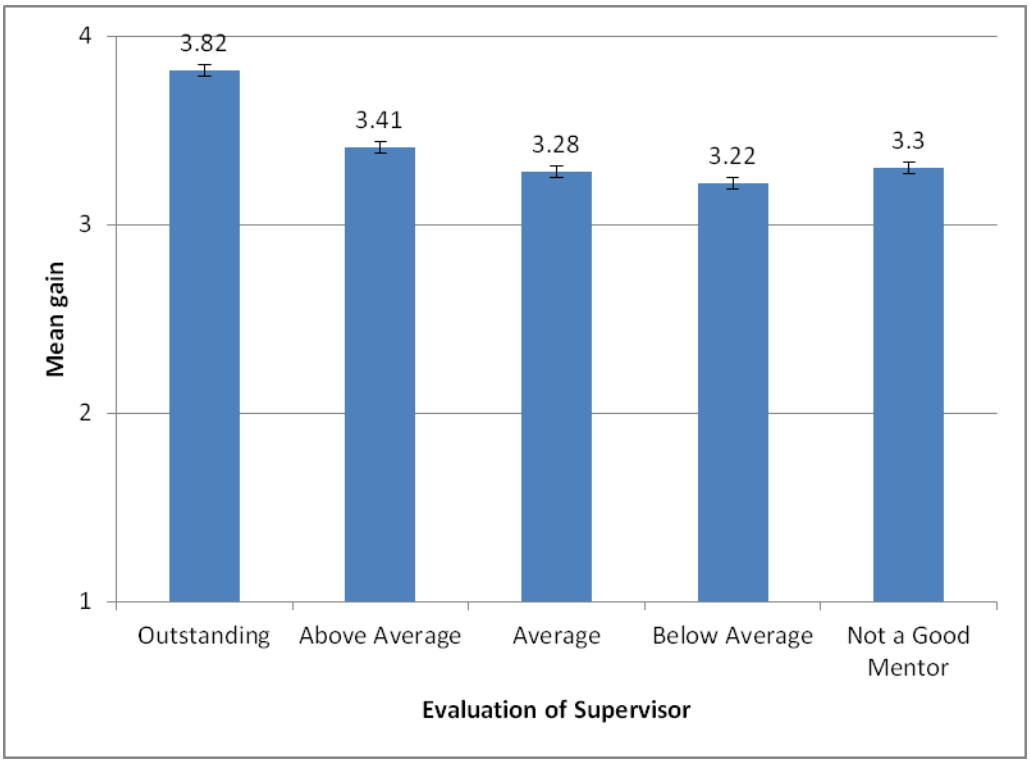

Figure 1. Learning gain evaluations from the mean of the 21 benefits shown in Table 1 were averaged for each student and classified according to the student's evaluation of his or her supervisor. Mean learning gains varied with supervisor evaluation. Error bars are 2 standard errors above and below the mean.

Students who no longer plan on science

In the SURE survey, it is typical for about 4% of the respondents to report that they started their research experience with the intention of going on in science, but as a result of their

[3] When I cite "SURE data" or "CURE data" I am referring to the national data collected by the author. Published data will be referenced by the publication citation. On the SURE, students evaluate their research supervisor on a scale of 1 (not a good mentor) to 5 (outstanding).

experience the changed their mind. In the 2015-2016 SURE data set, 136 student respondents reported that at the end of their research experience they no longer plan to pursue graduate education in science. This number is a very small proportion of the respondents (3.9% of the responses). It may be that students discontinue their plans for reasons irrelevant to their research experience. Nevertheless, an examination of the responses from these students shows differences between their experience and the experience of students continuing on a path to a science career. It may be that these students are discouraged from future science involvement. Figure 2 shows the mean ratings of learning gains for 136 students who had no plans to continue in science education. For comparison the mean learning gains of students who plan to continue toward a Ph.D. (N = 1,469) are shown. Students who did not plan to continue with science education after their research experience are labeled in Figure 2 as discouraged. Discouraged students evaluated most of their learning gains more conservatively than did other students. Discouraged students rated both their overall satisfaction (Mean = 4.32) with the research experience and their opinion of their research supervisor (Mean = 4.11) lower than students intending graduate school did (Means = 4.65, 4.32), although the overall ratings of both groups were quite high. As in previous years, discouraged students did not differ from other students on the variables of type of institution, sex, ethnicity, or field of research.

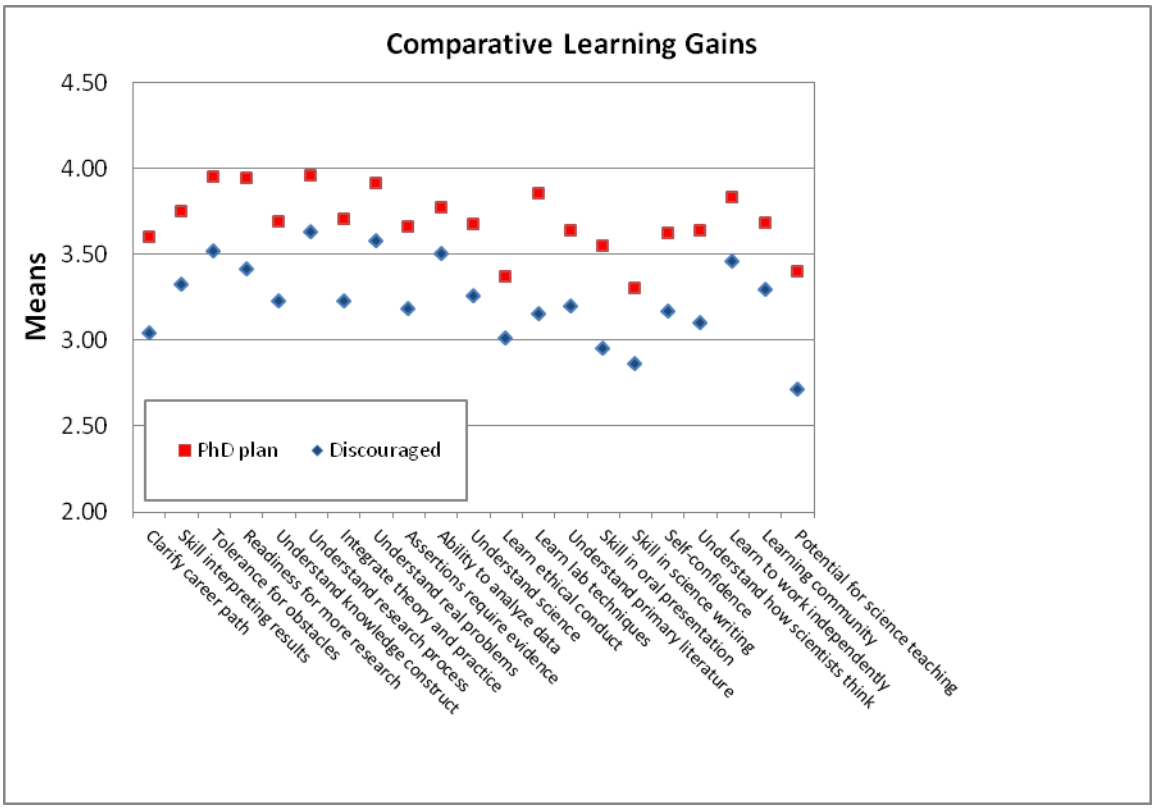

Figure 2. Mean learning gains reported by students who report that they are no longer planning to pursue a post-graduate education in science (blue diamonds) and students who report planning to pursue a Ph.D. in science (red squares).

Benefit ratings: SURE versus CURE

The CURE (Classroom Undergraduate Research Experiences) survey was originally designed in collaboration by four institutions (Grinnell College, Harvey Mudd College, Hope College, Wellesley College) to assess the value of research-like experiences in science courses. The work was continued and sustained by the current grant. For the academic year 2015-2016, a total of 10,608 pre-course surveys and 9,084 post-course surveys were collected. Figure 3 shows the comparative learning gains from the SURE survey and the CURE survey. As can be seen, the pattern of results is similar but less highly rated in the CURE than the SURE. The result is

highly plausible; the SURE respondents are evaluating a dedicated (often summer) research experience while the CURE respondents are experiencing research in the context of a course.

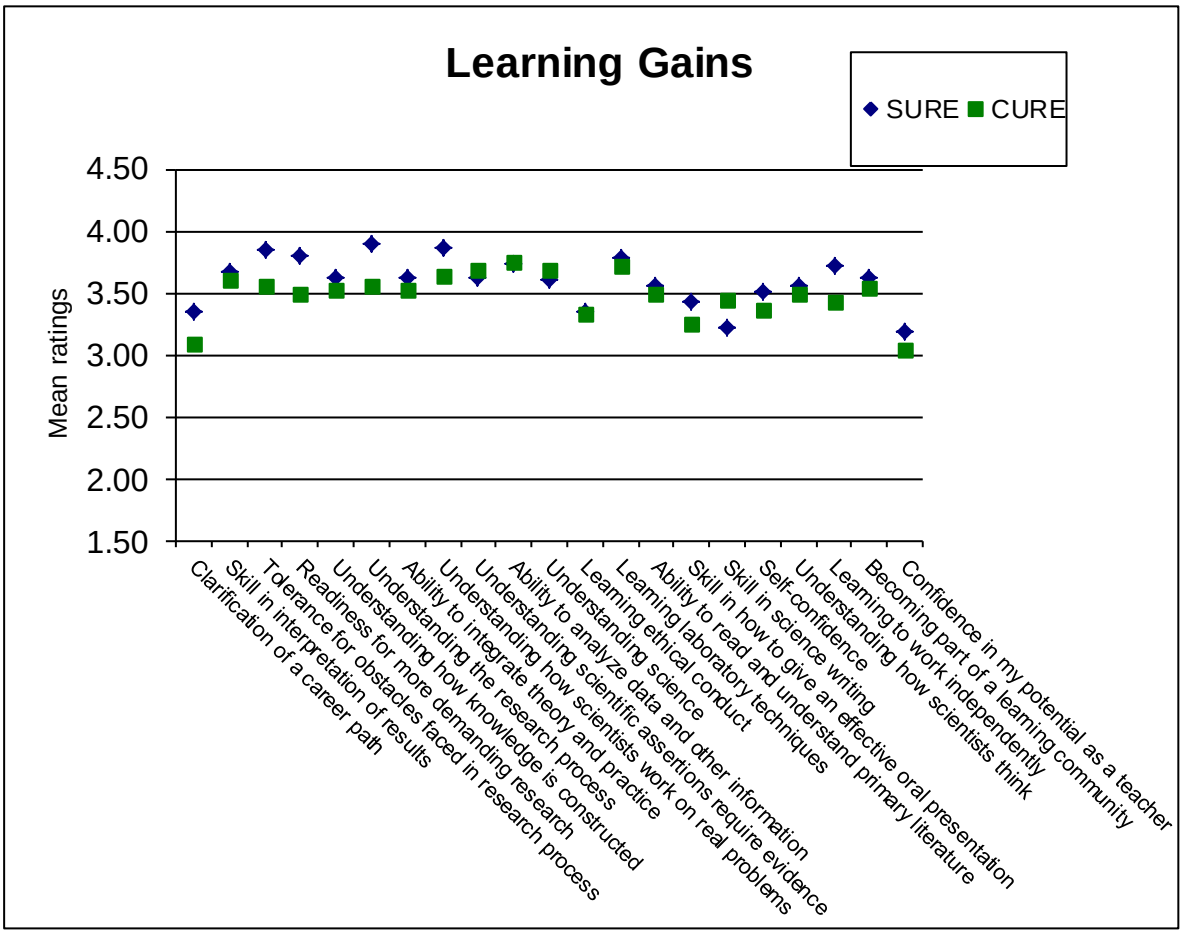

Figure 3. A comparison of mean learning gains on the CURE and the SURE.

The structure of the benefits section across common surveys.

One of the advantages of creating a family of related surveys (SURE, CURE, RISC[4]) is that items can be carried across surveys. As mentioned earlier, a common section of the three surveys is called the "benefits" section, which appears in the SURE as well as the post-course version of the CURE and RISC (N =807). Table 2 shows the results of an Exploratory Factor

[4] RISC is the Research on the Integrated Science Curriculum, which retains key items from the CURE and adds items relevant to interdisciplinary courses.

Analysis procedure performed on the 21 benefits data, repeated separately for the data from each survey (data from 2015-2016). Each EFA shows a unifactor solution, meaning that one underlying scale was created. The numbers in Table 2 (below) show the factor loadings (interpreted as correlations) for each item on the underlying factor.

Table 2. Factor loadings for benefit variables on the underlying unifactor for each survey. The loadings (considered ordinally highest to lowest) correlate across surveys. The correlation between SURE and CURE is .84; between SURE and RISC is .77; between CURE and RISC is .89.

Item	SURE	CURE	RISC
Clarify career path	.58	.68	.67
Skill interpreting results	.73	.82	.82
Tolerance for obstacles	.70	.82	.84
Readiness for more research	.71	.81	.85
Understand knowledge construct	.77	.85	.85
Understand research process	.72	.85	.84
Integrate theory and practice	.76	.84	.86
Understand real problems	.77	.84	.83
Assertions require evidence	.77	.85	.79
Ability to analyze data	.75	.82	.80
Understand science	.80	.84	.84
Learn ethical conduct	.70	.76	.73
Learn lab techniques	.60	.72	.74
Understand primary literature	.71	.79	.80
Skill in oral presentation	.70	.73	.77
Skill in science writing	.69	.77	.81
Self-confidence	.74	.78	.78
Understand how scientists think	.84	.86	.86
Learn to work independently	.71	.76	.77
Learning community	.76	.81	.81
Potential for science teaching	.66	.67	.72

This result suggests that the benefits data may be useful in at least two ways. First, it is possible to treat the scores as a scale, thus reducing the data to an average score for each student. Second, it is defensible to present the results of a course-embedded assessment by comparing the benefits to those of the SURE survey.

Evidence supporting validity: Published work

A demonstration of discriminant validity of the benefit responses comes from the work of Prof. Carol Bender and colleagues (2009), who demonstrated a pattern of benefit responses as well as intercultural learning gains Bender et al observed three groups of undergraduates, one group that had an intercultural experience (Semester at Sea), one group that had an undergraduate biology research experience at their home institution in the U.S., and one group that engaged in research abroad. All three groups completed the SURE survey and a survey of cultural gains from study abroad. As hypothesized, the two undergraduate research groups reported higher gains related to the benefits of research than the Semester at Sea group, while the Semester at Sea group and the group doing undergraduate research abroad reported higher gains in intercultural competence. The pattern of results suggests the sensitivity of the SURE to the research experience as well as discriminant validity, as the two measures were intended to capture different experiences.

General convergence

Several published accounts of the undergraduate research experience employ both the student surveys (SURE or CURE) and other measures of student success. These accounts do not attempt to code individual "unit data" to correlate student survey responses with other measures, rather, the aggregate student responses contribute to a profile of success supported by the other aggregate measures. Some of these accounts employ comparison or quasi-control groups to strengthen the conclusion that research experiences contribute to student success.

Lloyd, Shanks, and Lopatto (2019) reported a comparison of two groups of undergraduates, one that took a course in physiological psychology and one that enhanced the course with a UR experience. Both groups completed the CURE survey, and the aggregate

results of the 21 perceived benefits strongly favored the group that completed the research experience (see Table 2 of that study).

Jordan, et al. (2014) described the outcomes associated with the phage discovery research experience for first-year undergraduates. A version of the CURE survey was completed by students in the phage program, and the results were presented in a graphical comparison to national benchmark data for summer research students and students who completed a course with no research experience (Figure 2 of that study). The Figure shows that the phage group evaluated their learning benefits as similar to the summer research group and superior to the course group. These results generally converge with other reported outcomes for the phage students in the study, including superior retention in science and in course grades compared to traditional science courses (see Figure 3 of that study).

Staub, et al. (2016) reported on an adaptation of the phage-hunting research experience in which students completed an authentic research experience and were evaluated on measures including knowledge measures, lab math skills, understanding experimental design, and the CURE survey. All the measures triangulated toward a successful research experience, including the learning benefits (see Figure 3 of that study).

Nerio, et al. (2019) did a study of students working toward an associate's degree in the CUNY system. Students who participated in a one-year research experience evaluated that experience in a similar way to students in summer research programs (see Figure 4 of that study). The results were congruent with other measures of the research experience's impact, including retention and increasing likelihood of transferring to a four-year institution.

Correlations

The work of the Genomics Education Partnership (e.g., Lopatto, et al., 2008) has permitted the correlation of unit data using a version of the CURE survey together with a knowledge measure concerning gene annotation. Shaffer, et al. (2010) reported a relationship between the student reported learning benefits and annotation quiz scores (e.g., see Figure 7 of that study). The relation was not perfectly linear, but quiz scores were significantly higher for student groups who reported more learning. Shaffer, et al. (2014) presented results showing that student evaluation of the CURE/SURE learning benefits were similar for genomics students as for summer research students (see Figure 4 of that study). In addition, when the learning benefits were averaged for each student, analysis revealed that the average benefits were significantly higher for students who experienced more hours of instruction in gene annotation (see Figure 7; individual items for this analysis are shown in Figure 8 of that study). The GEP is preparing a paper on active learning (Lopatto, et al., in preparation) that will describe positive correlations between learning benefits and three subscales of the Test of Science-Related Attitudes (Fraser, 1978; 1981), including enjoyment of science, interest in science, and career interest in science.

Perera, et al. (2017) employed the list of learning benefits in a study of online and in-person versions of a science course. They performed an exploratory factor analysis that related 11 of the items on one factor they named "benefits" (see Table 3 of that study). They created a scale composed of these benefits that yielded a modest but significant correlation with course grades (0.16) and a stronger correlation with a science attitude scale they called "personal value" (0.52).

The SURE and CURE surveys remain popular options for course instructors and program directors looking for convenient instruments for assessment and evaluation. It is recommended

that the self-disclosed information of the undergraduate students be accompanied by other measures of program or course success to provide a more compelling argument for a credible outcome.

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