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ASSESSMENT

Incorporation and Evaluation of Authentic Research Experiences into the Curriculum through Development of a Theory of Action

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Abstract

A theory of action outlining undergraduate research program inputs and desired outcomes was developed and used to guide implementation of Course-Based Undergraduate Research Experience (CURE) sections and to create assessment tools to measure attainment of program goals in both apprentice-model undergraduate research and CURE. Student survey results for these two research programs were compared and suggest that many aspects of the academic goals such as designing an experiment, using equipment, collecting and analyzing data, and collaborating with others were achieved in both groups. Regarding the relationship with mentors, both groups reported receiving academic advisement in course selection and career options. Students in the apprentice-model program were more likely to discuss managing time, establishing career goals, networking, applying to graduate school, and building professionalism with their mentors. Students in the apprentice-model program also reported more time working with their research mentor, a higher quality research experience with their mentor, greater gains in communicating research findings, and more confidence in their research ability and future career path, at a statistically significant level. This approach and information may be useful to faculty mentors in improving the undergraduate researcher experience.

Keywords: *theory of action, apprentice model, course-based, authentic research experience, undergraduate research*

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New York City College of Technology, a branch of the City University of New York (CUNY), is a minority serving, open-access public institution. The college participated in a series of "Institutionalizing Undergraduate Research" workshops for mission-similar institutions focused on leadership and Council on Undergraduate Research (CUR) skills development (NSF 0920275, Elizabeth L. Ambos, principal investigator). A resulting goal was to expand authentic research experiences into the classroom to increase the number of students benefiting from undergraduate research. When the CUNY Central Office of Academic Affairs subsequently released a Student Success Request for Proposals (RFP) in fall 2013, the college successfully applied for funding to support "City Tech: Assessing the Impact of Undergraduate Research on Degree Attainment and Student Success." The project involved three major components:

1. Assessment of student outcomes for the college's Emerging Scholars program, an apprentice-model undergraduate research program in existence since fall 2006. Students in this program receive $500 stipends per semester of undergraduate research and are expected to conduct approximately 50 hours per semester of work as well as attend four professional development workshops on topics such as researching in libraries, writing abstracts, preparing posters, and understanding safety and ethics. They also submit an abstract and participate in the college's poster session at the end of each semester.
2. Expansion of Course-Based Undergraduate Research Experiences (CURE) into four laboratory courses and their assessment.
3. Development of a theory of action to guide the design and implementation of the CURE and development of assessment tools.

Previous work has reported on key aspects of CURE (Auchincloss et al. 2014). The Course-Based Undergraduate

Research Experiences Network (CUREnet) drafted an operational definition of a CURE that articulated what makes a laboratory course or project a "research experience." The five components of the definition are (1) use of scientific practices, (2) discovery, (3) broadly relevant or important work, (4) collaboration, and (5) iteration. These components can be described through a quantifiable framework. Instructors may use the framework to delineate their instructional approach, clarify what students will be expected to do, and articulate their learning objectives. Auchincloss and colleagues further reported that most studies reporting assessment of CUREs in the life sciences have made use of the CURE Survey (Lopatto 2010). The CURE survey is composed of three elements: (1) an instructor report on the extent to which the learning experience resembles the practice of science research, (2) student reports of learning gains, and (3) student reports of attitudes toward science.

The authors of this article hypothesized that CURE implementation was likely to be more successful if it took into account the context of the institutional mission and complemented other ongoing initiatives. To provide an institution-specific framework for the integration and evaluation of CURE as well as to better articulate and evaluate the apprentice-model undergraduate research program, a theory of action was developed and used to create assessment tools.

Development of the Theory of Action

A program theory of action is "an explicit theory or model of how an intervention, such as a project, a program, a strategy, an initiative, or a policy, contributes to a chain of intermediate results and finally to intended or observed outcomes" (Funnell and Rogers 2011). Theories of action are used broadly in both strategic planning and program evaluation (Frechtling et al. 2010; Patton 2008). For example, a well-articulated theory of action can be used for project planning purposes such as to develop agreement among various stakeholders about the nature of the program and serve as the basis for identifying whether programs are working.

Various methods can be used to develop or elicit a theory of action. Funnell and Rogers (2011) describe three approaches. The first, *articulating a program stakeholder mental model,* involves working with individuals to articulate how they understand a program to work or how they would like to see the program work—in other words, what the program would look like if it were successful. The second approach, *deductive development* of a theory of action, involves identifying the problem to be addressed as well as the causes, consequences, and effective practices through the review of formal and informal documentation such as relevant research and professional experiences. A theory of action can also be developed through an *inductive approach*, which involves inferring the program theory from the operation of the program based on observation and interviews with key stakeholders.

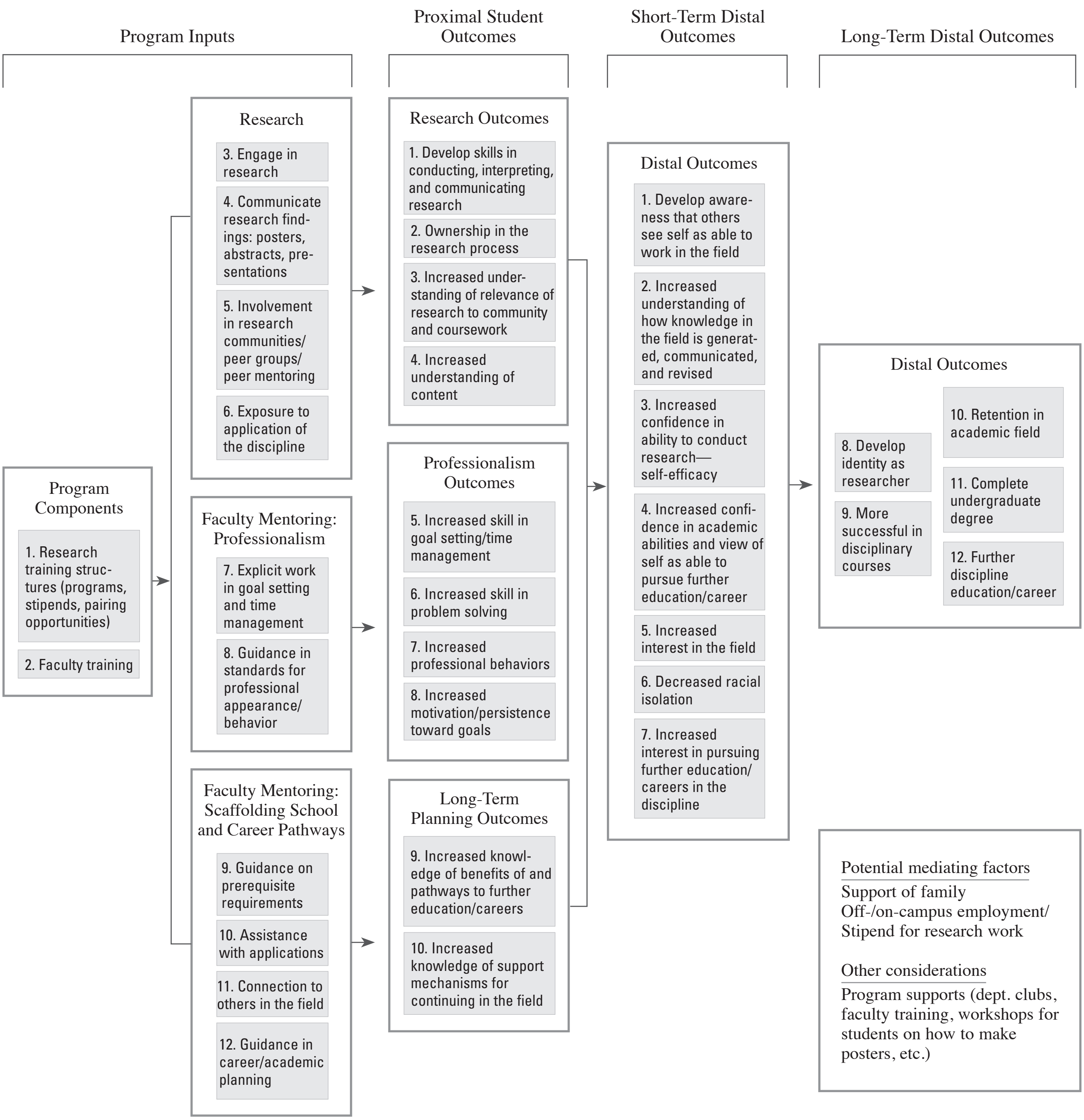
The project research partner Horizon Research, Inc. (HRI), used a combination of these approaches in developing a theory of action for the City Tech Undergraduate Research programs. First, HRI reviewed information on the apprentice-model undergraduate research program found on the City Tech website, along with information from the funding proposal. HRI also reviewed research examining the features of undergraduate research experiences and the impact of those experiences on students (e.g., Chang et al. 2014). This information was used to construct an initial theory of action for the program. The third data source was focus group interviews conducted at City Tech in May 2014 by HRI researchers. One focus group was conducted with members of the Undergraduate Research Committee (URC), who provided information on the characteristics and impacts of successful and less successful research experiences. URC is a group of City Tech faculty supporting undergraduate research through faculty mentoring efforts, faculty and student recruitment, and dissemination of information. Additionally, the URC reviewed the initial draft of the theory of action and provided feedback.

HRI also conducted three focus group interviews with 18 faculty members at City Tech representing 11 departments: architectural technology, biological sciences, chemistry, computer engineering technology, English, hospitality management, mathematics, mechanical engineering technology, nursing, physics, and social science. All but one faculty member had served, or was currently serving, as a faculty mentor in the undergraduate research program. During these focus groups, participants were asked to describe the effects of the most successful research experiences on students and to specify the elements that they believed led to those effects. Faculty members were also asked to describe characteristics of less successful research experiences. Finally, faculty members were asked about any barriers to offering high-quality research experiences for students and any additional resources they needed.

Participant responses were analyzed to identify common themes and revise the theory of action. The final theory of action is shown in Figure 1. The diagram is divided into three sections: (1) program inputs (PI), (2) proximal student outcomes (PO), and (3) short-term and long-term distal outcomes (DO).

The "program inputs" include experiences students may have as part of the City Tech undergraduate research program that includes centrally offered training in research skills, various aspects of the research experience, and mentoring on skills needed to work in a professional environment and preparation for future coursework and careers.

FIGURE 1. City Tech's Theory of Action in Its Undergraduate Research Program



The proximal student outcomes—those expected as a direct result of the research experience—include outcomes specific to learning about and experiencing research (such as skills in conducting, interpreting, and communicating research); outcomes related to professionalism (such as time management); and outcomes related to a students' long-term planning (such as increased knowledge of pathways to education and careers). The short- and long-term distal outcomes are outcomes expected as a result of students developing knowledge, skills, and attitudes from the research experience as well as the mentoring provided to them. For example, after successfully implementing a research project and having ownership in the process, students would develop awareness that others would see them as able to work in the field, would experience increased confidence in their ability to conduct research, and would eventually pursue further education and possibly a career in the discipline.

The theory of action was used to guide the design and implementation of the CURE sections and was also used in the development of tools that would be used to assess the quality and impact of both categories of research experiences. A description of these follows.

Design and Implementation of CURE

An RFP for faculty to implement CURE in a laboratory course was developed and forwarded to all full-time faculty members. The RFP included the CUR definition of undergraduate research, a brief literature survey highlighting some of the benefits of undergraduate research/inquiry-based learning, overarching curricular goals, eligibility, and budgetary and submission guidelines. A rubric was then developed for proposal evaluation that aligned with stated curricular goals (see http://www.citytech.cuny.edu/research/docs/Appendix_1_Proposal_Review_Rubric.pdf). The college's URC evaluated the submitted proposals. Funding was awarded to the most meritorious proposals for faculty summer salary for curricular development, and start-up materials and supplies for at least one section of the course. Prior to the official award, reviewer concerns were presented to the proposal submitters so that they could address and strengthen their projects. The participating faculty members were encouraged to incorporate the various components of the theory of action into the revised sections. Two CURE sections were first offered in fall 2014 and two in spring 2015. Three of the four CURE courses receiving funding were lower level, and one was upper level. One CURE section, General Biology I Laboratory, was not offered in spring 2015 when the survey administration occurred because of faculty teaching assignments and was not included in the survey. A fifth CURE section of General Chemistry II Laboratory, supported with alternate college funds but using the same approach, was included. A summary of all five CURE curricular innovations is presented in Table 1.

TABLE 1. Highlights of CURE Curricular Innovations

Course	Role in the curriculum	Curricular innovation	Enrollment, spring 2015
Advanced Solids Modeling, IND 2304	Required sophomore-level course in the associate in applied science degree programs in both mechanical engineering technology and industrial design and the bachelor of technology degree in mechanical engineering technology.	Students design and fabricate custom-designed orthopedic metallic implants (CDOI). Unlike the old course content that focused solely on software skills, the new approach motivates students to solve challenges in design, materials, and fabrication of metallic implants.	19
Plastic Product Manufacturing, MECH 4720	Required senior-level course in the bachelor of technology degree in mechanical engineering technology.	Groups of students choose a unique product to design. They conduct research into product specifications, customer needs, mechanical properties, and design issues related to environmental concerns. They then make the product and evaluate its performance to develop recommendations for improvement.	19
Network Fundamentals, CST 2307	Required sophomore-level course in the associate in applied science degree in computer information systems and the bachelor of technology degree in computer systems technology.	Students develop research questions related to networking challenges and create unique protocols to solve them. They then test their protocols using simulation labs.	24
General Chemistry II Lab, CHEM 1210L	Required freshman-level course in the associate in science degree in chemical technology, the bachelor of science degree in applied chemistry, and a required course or elective in several other majors. Also satisfies the general education scientific world requirement.	Students obtain samples of Hudson River water, develop research questions, and measure properties such as pH and conductivity to answer those questions.	24
Biology I Lab, BIO 1101L	Required freshman-level course in BS in bioinformatics, applied mathematics, and allied health degrees. Meets the general education life and physical sciences requirement.	Case study on measuring glucose to illustrate the analytical techniques in urinalysis. Forensic case study for studying paternity using DNA fingerprinting. Learning objectives in laboratory exercises were rewritten to be in the form of a question.	Not offered

Development of Assessment Materials

The final theory of action was used to revise the survey that had been administered in the past to students participating in the City Tech undergraduate research program; this was a version of the Undergraduate Research Student Self-Assessment or URSSA (Hunter et al. n.d.), which better aligned with the theory of action than the CURE Survey of Lopatto (2010). The URSSA items were mapped to the theory of action to determine the alignment. The mapping process indicated that, although there were a number of components of the theory of action that were addressed by the existing student survey, many components were not covered at all or were addressed by only one or two items.

As a result of this analysis, the survey was revised to better align with the theory of action and to gather additional data about the nature of students' research experiences, their activities during the experience, and their beliefs about what they gained. It should be noted that it was not feasible to examine every area depicted in the theory of action.Thus, a necessary part of the revision process was to prioritize the components of the theory of action that were most important to measure and for which reasonably reliable survey items were available. A cross-walk showing the theory of action mapped to the revised student survey is provided in Table 2. Although it was not feasible to do so in this context, it may also be possible to split the components among multiple surveys administered at different times so that no single survey is overly burdensome. For example, a survey could be administered that asks students about the nature of their research experience and the more proximal outcomes each year they participate, with the more distal outcome questions posed every other year or just before students graduate.

In addition to the revised student survey, a faculty survey was developed using the theory of action to collect information on their perceptions of the nature of the student experience, resources used, barriers encountered during the experience, and additional support elements that would help the faculty in the future. Survey results from the faculty and student surveys would thus allow the college to examine relationships between student and faculty responses about the program leading to improved experiences and outcomes. Discussion of those results is beyond the scope of this article.

Assessment Methodology

The revised postresearch experience survey was administered to the 132 participants conducting research under the apprentice model in the Emerging Scholars (ES) Program and 86 students in CURE sections during the last two weeks of the spring 2015 semester. Results for the two groups were analyzed and compared. Statistical analyses were conducted via a Chi-square for dichotomous response items, whereas an independent *t*-test with the Welch-Satterthwaite correction for unequal sample sizes and unequal variance was conducted for the Likert-type scale items.

Discussion of Results

The results for statistically significant differences for each of the goals measured in this study are presented in Table 3 (nature of the experience), Table 4 (quality of the experience), and Table 5 (impacts of the experience).

Nature of the Experience

Both groups (ES and CURE) reported that the mandatory workshops (and, for CURE individuals, in-class discussions) on using the library, database search methods, safety and ethics training supported their learning. There was no statistically significant differences in the reported ratings of learning opportunities for designing an experiment, learning to use scientific equipment, collecting and analyzing data, connecting the field of research to industry and real-world settings, and collaborating with other students The results also suggest that students felt that both CURE and the ES program contributed to developing important academic skills. However, as shown in Table 3, at a statistically significant level, students in the ES apprentice model were more likely to conduct library research, develop a research question, and present a talk or poster than the CURE students. This suggests that greater focus on building communication skills, developing a research question, and conducting library research in CURE sections would better emulate the ES apprentice model.

Both groups also reported discussing academic/career goals, course selection, time management, graduate school and the graduate school application process, networking strategies, and professional behaviors with their mentor. Discussion of academic/career goals, time management, applying to graduate school, and professional behaviors was more likely to happen at a statistically significant level in the ES apprentice model. Thus another possible area of focus in CURE is intentional reflection and information on personal goal-setting, time management, and professionalism.

Students in the ES program reported working on their project an average of 9.4 hours per week, significantly more than the 5.4 hours per week in CURE sections. Given a 15-week semester, this suggests that students are devoting much more than the 50 hours expected for program participation. Students in the apprenticeship-model research program may have more access to laboratories or may simply be more committed to their project.

Quality of the Experience

Both groups reported receiving training on safety and ethics. As shown in Table 4, although both groups gave

TABLE 2. Survey Alignment with City Tech's Undergraduate Research Program Theory of Action

Theory-of-Action component	Corresponding survey items
Program components	
PI-1 Research training structures (programs, stipends, pairing opportunities)	8
PI-2 Faculty training	
Research experience	
PI-3 Engage in research	1, 3, 4 ,6, 7
PI-4 Communicating research findings: posters, abstracts, presentations	1
PI-5 Involvement in research communities/peer groups/peer mentoring	1, 3, 7
PI-6 Exposure to application of the discipline	1
Faculty mentoring: Professionalism	5, 6, 7, 9, 11
PI-7 Explicit work in goal setting and time management	2
PI-8 Guidance in standards for professional appearance/behavior	2
Faculty mentoring: Scaffolding school and career pathways	5, 6, 7, 9, 11
PI-9 Guidance on prerequisite requirements	2
PI-10 Assistance with applications	2
PI-11 Connecting with others in the field	2
PI-12 Guidance in career/academic planning	2
Research outcomes	
PO-1 Develop skills in conducting, interpreting, and communicating research	12, 13
PO-2 Ownership in the research process	14
PO-3 Increased understanding of relevance of research to community and coursework	12, 13
PO-4 Increased understanding of content	12
Professionalism outcomes	
PO-5 Increased skill in goal setting/time management	10, 14
PO-6 Increased skill in problem solving	12
PO-7 Increased professional behaviors	10, 14
PO-8 Increased motivation/persistence toward goals	10, 15
Long-term planning outcomes	
PO-9 Increased knowledge of benefits of and pathways to further education/careers	15
PO-10 Increased knowledge of support mechanisms for continuing in the field	15
Short-term distal outcomes	
DO-1 Develop awareness that others see them as able to work in the field	14
DO-2 Increased understanding of how knowledge in the field is generated, communicated, and revised	12, 13
DO-3 Increased confidence in their ability to conduct research—self-efficacy	12
DO-4 Increased confidence in academic abilities and viewing themselves as able to pursue further education/career	12, 15
DO-5 Increased interest in the field	15
DO-6 Decreased racial isolation	
DO-7 Increased interest in pursuing further education/careers in the discipline	15

Note: PI = program inputs, PO = proximal student outcomes, DO = distal outcomes

high ratings to their working relationship with the mentor, group members, time spent doing meaningful research, and advice received from the mentor, there was a statistically significant increase in the ratings reported by those in the ES program compared to CURE respondents. The increase was reported in support and encouragement, constructive and useful critique of work, motivating, answering questions, acknowledging contributions and extending abilities by being challenged by the mentor, among others. This suggests that, although scale-up from the apprentice model to CURE is possible, some benefits may be lost. This may be due to time on task. Although in theory the time spent time in each program over a semester is comparable (approximately 50 hours per semester in the ES programs compared to a one-credit laboratory course of approximately 45 hours per semester), students reported spending approximately 4 more hours per week working on their project in the ES program. Another explanation is the opportunity for more individualized attention from the mentor. A possible direction for a relatively low cost

TABLE 3. Highlights of Statistically Significant Postundergraduate Research Experience Survey Responses—Apprenticeship-Model Emerging Scholars (ES) Compared to CURE Spring 2015—Nature of Experience (Most Recent Experience)

1. Which of the following did you do as part of your most recent research experience?
(Select all that apply)—method: X^2 Independence[c]

Q1	ES results[a]	Cumulative CURE results[b]
Library research	48%	23%
Developed a research question	38%	10%
Presented a talk	34%	15%
Presented a poster	73%	10%

2. Which of the following did you discuss with your mentor?
(Select all that apply)—X^2 Independence[c]

Q2	ES results[a]	Cumulative CURE results[b]
Your academic/career goals	59%	39%
Time management	60%	34%
The process for applying to graduate school	21%	3%
Networking with other professionals	38%	15%
Professional behaviors and/or appearance	34%	15%

3. How often did you do each of the following?
1 = Never, 2 = Rarely (e.g., once or twice during the semester), 3 = Sometimes (e.g., once or twice a month), 4 = Often (e.g., once or twice a week)—*t*-test[c]

Q3	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
Worked with your research mentor on your research project	3.8	0.9	2.9	1.1	t = -6.00
Read papers related to your research project written by your mentor	3.0	1.2	2.5	1.0	t = -2.78
Read papers related to your research project *not* written by your mentor	3.3	1.1	2.8	1.0	t = -2.89

4. How many hours per week did you work at research-related activities?
3 = 1–5 hours, 8 = 6–10 hours, 13 = 11–15 hours, 18 = 16–20 hours, 21 = 21 or more hours—*t*-test[c]

Q4	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
How many hours per week did you work at research-related activities?	9.4	6.0	5.4	3.5	t = -5.02

5. On average, how many hours per week did you spend talking with your mentor?
1 = 1 hour, 2 = 2 hours, 3 = 3 hours, 4 = 4 hours, 5 = 5 or more hours—*t*-test[c]

Q5	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
On average, how many hours per week did you spend talking with your mentor during your most recent research experience?	2.9	1.5	1.8	1.0	t = -5.85

[a]ES results N = 82/132, 62% response rate
[b]Cumulative CURE results, N = 61/86, 71% response rate
[c]Significance level, $p < .05$

may be adding peer mentors in CURE sections to help support group dynamics and provide more personalized mentoring.

Impacts of the Experience

There was no statistically significant differences in reported gains related to analyzing data for patterns, problem solving in general, understanding the theory and concepts guiding the research project, engaging in scientific writing, defending an argument, maintaining a lab notebook, making observations, using statistics to analyze data, calibrating instruments, working with computers, strengthening interest in the field of study, preparing for graduate school or employment, heightening motivation, or advancing in knowledge. As shown in Table 5, at a statistically significant level, students in the ES program reported greater gains in making oral presentations, preparing posters, understanding journal articles, and conducting database or Internet searches. Additionally, at a statistically significant level, students in the ES program reported greater confidence for future research or advanced coursework and greater gains in their mentor's confidence in them. These results correlate with findings already discussed in the nature of the experience—more effort to incorporate professional communication skills in CURE sections is an area for improvement, as this could both improve communication skills and confidence.

TABLE 4. Highlights of Statistically Significant (*t*-test[a]) Postundergraduate Research Experience Survey Responses—Apprenticeship-Model Emerging Scholars (ES) Compared to Course-Based Undergraduate Research Experiences—Spring 2015—Quality of Experience

1. Please rate the following regarding your research experience:
Missing = N/A, 1 = Poor, 2 = Fair, 3 = Good, 4 = Excellent

Q6	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
My working relationship with my research mentor	3.7	0.7	3.0	1.4	$t = -5.06$
My working relationship with research group members	3.5	1.4	3.0	1.4	$t = -3.49$
The amount of time I spent doing meaningful research	3.4	0.9	3.1	1.4	$t = -2.75$
The amount of time I spent with my research mentor	3.5	0.9	2.7	1.3	$t = -5.06$
The advice my research mentor provided about careers or graduate school	3.4	1.4	2.8	1.4	$t = -3.25$
The research experience overall	3.7	0.8	3.1	1.3	$t = -4.50$

2. Please rate the following aspects of your most recent research experience:
Missing = N/A, 1 = Very dissatisfied, 2 = Somewhat dissatisfied, 3 = Somewhat satisfied, 4 = Very satisfied

Q7	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
Support and guidance from program staff	3.6	1.3	3.2	1.4	$t = -2.85$
Support and guidance from my research mentor	3.7	0.9	3.3	1.1	$t = -3.28$
Support and guidance from other research group members	3.6	1.5	3.2	1.4	$t = -2.67$
Research group meetings	3.5	1.4	3.1	1.4	$t = -2.83$

3. How much did the following activities support your learning?
Missing = N/A, 1 = Not at all, 2 = A little, 3 = A good amount, 4 = A great deal

Q8	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
Session(s) on science writing and presentation	3.3	1.3	2.9	1.3	$t = -2.30$

4. Indicate the extent to which you agree or disagree with each statement listed below:
1 = Strongly disagree, 2 = Disagree, 3 = Slightly disagree, 4 = Agree, 5 = Strongly agree

Q9	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
My mentor was accessible	4.6	0.9	4.2	0.8	$t = -2.93$
My mentor demonstrated professional integrity	4.7	0.9	4.3	0.7	$t = -3.46$
My mentor demonstrated content expertise in my area of need	4.7	1.0	4.4	0.7	$t = -2.62$
My mentor was approachable	4.7	0.9	4.3	0.7	$t = -3.68$
My mentor was supportive and encouraging	4.7	0.9	4.3	0.7	$t = -3.79$

(*table continues*)

TABLE 4. (cont.)

Q9	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
My mentor provided constructive and useful critiques of my work	4.6	0.9	4.3	1.0	$t = -2.90$
My mentor motivated me to improve my work product	4.7	0.9	4.3	0.9	$t = -3.00$
My mentor was helpful in providing direction and guidance on professional issues (e.g., networking)	4.6	1.0	4.2	0.9	$t = -2.91$
My mentor answered my questions satisfactorily (e.g., timely response, clear, comprehensive)	4.6	0.9	4.3	0.9	$t = -2.57$
My mentor acknowledged my contributions appropriately (e.g., committee contributions, awards)	4.6	1.1	4.0	1.0	$t = -3.48$
My mentor suggested appropriate resources (e.g., experts, electronic contacts, source materials)	4.7	0.9	4.2	0.9	$t = -4.13$
My mentor challenged me to extend my abilities (e.g., risk taking, try a new professional activity, draft a section of an article)	4.6	1.2	4.1	1.0	$t = -2.96$

[a]Significance level, $p < .05$

TABLE 5. Highlights of Statistically Significant (*t*-test[a]) PostUndergraduate Research Experience Survey Responses—Apprenticeship-Model Emerging Scholars (ES) Compared to CURE Spring 2015—Impacts of Experience (Most Recent Experience)

1. How much did you gain in the following areas?
1 = No gains, 2 = A little gain, 3 = Moderate gain, 4 = Good gain, 5 = Great gain

Q10	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
Managing my time	4.1	1.1	3.6	1.2	$t = -2.61$
Ability to work independently	4.3	1.2	3.9	1.3	$t = -2.07$
Ability to conduct myself in a professional manner (e.g., how to dress, communicate)	4.2	1.2	3.6	1.4	$t = -3.29$

2. How much did you gain in the following areas?
1 = No gains, 2 = A little gain, 3 = Moderate gain, 4 = Good gain, 5 = Great gain

Q11	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
Figuring out the next step in a research project	4.1	1.0	3.7	1.2	$t = -2.52$

3. How much did you gain in the following areas?
1 = No gains, 2 = A little gain, 3 = Moderate gain, 4 = Good gain, 5 = Great gain

Q12	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
Making oral presentations	3.7	1.4	3.2	1.5	$t = -2.51$
Explaining my project to people outside my field	4.1	1.1	3.6	1.4	$t = -2.98$
Preparing a scientific poster	3.8	1.3	3.3	1.5	$t = -2.40$
Understanding journal articles	3.8	1.4	3.3	1.3	$t = -2.18$
Conducting database or Internet searches	4.2	1.2	3.8	1.1	$t = -2.27$

(*table continues*)

TABLE 5. (cont.)

4. Rate how much you agree with the following statements.
1 = Strongly disagree, 2 = Disagree, 3 = Slightly disagree, 4 = Slightly agree, 5 = Agree, 6 = Strongly agree

Q13	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
My research experience has prepared me for advanced coursework or thesis work	5.2	1.4	4.7	1.2	*t* = -2.22
My research experience has made me aware of different options for furthering my education.	5.1	1.3	4.8	1.2	*t* = -2.07

5. Rate how much you agree with the following statements.
1 = Strongly disagree, 2 = Disagree, 3 = Slightly disagree, 4 = Slightly agree, 5 = Agree, 6 = Strongly agree

Q14	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
My research experience has made me more confident in my ability to conduct research.	5.2	1.5	4.5	1.4	*t* = -3.60
During my research experience, my mentor became more confident in my ability to conduct research.	5.2	1.5	4.5	1.4	*t* = -3.47
My research experience has made me more confident in my ability to succeed in future coursework/career.	5.3	1.6	4.7	1.3	*t* = -3.10

6. Compared to your intentions before doing research, how likely now are you to:
0 = N/A, 1 = Not more likely, 2 = A little more likely, 3 = Somewhat more likely, 4 = Much more likely, 5 = Extremely more likely

Q15	ES		Cumulative CURE		*t* statistic
	Average	Standard deviation	Average	Standard deviation	
Enroll in a PhD program in science, mathematics, or engineering?	3.6	1.8	2.8	1.8	*t* = -3.03
Enroll in a master's program in science, mathematics, or engineering?	3.8	1.9	3.3	1.8	*t* = -2.21
Enroll in a combined MD/PhD program?	3.5	1.8	2.8	1.7	*t* = -2.74

[a]Significance level, $p < .05$

Lessons Learned

Compelling reasons for incorporating authentic research experiences into the curriculum include opportunities to increase the number of students that can benefit beyond the apprentice model—particularly students who might not self-select to participate—and to motivate promising students to continue research. However, this is a relatively new curricular goal with few models of best practices. A theory of action, which articulated program inputs and desired outcomes, was developed after interviewing faculty committed to undergraduate research. The theory of action provided an institutional framework for developing, implementing, assessing, and ideally improving CURE. Analysis of survey results suggested that many aspects of the program goals related to the research experience such as designing an experiment, using equipment, collecting and analyzing data, and collaborating with others were achieved in both groups. In terms of the relationship with their mentors and the quality of the experience, both groups reported receiving academic advisement regarding course selection and career options. Students in the ES apprentice model were more likely to report discussing time management, career goals, networking strategies, graduate school application procedures, and professionalism with their mentors, as well as having an opportunity to communicate research findings, at a statistically significant level. These results suggest areas for improvement in CURE sections such as the following:

1. Incorporate more opportunities for students to conduct library research and communicate their research findings such as a CURE poster session or mini-conference.

2. Schedule faculty-student meetings with individual or small groups of students and faculty to discuss research, additional research opportunities on and off campus, career goals, professionalism, and graduate school. These meetings, of course, would require a very strong commitment on the part of the faculty. Alternatively, institutions could invest in training and hiring peer mentors to fill some of these roles.

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