Measuring Student Learning Gains in Independent Research Experiences in the Sciences through Reflective Practice and ePortfolios

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Abstract: Undergraduate scientific research experiences provide students unscripted, active learning opportunities where the students take the lead in inquiry, problem solving, and analysis. Biology and chemistry majors at St. John Fisher College participate in a competitive 10-week summer research experience mentored by a faculty member. Evaluation of the program began in 2016 with a final reflection at the end of the experience being required of students in this cohort. In 2017, students were guided through three prompted reflection exercises and then utilized an ePortfolio to house their reflections and key components of their research experience. Students in both cohorts were required to complete both the Preflection and SURE III nationally-vetted surveys designed to measure self-reported learning gains in independent research by Professor Lopatto at Grinnell College. In 2016, students rated their learning gains on the SURE III survey lower than those students who participated in the survey at other colleges and universities across the country. In 2017, the cohort that completed the reflections and ePortfolios, reported their learning gains on par with students nationally. The coding of student reflections and SURE III survey data taken together show synergy and agreement pointing to areas of focus for program improvement moving forward.

Key Words: undergraduate research, reflection, metacognition, ePortfolio

Introduction

Undergraduate research as a high impact practice allows students to foster broad knowledge of human cultures and the natural world, strengthen intellectual and practical skills, and practice integrative and applied learning (AAC&U, 2007; Kuh, 2008). Graham et al. (2013) have identified early research experiences and active learning as key components for increasing confidence and motivation for STEM majors and for strengthening their persistence (Toven-Lindsey et al., 2015; Bandura, 1997; Estrada, 2011).

As a result, many colleges and universities offer intensive, faculty-mentored summer research experiences in the sciences. National Science Foundation supported programs are common, but one is not available on our campus at St. John Fisher College at this time. Our Summer Fellows Research Program aims to support students as they engage in an intensive summer research experience, practice goal-setting and critical self-reflection, and learn to communicate research findings to peers and a broader community of scholars. The program also aims to support mentors as they intellectually engage the next generation of scholars in their discipline as they also extend their scholarship. In efforts to provide improved holistic student support, we have critically examined our program and implemented guided, metacognitive reflective practice for students in this program.

While the literature is slim regarding support for reflection and ePortfolios with science students, there is growing support for these impactful pedagogies (Harring & Luo, 2016; Onorato, 2014). Other noted benefits of ePortfolios supported in the literature are described by Haave (2016) who noted students did not realize skills like critical thinking, communication and research skills were part of their degree, instead focusing on the science specific skills, while ePortfolios allowed for the conversation on the development of those types of skills through metacognition and reflection. Also, Haave (2016) remarks on the ability to make connections across multiple courses, the requirement for students to read and reflect on instructor provided feedback, and finally, students' ability to use the ePortfolio for potential employment opportunities in the future all result in positive student outcomes.

Few of those who adopted ePortfolios began with reflection as a primary goal, however most came to recognize the role of reflection very quickly in the use of ePortfolios. Instructors were surprised at

students' lack of ability to reflect and therefore needed to spend time teaching students this skill. Reflection was used in a wide variety of courses and programs using ePortfolios, but the specific types of reflection fell into two categories; helping students make connections between their learning and other experiences and to help students reflect on themselves (metacognition) (Landis et al., 2015).

"Folio thinking is a reflective practice that situates and guides the effective use of learning portfolios. Drawing upon the literature in experiential learning, metacognition, reflective and critical thinking, mastery orientations to learning, and, of course, learning portfolios, folio thinking aims to encourage students to integrate discrete learning experiences, enhance their self-understanding, promote taking responsibility for their own learning, and support them in developing an intellectual identity" (Light, Chen, & Ittelson, 2012).

Reflection does not come naturally to students, however, and instead must be taught and encouraged to see its benefits. Providing students with coaching support through the creation of an ePortfolio leads to students becoming "reflective practitioners" (Hadley, 2007; Parkes et al., 2013).

Importantly, students in the sciences often feel a high level of pressure related to future career aspirations, based on the number of available jobs and being able to adequately differentiate themselves from other job or graduate and professional school candidates. Wilson et al. (2018) reinforces the scholarly data on the positive impact undergraduate research has on STEM majors' career success, and the use of ePortfolios, along with career development learning tasks, can increase students' confidence in their own ability to apply and acquire graduate positions and jobs in their desired field (Yang et al., 2014). Oehlman et al. (2016) describes how creating an ePortfolio as a living document over a four-course and two-summer research experience allowed students to focus on their reflection skills, communication and writing skills, develop a professional identity and demonstrate their learning for external audiences. Complementing scholars' high-quality liberal arts curriculum, like that offered at St. John Fisher College, research experiences are one way to ensure scholars have the in-demand communication, collaboration, and problem-solving skills employers seek, further setting our students up for future success (Supiano, 2013).

Along with the use of a widely-used, nationally vetted survey tool (SURE III; Lopatto, 2004), we have implemented the use of student reflections and ePortfolios to guide students as they develop and recognize their own learning through the independent research experience. The reflections and ePortfolios provide a mechanism for students to study and then communicate their own progression and development as scientists in a way that research alone does not provide. The metacognitive practice of prompted reflection and composition of the ePortfolio itself improves students' recognition of their learning gains. Reflection prompts were designed to encourage and foster a growth mindset, which is especially critical to success in the reiterative process of scientific research (Howitt & Wilson, 2016).

Methods

The student surveys utilized in this study were supported by Grinnell College's Professor Lopatto, designed with support through HHMI funding (Lopatto, 2004). The Preflection survey helps to gauge a student's perception on their experience before they begin their research. The SURE III (Survey of Undergraduate Research Experiences) survey collects quantitative data on student research experiences and provides benchmarking data comparing our students to all those that participate nationally in the same time frame. Evaluation of student reflections took a qualitative approach similar to that utilized by Hunter et al. (2007), where ethnographic coding and analysis was utilized.

Results and Discussion

In 2016, 12 of our biology and chemistry summer research students completed the Preflection and SURE III surveys, 75% of whom were new to research. Nationally, 2,777 students took the Preflection survey and 3,478 completed the SURE III survey.

Our students identified the following as their *strongest* learning gains:

- Tolerance for obstacles in the research process
- Readiness for more demanding research
- Understanding how scientists work on real problems
- Learning laboratory techniques
- Learning to work independently

Our students identified the following as their *weakest* learning gains:

- Learn ethical conduct
- Skill in science writing

Figure 1 depicts how our students noticeably rated their learning gains lower than the national peer pool on the SURE III survey. With the exception of *learn*

lab techniques and *learn to work independently*, obvious components of a summer research program in the sciences, all other learning gains appear to be a concerning, stark difference compared to other students.

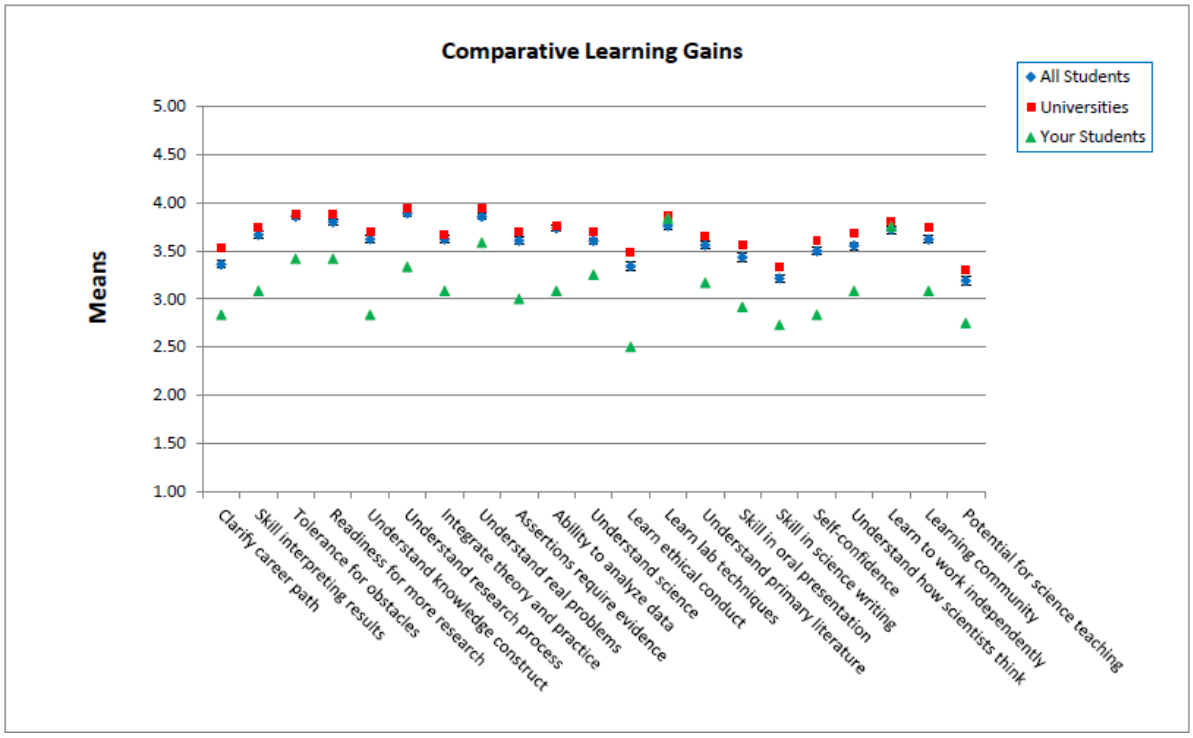

Figure 1: SURE III survey results, 2016. St. John Fisher College students in the summer research program are represented by green triangles, n=12. The blue diamonds represent n≤3478 responses from students nationwide who also took the SURE III survey between January 1 and September 8, 2016. The vertical lines depict plus or minus two standard errors.

This evidence that the students self-identify as less competent compared to the national peer pool was surprising and although students otherwise indicated a positive research experience (e.g. positive mentor ratings and finding research interesting), we felt action and further investigation was critical to providing a rich experience for our summer research students.

In our effort to utilize assessment data collected in 2016 to close the loop, we implemented a small, but significant change to the student experience and assessment plan through requiring students to reflect, with guidance, on their experience. These reflections were not used to formally evaluate or rate students in any way and did not influence their ability to earn a stipend or count toward a grade if the student was earning course credit.

Student reflections not only provide an assessment tool, but encouraging directed metacognition serves to support a growth mindset and the practice of recognizing self-growth in students (Howitt et al., 2016; Hunter at al., 2007). Also, we implemented an ePortfolio requirement as ePortfolios are considered a meta high-impact practice (Eynon & Gambino,2017). Student responses to the prompts below were uploaded to the students' required ePortfolios throughout the experience.

Reflection 1 – Week 2: What are your goals for this summer research experience? Describe at least one that relates to your academic growth and at least one that relates to your personal growth. Then, tell which goal you think will be easiest to reach, which will be the hardest to reach, and why for both.

Common themes identified through coding student reflection #1:

- To become independent in the lab
- Increase confidence
- Learn new techniques, how to use new equipment, and new methodology
- Gain experience for work or graduate school

- Improve information literacy skills
- Help clarify career path
- Improve note taking skills
- Improve problem solving skills
- Move out of comfort zones (physically and mentally, be open to new ways of learning)
- To contribute scientifically

<u>Skills Matrix Activity – Week 5:</u> Prior to completing the second reflection (prompts below), think about your goals for after Fisher. You could think about your immediate next step (e.g. graduate school, professional school, employment) or further out (e.g. your career in 5-10 years) and then complete the matrix below for yourself:

<u>Reflection 2 – Week 5 (after skills matrix activity):</u> How do you feel about this research project? What parts of it do you particularly like? Dislike? Why? Is there a particular aspect of the experience that is satisfying or frustrating? Describe.

	WHAT I *HAVE*	**WHAT I *NEED***	**IDENTIFY 1 OR 2 AREAS OF <u>NEED</u> AND DESCRIBE HOW YOU WILL TAKE A STEP TOWARD MOVING *FORWARD* IN THIS AREA.**
ACADEMICS ***(E.G. COURSES TO TAKE, MAJORS/MINORS)***			
EXPERIENCE & SKILLS ***(E.G. LAB SKILLS/TECHNIQUES, DATA ANALYSIS, TROUBLESHOOTING, DESIGNING DATA SLIDES, WRITING, ORAL PRESENTATION)***			

Table 1: Skills matrix activity students completed prior to writing their reflection at the mid-way point of the 10-week research experience.

Likes	***Dislikes***
Research topic	Data analysis
Accomplishing a set task	When experiments don't "work"
Being independent and trusted	Data interpretation
Contributing own ideas	When equipment failure impedes progress
When an experiment "works"	Reading so many articles
Applying class knowledge to the lab	Volume of data
Being responsible for something important	Worry about doing something "wrong"
Learning what they like and dislike	Making mistakes
Having time to focus on research	Writing & preparing presentations

Table 2: Common student responses to reflection #2 prompt. Students reported on what they liked and disliked about their projects at the mid-way point in the 10-week summer research experience.

<u>Reflection 3 – Final Reflection – Week 10:</u> You must complete a final, written reflection. As a guide, plan to write 2-3 pages (although, more is great if you have more to say).

- *What did you learn about yourself as you worked on this project?*
- *If you were to continue on in research, what would you want your next mentor to know about you? (What things are you good at? What would you like help with?)*
- *What work would you show your mentor to help them understand those things (question above)?*
- *How has using the ePortfolio and reflection activities for this experience impacted your responses to the above questions/prompts?*

Common themes identified through coding student responses to the first bullet point prompt, reflection #3, related to students' areas of personal growth and self-recognition:

- Increased confidence to apply to external research programs
-
- Capable of working independently
- Able to do more than they thought they could
- Proud of their work and how they learned from their mistakes
- Research requires an entirely different way of thinking
- Clarity in future career path and what they are passionate about
- Think this experience will help them tackle unexpected experiences in work and life
- Growth as a scientist (Students began calling themselves *scientists*!)

Areas of self-reported improvement	***Students want help with***
Techniques & following protocols	Data analysis & calculations
Problem solving	Data interpretation
Information literacy skills	Writing & preparing presentations
Patience	Organizing data & determining relative importance
Overcoming obstacles	
Seeing the importance of small goals that lead to large goals	Access to mentors for asking their questions (want this to remain)

Table 3: Common student responses to reflection #3, second prompt statement. Students reported areas they felt they had improved and specific areas they feel they still would like support.

Common themes identified through coding student responses to the final bullet point prompt, reflection #3, related to writing reflections and using ePortfolios:

- Can now see how far they've come compared to their original goals
- Helped keep track of their progress as a person and as a scientist
- Never would have spent time thinking about self-development
- Made them think about the experience in a different way
- Would use their ePortfolio to show their progress
- Gave them a chance to "say what they feel"

- The reflections are not just for "me" – they are for future employers/grad applications
- This will improve medical school application because they've already thought about what the experience has done for them
- Saw how much was accomplished
- Made this a personal experience
- Allowed them to be constructively self-critical and to achieve goals

In 2017, 17 of our biology and chemistry summer research students completed the Preflection and SURE III surveys, 59% of whom were new to research. Nationally, 1,817 students took the Preflection survey and 2,252 completed the SURE III survey. Our students identified the following as their *strongest* learning gains:

- Tolerance for obstacles in the research process
- Understanding how scientists work on real problems
- Learning laboratory techniques
- Learning to work independently
- Understanding the research process

Our students identified the following as their *weakest* learning gains:

- Learn ethical conduct
- Skill in science writing
- Skill in how to give an effective oral presentation
- Becoming part of a learning community
- Clarification of a career path

In 2017, our students, again, indicated a positive experience as they did in 2016 through strong mentor ratings and finding research interesting. Yet, interestingly, this cohort, who completed the reflections and utilized ePortfolios, self-identified as equally or more competent compared to the national peer pool on most learning gain areas measured by the SURE III survey. Again, the survey reveals areas for program improvement that we are using to continually improve our summer research experience at St. John Fisher College.

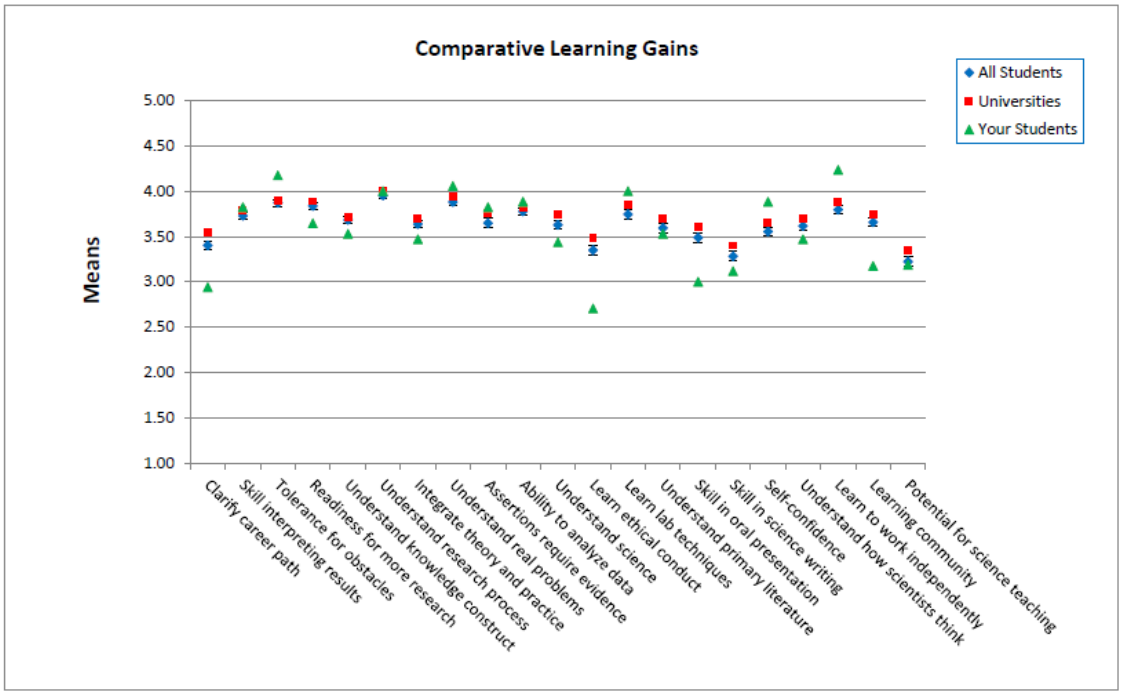

Figure 2: SURE III survey results, 2017. St. John Fisher College students in the summer research program are represented by green triangles, n=17. The blue diamonds represent n≤2252 responses from students nationwide who also took the SURE III survey between January 1 and September 4, 2017. The vertical lines depict plus or minus two standard errors.

Conclusion

This article describes a case example of how a sound assessment plan can measure student learning, improve the student experience, and lead to overall program improvement of the high-impact practice of undergraduate research in the sciences. Often times students engage in a mentored research experience, complete a final poster or paper, and even perhaps present their work to others without reflecting upon their own development through the process. In order to have the promised impact, students must be able to recognize the skills and habits of mind they are developing in order to continue to improve. Our program offers students structured reflection activities, along with professional presentation of their ideas through the use of an ePortfolio, to document their growth. Also, we employ the use of nationally vetted survey tools and a homegrown rubric for mentors to measure student laboratory skill development (not described here). This rubric is meant to stimulate discussion between mentors and student researchers along the experience, provide measurable outcomes, and to facilitate mentor writing of letters of recommendation for students in the future. Overall, our plan is effective in measuring multiple aspects of student learning through science research, providing actionable data for mentoring improvement, and overall data for program-wide improvement.

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