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Exploring the Experience of Undergraduate Research: A Case Study Using facebook

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Introduction

Participating in research as an undergraduate can be a powerful learning experience, helping students form connections with faculty, put classroom knowledge into practice, develop research skills and prepare for graduate study. Undergraduate research is a "high impact" educational practice[1] that can be particularly effective for engaging students from diverse backgrounds.[2–5] The NSF makes a substantial investment in undergraduate research experiences, which it views as "one of the most effective avenues for attracting talented undergraduates"[6] and preparing them for graduate study and careers in academia and industry.

In an effort to better understand the day-to-day experience of undergraduate research, eight students participated in a self-study of their own experiences as undergraduate research assistants. These students were part of a larger summer program at Michigan State University, where students engaged in ten weeks of full-time research with faculty in various Engineering disciplines. With the summer program coordinator serving as their research mentor, these eight students participated in a series of online conversations to explore their own experiences as they engaged in undergraduate research. Facebook was used as a platform to facilitate these student interactions, which included both prompted and spontaneous discussions. After the summer research experience had concluded, the students and their mentor analyzed the conversational threads to find evidence of changes in students' domain knowledge, research abilities, and personal, academic and professional goals.

Background and Motivation

Undergraduate research experiences have been shown to help prepare and recruit students for graduate study;[7–9] to engage and retain engineering undergraduates;[10–12] to connect students with faculty mentors;[13–16] and to help students understand research in a broader context.[17,18] Typically, undergraduate research experiences are evaluated through surveys of students and mentors, or from feedback gathered after various program activities. These assessment methods have been successfully used to measure both short-term impacts[8,19–21] and longer-term outcomes[14,18] of undergraduate research experiences. However, pre- and post-testing asks students to report on their experiences after the fact. The case study described here was motivated by a desire to document students' thoughts and experiences in "real time" as they evolved during the course of an undergraduate research experience.

Materials and Methods

The autoethnographic research study described here took place in the summer of 2012 at Michigan State University (MSU). The eight student participants in this study were a self-selected subset of a larger group of undergraduate research assistants participating in the MSU EnSURE (Engineering Summer Undergraduate Research Experience) program. This section

describes the structure of the EnSURE summer program, which was the broader context for this study, and the process of developing the self-study.

Summer Program Structure and Prior Research

EnSURE is a 10-week program coordinated by the College of Engineering at MSU. Applications are open to undergraduates from any major and institution, and at any level of experience, with a 3.20 minimum GPA. Faculty members submit a brief research project proposal and select their own research assistant from the applicant pool. During EnSURE, students engage in full-time, faculty-mentored research in one of six Engineering departments. In addition, students participate in weekly professional development seminars designed to help them prepare for graduate studies. At the end of the program, students present research posters at a campus-wide forum; in 2012, this forum involved more than 225 undergraduates from nearly 60 institutions, all sharing their experiences conducting research with faculty at Michigan State University.

The structure of the EnSURE program is modeled after successful NSF REU (National Science Foundation Research Experience for Undergraduates) programs.[6] However, this is not an NSF-funded REU site. Instead, about half of the funding for EnSURE comes from the MSU College of Engineering, with support from the MSU Associate Provost for Undergraduate Education; the remainder comes from the faculty mentors' research budgets. In the summer of 2012, the EnSURE program funded 89 undergraduates from 18 different institutions. 22% of these participants were female; 18% were from populations historically underrepresented in STEM; and 84% were domestic students. The average GPA for all students was 3.64 / 4.0.

The EnSURE program has been evaluated for a number of years, primarily using a combination of pre- and post-test surveys of undergraduate student participants; this prior research indicates that the professional development activities are successful at increasing students' awareness of and preparation for graduate studies.[8] In addition to these studies of the EnSURE program specifically, student participants were invited to participate in a broader, campus-wide study of undergraduate research experiences that builds on prior studies at Michigan State University[17] and examines the experiences of both students and research mentors through pre- and post-testing.

Development of the Self-Study

While the ongoing, survey-based assessments of undergraduate research experiences at Michigan State University have provided valuable data, the pre- and post-testing methodology is limited in its ability to capture students' insights and experiences as they unfold during a 10-week summer research program. In an effort to explore and capture students' insights in "real-time," the EnSURE program coordinator established a private group in Facebook to give students a forum to discuss their experiences as undergraduate research assistants during the course of the summer program. Students' participation in the Facebook group was voluntary and about 83% of the EnSURE students chose to join the group. The EnSURE coordinator posted weekly reflection prompts, and many students responded enthusiastically. These Facebook conversations, both prompted and spontaneous, led to real-life conversations about learning communities, undergraduate research, and the fact that there was a whole field of educational research that explores the practice of undergraduate research. Ultimately, a subset of the EnSURE student

participants decided to conduct a self-study of their own learning experiences during the summer program.

With the EnSURE program coordinator serving as the primary investigator, 12 students completed human-subjects research training and went through the IRB (Institutional Review Board) approval process in order to conduct an autoethnographical study of their own learning experiences during the EnSURE program. Of the 12 initial students, 4 decided that that they were too busy with their summer research to participate in this project, and 8 contributed to the online conversations that generated data for this study. All of these conversations took place in a separate Facebook group established with "secret" security settings, meaning that no one outside the group was able to see the existence of the group, its members, or the content of conversations.

The choice of Facebook as a platform for this study was motivated by students' familiarity with the social media tool and the availability of options for establishing private group conversations within Facebook. Many students already document their "real time" experiences and insights using social media platforms, such as Facebook.[22] Educators have experimented with using Facebook to coordinate student communications for group projects and learning activities.[23–25] Certainly, there are some potential drawbacks to the use of Facebook, such as concerns about privacy[26–29] and variations in students' motivation and interest in using social media for non-social purposes.[30–36] For the self-study described here, however, Facebook proved to be a convenient and private forum for the eight student participants to explore and record their experiences as undergraduate research assistants.

Research Questions and Data Collection

The self study described here was motivated by a desire to document students' thoughts and experiences in "real time" as they evolved during the course of an undergraduate research experience. To investigate the efficacy of this approach, the following research questions were developed for this study:

1. Are conversational prompts effective in encouraging reflection and discussion?
2. Are students interested in initiating and responding to spontaneous conversations?
3. Do the conversations reflect changes in students' understanding or experiences over time?

The self-study involved two types of Facebook-mediated conversations: prompted conversations, and spontaneous conversations. The prompted conversations were initiated by the program coordinator, who articulated a brief question or statement asking students to reflect on key aspects of their undergraduate research experiences, including:

- students' expectations and goals for participating in the program
- students' goals for their research projects
- ways to handle research obstacles
- lessons students learned through research
- students' future goals and plans related to research, graduate study and careers

Other than posting these initial conversational prompts/questions, the program coordinator did not participate in any of the conversations or respond to any of the students' posts. In addition to these prompted conversations, many students started new conversational threads within the Facebook group – posting questions, sharing interesting articles, and suggesting resources for further exploration. These conversations were entirely student-initiated and student-driven, and spanned topics from how to get into a good graduate program to articles about math education and science careers that students found interesting. The prompted and spontaneous conversations were conducted entirely in the secret Facebook group. The content of these conversations formed the data for this study, and the following section describes the data analysis process.

Analysis of Data

The study participants concluded their online discussions after finishing the 10-week EnSURE program, and the program coordinator did an initial review and organization of the data (culled from both prompted and spontaneous conversations). For the prompted discussions, students' responses were examined in light of existing research about key elements of undergraduate research experiences. Each of the conversational "threads" (initial prompt plus student responses) for the prompted discussions was examined separately during the analysis process to identify examples of positive and negative outcomes/experiences within each conversational topic.

The analysis of students' spontaneous conversations was not organized according to conversational "thread" because that is not how students' started or participated in these conversations. Students could start their own "thread" by posting a new comment or asking a question within the group, on any topic they chose. Sometimes other students responded in the "thread" on the same topic, while at other times the same theme was discussed across multiple "threads" or posts. All of the spontaneous conversations were examined as a group, and organized by major themes and topics of conversation.

The student participants of this study, guided by the program coordinator, took an active role in this process of reviewing the conversational data, organizing by thread or topic, summarizing key themes and comparing to existing literature about undergraduate research. The students helped identify key themes, provided feedback, comments and changes to the summaries and analysis, and ultimately prepared the current paper with guidance from the program supervisor.

Results – Prompted Conversations

Each of the prompted conversations was analyzed as a separate "thread" that included the original prompt (posted by the program coordinator) and all of the student responses to that prompt. The remainder of this section describes each prompted discussion and the **key themes and outcomes** (indicated in bold text) that were cataloged within the conversation during the analysis process.

<u>Prompt 1: Students' Expectations</u>

At the beginning of the EnSURE program, students' were given the conversational prompt: "What do you hope to learn this summer by participating in the EnSURE program? Students listed a variety of skills and experiences they hoped to gain during the summer – from broad

interests in exploring an area of research to very specific desires to complete an experiment or publication. Most of the student responses to this prompt reflected a broad desire to leverage the summer research experience as preparation for graduate school and/or future careers; this result is in keeping with existing research that indicates that undergraduate research experiences can help participants clarify academic, personal and professional goals.[1,5,7–9,11]

For some students, the EnSURE experience offered very practical supports on their **path toward graduate school**; for instance, STUDENT-A commented: "This summer I hope to gain a better understanding of what will be expected from me when I apply for graduate school. I am looking forward to learning new ways of putting my applications together. It is also a great way to gain a better understanding of [this university] and see if this is a place that I would like to pursue further education." STUDENT-B also expressed a desire to explore **academic and professional options**: "I, too, hope to decide whether I want to pursue a graduate degree or go into industry. I also want to deeply learn my topic and make a meaningful contribution in the field." STUDENT-D identified both broad and specific **personal and professional goals**: "I want to fundamentally awaken the PhD within and shift my mind set from being a student to being a researcher. The professional development seminars coupled with a good research project can help me make that transition successfully. I want to learn more about metagenomics and how computer science can assist in answering questions in this field. Develop hypotheses to test experimentally to see if I can in some small way contribute this summer." Similarly, STUDENT-F hoped to **gain additional experience**: "This summer, I hope to learn more about writing a research paper and getting published. I hope that I am able to really learn what goes into presenting the data that we have been collecting and mostly learn about how we can discuss it as part of a broader picture." STUDENT-G also identified specific goals: "I believe this summer program is a good opportunity to train me as a real researcher, and learn how to write research statement, academic resume and abstract. The poster forum also is a good chance to help us know and present our idea and how we solve the problems in research…. I feel this program is a good beginning for us before entering the graduate school and academic life, and I cannot wait to meet new people in other labs and share our research experiences."

In addition to this major theme of using the summer research experience to explore post-graduate options, two other themes emerged in the responses to the first prompt. One was the idea of using undergraduate research experiences as an opportunity to **put classroom knowledge into practical use**.[17] For STUDENT-C, EnSURE offered the opportunity to "learn more about what it means to actually be an engineer. The classes in the engineering college can be very boring and dry. They have a tendency to scare people away. I love research, it is a project with a purpose and an end goal. I hope to learn more about that, about how to conduct important studies and think about things more than the basic pattern that everyone knows."

The second minor theme that emerged in response to the first prompt was students' concern about whether they could manage the tasks and responsibilities involved with research. For example, STUDENT-E expressed concerns about **time management**: "My goal for the summer is to finish my project on time and without working extra (like during the weekend or staying until late at the lab). For this, I will have to manage my time at work very effectively and set short and middle term goals, for example, daily or weekly."

Prompt 2: Autonomy and Responsibility

The second prompt was posted at the end of the first week of the EnSURE program, and asked students to "add a post listing one thing from this week that surprised you, or one thing you learned this week that you wish you knew before the summer started." The most common theme within this conversation was that students were given more autonomy and responsibility than they had expected. For example, while STUDENT-F continued working in the same lab during EnSURE, the summer experience brought **new responsibilities**: "I was surprised to find that contrary to what I thought, I would be the owner of a project that I thought was going to be assigned to a grad student. It's already presented its challenges and I'm waiting to see how it turns out. If it works it should be pretty cool." STUDENT-B "was surprised at how diverse the work I've been able to do has been. The variety of equipment that I have been using to both make and test solar devices has been awesome. The work is also remarkably independent and I feel responsible for the project. It's vastly different from the internship and co-op work that I've done. Loving it!"

For STUDENT-C, the ability to **focus on research** was a dramatic change of pace from the academic year: "The thing that surprised me most is how different this is over taking classes. I have one major and two minor projects for the summer, which is so much nicer than classes as I have an end goal and work to do to get there, against doing repetitive homework or being tested." STUDENT-A also had a better understanding of the scope of the summer experience after the first week of the program: "The main thing that I learned after my first week in the program was that it was going to be a very fun and informative summer. Being able to learn new things is always great. In the computer science program, it is always important to keep yourself update with the changing programs and methods that are used in the industry. This summer looks like it will be a great opportunity to learn new ways to code that I would never have the ability to learn at my home institution."

Prompt 3: Setting Research Goals

By the end of the second week of EnSURE, students were getting settled in their research groups and had a chance to figure out what their summer projects might involve. They were prompted to share "what you hope to accomplish in the next 8 weeks of research, and any challenges you anticipate in that process." This prompt was inspired in part by prior research indicating the importance of helping students set goals and work through challenges as part of successful undergraduate research experiences.[10–12]

Many students responded to this prompt with goals related to **research publications**. Some, like STUDENT-B, had high hopes for the summer: "My goal is lofty: to get a data set good enough that it can be used in a publication. Challenges: Time constraints and general unforeseeable lab equipment problems." STUDENT-G had already submitted a research poster to a national conference, and hoped "to write a manuscript for this project and see could it [be published] or not. However, there are many challenges [that] I am going to face. First, my graduate colleague is going to travel next week for a month, and he had appointed an undergraduate student to me so I have to train the student until my colleague comes back. Second, the results might not be what I expect, so how to do an efficient troubleshooting is important. Last, I am still confused in how to

start a manuscript because different journals have different formats and requirements, so I have to discuss with my professor…."

For STUDENT-F, an experienced student with prior research results, the summer would focus on **gathering data**: "I want to collect and analyze data from 6 subjects in order to verify the regression methods I have been using on the data from the first two subjects. I haven't had much luck finding subject with the right size feet though. My challenge is that I only have one set of pressure insoles that are working correctly. If I can get that done, I want to start [a standard operating procedure] for the lab and start writing a paper on [this] project for publishing." STUDENT-D was new to research at MSU, but also developed very specific, data-centric goals for the summer: "My goal is to evaluate sensitivity/specificity of metagenomic assembly on test data sets. For example, evaluate how much of what should be recoverable *is* recoverable on the HMP test data set. If I work hard and am lucky I will be able to publish this work as a follow up to [previous research published by my mentor]. Challenges include; learning to program in Python, learning new stats software, and developing strong experimental design to evaluate the data set."

Other students expressed the desire to **gain technical skills and disciplinary knowledge**, as illustrated by STUDENT-A: "During this summer of research, I hope to learn a new computer language (or at least start learning), gain a further knowledge of what is required of a computational biologist, and to complete my research project. I am also excited to work with my mentor and to gain a better understanding of what graduate school will be like. The biggest problem that I anticipate is getting acquainted with the research that I will be performing. I look forward to the challenges that lie ahead though."

Prompt 4: Overcoming Obstacles

Unexpected challenges and setbacks arise in most research projects, and for undergraduates with limited previous experience these obstacles can be particularly frustrating. In the fourth week of EnSURE, students were asked to share some of their frustrations and challenges. Since part of research is learning to work through challenges,[1–3,10,12] students were specifically asked to share not just the challenges they encountered, but also how they overcame the problem – or what they had tried so far if they had not found a solution yet.

Several students discussed the challenges of **learning new processes, skills and tools**. STUDENT-A noted: "The biggest problem that I have encountered so far is trying to learn a new computer programming language. Luckily, the post docs in my lab have been very understanding about this learning curve and hosted information sessions on how to run certain aspects of the program. All the help so far has been great!!!!" STUDENT-D noted that: "my biggest challenge has been in the experimental design and method phase. When you're working on something so novel there is no rubric to measure what you're doing. Having no clear cut direction to go in is exciting and hard at the same time. I have been doing a lot of trial and error. It seems to just be determined enough to not give in to frustration is my best strategy for now!"

STUDENT-C reflected on the **difficulties of experimental work**: "For my research this summer I need to apply equal loading to different parts of the body, both in normal and shear. The

challenges come in finding a material that can be used on the body to apply the proffered loads and also a posture that will make it simple to do so. Also, nothing ever works the first time. It is much more common for everything to go wrong for the first couple tries. This can prove difficult and frustrating. As an example: we just bought new amplifiers for using with our load cells, however to get them to work properly took a day and a half of moving computers, hunting down calibration values, tinkering with software. It was a pain."

For STUDENT-F, **working with a research team** presented some challenges: "My research this summer involves processing thousands of data points, so post-processing the data in Excel has been slowing down analysis a lot. To get around this, we have been working on a macro. However, our [obstacle] has been deciding exactly what statistics to run and getting all the data to look the same, since this project has been worked on by a lot of different people. We finally had an in person discussion to finalize the way we would process the data and are now working out the kinks in writing a Macro."

STUDENT-G, who had nearly two years of experience prior to EnSURE, reflected on some of the challenges of a **longer-term research** project: "When I entered this lab, this project is brand new to my mentor and me, so I was assigned to start this project by myself. We did a lot of screening on different metal-catalysts, pH, concentration loading, etc. After a semester, there was a new PhD student join our lab, so the PhD and I decided to separate this work into two: he focused on the copper catalysts and I focused on the iron catalysts. We did a lot of references searching and trouble shooting, and accumulate our knowledge of each catalyst. Fortunately, both of us got significant results this year and have potential to publish two publications before the end of this year. It takes almost two years for us to solve the problems, and we spent a lot of time in the lab and tried to find the problems. I think the way how we survive and complete this project is because we share our mistakes and experiences, and we had asked and visited many scientists who had done in the similar field and share our experiences. Therefore, I think sharing the experience and knowledge but also protect your research is important."

Towards the end of the EnSURE program, STUDENT-B added to this conversation about research obstacles: "My project initially was to characterize how different thin film deposition parameters (pressure, temperature, etc) changed the properties of indium tin oxide (ITO), a material used as the anode and cathode in some transparent thin film organic solar cells. However, as I deposited more and more ITO, I learned that sometimes the material is deposited as an opaque layer. Before we can characterize different deposition methods, we had to step back and figure out why this was happening. We've figured out very generally why it occurs; now I'm working on ensuring it doesn't happen again so that my initial project can proceed. However, we may come back to this as there may be another story (aka publication) lurking in this roadblock."

Prompt 5: Short-Term Lessons and Longer-Term Impacts

In the final weeks of EnSURE, students were asked to reflect on what they learned during the 10-week program, and what impacts they thought the summer experience would have on their future plans. Many students reflected on the growth of their research skills and domain knowledge during the summer, and talked about their plans for further research. The positive outcomes

identified here are reflections of existing research about the benefits of participating in undergraduate research experiences; references to related work are included as appropriate below.

For STUDENT-E, the EnSURE experience **confirmed major and career choices**:[1,4,12,17] "The EnSURE program has been a very enriching experience in many senses. Now, as early as a rising sophomore, I already have a basic understanding of the research process, graduate school, and a field I would like to work on. Beyond the research work scope, I also made networking with people at different academic and professional levels, plus I got a pretty good idea of what it is to have a full time job. The two professors I worked with during the summer made me very enthusiastic about research." STUDENT-D also remarked about the importance of **developing professional networks and mentoring relationships**:[13–17] "being here has given me a clearer idea of how to transition to graduate school and what it will mean to be successful there. I never realized how important it was to find that mentor and community/Lab, or how much these relationships will dictate and determine your life for the next 4-10 yrs. This realization has me focusing on the lab and mentor I would like to work with first and foremost and not just the University alone." STUDENT-F also built important connections during the summer: "Although I like the responsibility of my own project, I found I was most productive when I had someone to talk through ideas and problems with, often consulting with my mentor and other students not working on the same project. As far as my professional development, the seminars were helpful in getting to see the general picture of applying to and attending grad school, but the most important help came from people in my research group. My mentor and one of his former students helped me network with professors in the graduate program at [the university] that I think I want to be in. So my goals for the fall are to visit [that university] and the professor I was introduced to and reach out to a few other professors that I am interested in meeting with. In the long term, I hope I can work for one of the [professors at that university] next summer and go to grad school there."

Several students reflected on the ways EnSURE helped them **develop research skills and prepare for graduate study**.[7–9] STUDENT-D "picked up skills on how to script in Python, and how to rent and run large computers on the cloud for working with Big Data. Of more significance, I developed an understanding of what are the interesting problems in my field and who has been trying to solve them. This information which was previously hazy, will help me grow in the right directions and make the right connections." STUDENT-B "learned a lot about the research process and how you can never predict where your research will take you. My initial project changed completely over the 10 week experience due to an unforeseen material behavior. I've learned that both patience and perseverance are key traits a successful researcher needs to have. I've also learned that writing a personal statement [for graduate school] is really challenging for me, and I'm glad to have had the support that this program has given me!!" STUDENT-A remarked that the summer led "to both personal and professional growth. After my time here at MSU, I have been able to gain a better understanding of the research that I see myself doing in the future. I also have a greater knowledge of the courses that I should be taking going forward to achieve the goals I have set for myself." In a subsequent comment, STUDENT-A detailed some short-term impacts of the summer experience: "I plan on presenting my work to my peers back at [my home institution]. Additionally, I am hoping to be presenting it at Annual Biomedical Research Conference for Minority Students in San Jose in November. I also plan on

taking the knowledge of research design that I have gained this summer and applying it to my current project that I am working on at my home institution."

Results – Spontaneous Conversations

In addition to the review of prompted conversations, discussed above, we also analyzed the spontaneous, student-initiated conversations within the Facebook group. These conversations were entirely student-initiated and student-led, with no input from the program coordinator. In analyzing these spontaneous conversations, we identified several themes and topics of particular interest to the students. The remainder of this section describes these themes in more detail.

Thinking about Graduate Studies

Some of the most detailed and lengthy conversations students initiated were about graduate studies – when and whether to pursue advanced degrees; how to find a mentor and institution that is a good fit for students' interests and needs; and how to prepare for and apply to a graduate program. STUDENT-G started a conversation about why students should consider graduate studies, and how participating in EnSURE could further that goal: "I am interested in doing experiments, reading the references and creating something new, and I would like to take research as the job in my career. I [was] inspired by my mentor so I want to be a research professor and do research in academic. In academia, I think the main goal is how to develop a new method to improve our life and make the environment better, and it is quite different than the industry. So the graduate school is necessary for my dream, and I will look for a post-doc position after graduate school. I think this program [will] really help me to develop my academic resume and academic/personal statement, and provide abundant information about what we should know before applying for graduate school, like NSF graduate fellowship, [responsible conduct of research], research ethic, etc. I had never known some of the information after the seminars, and they are very useful!"

This post prompted a response from STUDENT-H: "Going with what you said about EnSURE helping us for graduate school, I think an interesting take on it is how this is the first real glimpse that we get into what graduate school is like for some people in the program. I know that, seeing as this is my summer after freshman year, this is the first full-time "job" that I've ever had. It's really different going from only 8-12 hours a week working during classes to being able to be completely devoted to this singular task."

STUDENT-F also participated in the conversation about research, graduate studies and EnSURE: "I don't know about the rest of your projects, but last summer I was the owner of my project and helped transition it from one grad student leaving to a new grad student coming in, so I felt like I was getting a real feel for what grad school would be like. This summer I'm the main person in charge of my project with a part-time PhD student coming in to help me only occasionally. Research is a place where I feel independent and a lot more like a grown-up. It also helps motivate me to know that my projects are my own. I don't feel as much like I'm working for someone else as I do during my part-time job during the school year. As far as why I want to go to graduate school, I started doing research projects [in high school] (not very sophisticated but entirely student driven) so I kept doing it in college. I would encourage other students to at least

try an industry job like I did. I worked at [a major manufacturing company] and I liked it. However, it confirmed for me that I really like the independent nature of research more than the sometime bureaucratic atmosphere at a big company."

In a separate thread, STUDENT-G shared news articles about increasing competition among graduate school applicants, the impact of the new version of the GRE (Graduate Record Examination), and the increase in international student applications to graduate programs in the United States. STUDENT-D responded "It seems as though it is getting harder to get in [to graduate school] and less rewarding once you're there. I don't know what the answer is to the global education and job markets. But whatever it is I feel as though in general we as a generation are not prepared. We have to work harder, do more, get better grades, and get a lot more research experience; and on top of that face the reality that it does not mean we will get to go where we want to for studies or do the type of work we have been trained for, or even have a job!" STUDENT-G replied "I think the best way is learning without boundaries. Reading the news and articles so we know what happen to the world and how the science goes so far. Learn the new technology and know how it basically works can give us more idea to use in future. Open the global view because we cannot predict where we are going to work, maybe the job has many business trips or is in foreign area."

In reviewing these conversations, we were not surprised by students' views that participating in undergraduate research was a good way to explore and prepare for graduate studies – many previous researchers have found similar sentiments in surveys of undergraduate researchers.[7–12] What was most interesting about these conversations was the glimpse of students' thought processes; for instance, several commented that they were surprised about the different pace of full-time research, when compared to taking undergraduate classes. It was also interesting to see some negative comments and perceptions about the difficulty of getting into a good graduate program – and whether obtaining a graduate degree would necessarily lead to a job or career.

Research Writing and Reflection

STUDENT-D initiated a conversation about the importance of writing and reflecting throughout the research process: "Start writing before the experiments are complete. Start writing while you are still doing the experiments. Writing often evokes new ideas: you may realize that there are additional experiments to run or additional controls that you need to add. If you wait until you are done in the lab, have dismantled the equipment, and possibly moved on to another position, you will not have the opportunity to test these ideas." In response, STUDENT-E noted that "if you don't start writing, you will probably forget the ideas!" and STUDENT-G shared this approach: "I usually make flow charts on PowerPoint slide for my idea, experiments and references (time line). It really works when I want to share them with my mentors because it's easy to see." The conversation then returned to STUDENT-D, who commented "I like the power-point flow chart idea. I have never tried it before for this but I think I will do so this week. Thanks for the tip!"

A few days later, STUDENT-E returned to the topic of writing: "So at the beginning of the summer I decided to write a 7 line reflection [in my research] notebook everyday; and yesterday I decided to look back and read from the beginning. It made me realize how frequently my results have brought me up and down through the program. One of the most valuable lessons I have

learned in this experience is that in research, things go the way you expect less than usually. Sometimes, even when you think you followed the same protocol for an experiment, you get a different result. That is really frustrating."

Previous studies have indicated that participating in undergraduate research can help students develop stronger analytical and communication skills,[1,18,19] and REU-style experiences very often include experiences developing research papers, presentations, posters or other publications. The student conversations recorded here give an interesting perspective on students' research writing processes, and the value they perceive in writing as a developmental or learning exercise.

Research Presentations and Time Constraints

Towards the end of EnSURE, students began to post about the upcoming campus-wide research forum, where they would present their research. STUDENT-H started the conversation: "Something that I've been thinking about in the past few days with the poster/oral presentations coming up: How confident did you guys feel putting things together from (possibly) only nine weeks of research under your belt? Personally, I felt like my presentation was much more reflection oriented than anything, just because the nature of the research requires a little more time to get solid results." The response from STUDENT-A shared the concern about how much research could realistically be accomplished in a 10-week summer experience: "I would agree that it seems to be more of a reflection presentation that I will be giving. Although I am still confident that I will have some sort of result to present, the project that I am working on could definitely use more time to take it to that next level."

STUDENT-E extended the conversation by talking about how to approach the presentation process when research does not go according to plan: "The approaches you give to a project do not always go as expected. As [the EnSURE coordinator] said during one of the seminars, rather than finding a way of doing things, you might end up reporting a way of how not to do things. This is what my presentation is going to be focusing on. It is a little daunting, especially for someone like me new to research. But "bad results" (results you don't want but that are part of the data) are important too. Even though this is not normally what a researcher is aiming for. However, it is definitely part of the process."

In a separate conversation, STUDENT-D shared frustration with the limited timeframe for the summer research experience: "Probably the most frustrating aspect of this summer is the small window of time we have for research. For me I finally have all my data generated but I am having real challenges learning how to use complex new programs to analyze and graph huge data sets. It is as though the learning curve for becoming proficient in these is as steep as for actually generating the data itself. When you are down to the crunch and trying to pull your work together the stress and adrenaline are palpable. You wish you had more time but you have to make do. I guess this what it will be like in industry or academia, so I am glad to get the chance to develop coping mechanisms now rather than when my job is on the line."

Prior studies of undergraduate research participants have indicated that many find they develop better time management and organizational skills through their undergraduate research experiences.[1,17,37,38] Through the conversations recorded here, students in the EnSURE suggested

some of the ways that those time management skills develop over time – and how they dealt with the constraints and unpredictable nature of research processes.

Building Community and Sharing Resources

Many of the students used the Facebook group as a place to share interesting articles and resources on a variety of topics related to research, graduate studies, and STEM. Through these exchanges, students developed an informal network of like-minded colleagues and had the opportunity to practice communicating across disciplines and topics – a valuable skill for personal and professional success, and one of the positive outcomes noted in prior research.[12,13] STUDENT-D reflected on the importance of these types of intellectual exchanges: "I think it is in forums like this where we are being developed as emerging scientist that we can evolve networks and build the skills I mentioned bellow. I guess that is one of the reasons I am so excited to be involved. It would be nice if we had some sort of social time to get to know each other better and bond. The intangibles I think are often what is left out in terms of social connections and just making the time and/or space for these ideas to develop and grow."

Discussion

In reviewing the prompted and spontaneous conversations recorded via Facebook, it became clear that the answers to our first two research questions were a qualified "yes":

1. Are conversational prompts effective in encouraging reflection and discussion?
2. Are students interested in initiating and responding to spontaneous conversations?

As demonstrated by the data and analysis in the previous two sections, students were eager participants in the online conversations, both prompted and spontaneous. However, it should be noted that the eight students in this study were a self-selected group, and the simple existence of this research study (and the goal of publishing a paper co-authored by the student participants) likely helped to motivate participation. The students in this study also had opportunities to interact in person, as well as online, and many remained in contact with each other after the conclusion of the EnSURE program. Thus, while this study can offer some insight into the use of prompted and spontaneous online conversations within a small group of motivated undergraduate researchers, its findings may not be universally applicable.

Our third research question was: "Do the conversations reflect changes in students' understanding or experiences over time?" Again, the answer seems to be "yes" with some qualifications. Summarizing the analysis of the data presented in the previous two sections suggests several overarching trends, including:

- Growth in students' research skills, familiarity with research processes and content/domain knowledge
- Students receiving guidance, support and mentoring from faculty and other, more experienced researchers
- Developing a community of peers for students' personal and professional support
- Overcoming research challenges and helping students persevere through obstacles

- Increasing students' independence and autonomy, while also encouraging collaborative research
- Opportunities for students to develop written and oral communication skills for research contexts
- Helping students understand the nature of graduate studies, and helping to clarify students' personal, educational and professional goals

The conversations recorded in this case study support existing research about the key elements of meaningful undergraduate research experiences,[1,12,17–19,37] and offer a unique opportunity to observe the evolution of students' understanding during the course of an undergraduate research experience. For the eight student participants in this case study, Facebook provided a forum for ongoing reflection about their undergraduate research experiences. The combination of prompted and spontaneous conversations and the use of Facebook to capture students' thoughts and experiences in "real time" provide a unique perspective on undergraduate research experiences. However, the results should be viewed within the context of the participants – a small, highly motivated group of undergraduate researchers participating in an autoethnographical study.

Conclusions and Future Work

Throughout this study, we have seen examples of growth and change in students' understanding about research, graduate school, careers and their personal and professional goals. Perhaps the greatest value of this Facebook-mediated study is the ability to capture these student experiences in "real time," during the course of a 10-week summer research experience. For example, consider this pair of quotations from STUDENT-D. At the beginning of the summer experience, STUDENT-D talked about the reasons for participating in undergraduate research: "I am already very motivated to go to graduate school. I have already spent 15 years working in and involved in other careers. So for me, when I decided to pursue education, it was with the intent of getting my PhD and then either working in industry and/or Academia. My main interest outside my field is to inform others about science and how it has the power to transform peoples' lives tremendously. I see a huge need in this area because scientists do a poor job of communicating what they are doing to world at large. Most regular people experience the effects of technology and science, but they generally have a very poor understanding of what it is and what work is being done. This is a very difficult issue to overcome because [scientists do] not communicate it well traditionally. Something I am intent on changing! Secondly, because much of the populous is really biased to real scientific understanding either by religion and/or culturally. These are just some of the ideas I am passionate about and I would like to help motivate my peers to not only do great research but also be active agents in making us a community of science educators and teachers. And not in just the academic sense but in an everyday lived knowledge and more imbedded in our culture and thinking sense. I think we have to because of the resource scarcity our planet is facing and new demands of a global society."

10 weeks after this enthusiastic post, the same student reflected about what had been learned during the summer: "I have learned that you don't know what you don't know, and that this is the primary culprit for me as a young researcher. It means you don't know what to ask. It means you don't know what things will actually be challenging and what is rather simple to overcome. This all means you do not know how to manage your project overall, time wise and resource wise. So

far my best approach in overcoming this, is to attack every problem and task with 150% effort and energy otherwise you risk falling short of your goals. Looking back I have been challenged and I have learned an enormous amount this summer. I am really happy I had this blinded, grasping, stumbling to learn and solve experience. It has made me more confident in my ability to overcome the unknown and that which I perceived to be impossible."

These comments from STUDENT-D are characteristic of the passion, engagement, and perseverance demonstrated by students engaged in this self-study. Certainly, not all undergraduate researchers are as committed to the experience, and the self-selected nature of this study group warrants caution in interpreting the data. However, this case study provides a unique and valuable perspective on the specific experiences and mechanisms of undergraduate research that may contribute to the positive outcomes documented through the many studies that compare pre- and post-test data.

EnSURE is an annual summer program, and part of a larger undergraduate research initiative at MSU that involves many hundreds of students each year. With this large pool of potential research subjects, additional studies are planned using Facebook and other social media tools to capture students' research experiences in real time. Repeating the prompted conversation process with a larger sampling of student researchers would provide a broader context for identifying positive and negative impacts on undergraduate research experiences. Additionally, the 2012 EnSURE program participants are piloting an undergraduate research blog intended to inform the general public about research activities at Michigan State University, and to recruit new undergraduates to participate in this "high impact" learning experience.[1]

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