



A Case Study Exploring the Influences of Engaging Community College Students in Undergraduate Biomedical Engineering Research Experiences

Megan E. Faurot, Illinois Institute of Technology

Mr. Frederick Doe, Illinois Institute of Technology

Ms. Elana Rose Jacobs, Illinois Institute of Technology

Elana Jacobs is a first year doctoral student in Science Education at the Illinois Institute of Technology. With an M.Ed. in Instructional Leadership from the University of Illinois at Chicago and a B.A in Environmental Science from Hampshire College, she has over five years of experience working as a teacher in middle school science, math, and ESL in urban schools. In addition, she has extensive experience teaching science in museums and other informal learning environments. Her research interests include middle school science classrooms, how community college student navigate STEM majors, Research Experience for Undergraduate Programs.

Dr. Norman G Lederman, Illinois Institute of Technology

Dr. Eric M Brey, Illinois Institute of Technology

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Abstract

This study investigated a Research Experience for Undergraduates (REU) program at a Midwest research university that had two community college student participants in the summer of 2012. In the 10-week summer program, under the supervision of a faculty member, the community college students were paired with a graduate student and an experienced undergraduate researcher to work on a biomedical engineering research project. The research question of this study was, “What do community college students’ gain from an undergraduate research experience?” As this was the first year community college students participated in the REU, a case study approach was used to gain an in-depth, meaningful understanding of students’ experiences. Data was analyzed from pre- and post-surveys and an exit interview to construct the case study. A constant comparative method was used to develop conceptual themes that addressed the research question. The community college students experienced *self, perspective, support, knowledge, and relationship* gains. This study concluded that the main reason for the gains were the multilevel support systems that was in place for them in the laboratories and received by their families throughout the duration of the program. Study implications are that more research universities should target community college students to apply to their REU. However, future studies are critical to develop more effective research programs for community college students to pursue their science and engineering academic and careers goals.

Introduction

The American Association of Community Colleges reported in 2012 that 44% of undergraduate students in the U.S. were enrolled in community colleges¹. Approximately 50% of the African Americans and Hispanics who were undergraduate students attended community colleges. In addition, 57% of community college students were females and 46% of all community college students received some form of financial aid¹. Based on the increasing enrollment numbers and student demographics, community colleges play a critical role in supporting the U.S. efforts to increase the diversity, knowledge base, and skill level of the science and engineering workforce².

Community colleges are facing numerous challenges that hinder their success, including the transfer rates of students into 4-year universities to earn bachelor degrees, particularly in the science and engineering fields³. Research has indicated that 44% of community college students who intended to transfer dropped out or stopped out within six years and only 26% obtained bachelor’s degrees within nine years⁴. Factors contributing to these challenges include the lack of resources at community colleges to support innovative educational practices and opportunities and the lack of collaboration between community and research universities^{3,5}.

With the release of the Boyer Commission Report in 1998 there has been a substantial increase of student participation in undergraduate research and a widespread trend at research universities to develop institution-wide, centralized undergraduate research programs^{6,7}. Most of

the existing literature on undergraduate research focuses on the student benefits gained from participating in undergraduate research experiences. Most of these studies were conducted on undergraduate research programs at liberal arts colleges and have reported that undergraduate research experiences have professional, intellectual, and personal benefits on undergraduate students⁸⁻¹². Further research on the student benefits at all types of institutions, especially research universities, is critical in order to gain a better understanding of their impact and to develop the most effective practices for various educational environments. Developing a broader literature-base on undergraduate research would be of particular importance to research universities as they face the challenge of not having enough research opportunities to the increasing number of interested undergraduate students¹³⁻¹⁵. Thus, the purpose of this study was to examine the gains of two community college students who participated in an undergraduate research program at a research university.

Description of Program

From 2006 - 2012, a Midwest research university has delivered an REU. For 10-weeks in the summer approximately 10 - 15 undergraduate students participate in this program. Students are paired with a faculty member based on project rankings, student backgrounds, academic levels, and previous experiences. Depending on the structure of the laboratory, the undergraduate student either works directly with the faculty member or the faculty member assigns a graduate student to work with the undergraduate student. Under the guidance of the faculty member or faculty member/graduate student, each undergraduate student conducts a research project focused on engineering approaches to study the treatment of diabetes or its complications. The graduate student and undergraduate pairs have periodic meetings with the faculty member to report their progress and discuss data/results.

Participating faculty are from a variety of departments, including Biomedical Engineering, Chemical Engineering, Mechanical Engineering, Biology, Chemistry, and the School of Medicine. Diabetes is a complex pathologic condition, and addressing the disease requires a diverse set of approaches ranging from fundamental understanding of disease pathology, disease management, and treatment of either the disease directly or one of its many complications. The students' research projects are developed from ongoing work in the laboratories. The undergraduate students' research projects covered a diverse array of topics related to diabetes including metabolic engineering, biomaterials, biosensors, and tissue engineering.

In addition to conducting research, students participated in weekly seminars on topics related to diabetes (basic research, clinical treatment, public health, and healthcare policy), weekly ethics seminars, and off-campus tours of research and clinical facilities. These activities were designed to expose students to the broad health impact of the diabetes and the importance of research related to the treatment and potential cure of this disease and related complications.

Sample

Since the launch of the REU in 2009 at the Midwest research university, there have been a total of 50 student participants. This study focused on two of the 13 students who participated in an REU in 2012. Eleven of the 13 students were enrolled in either four-year universities or

liberal arts colleges from across the U.S. and two students understudy were enrolled in community colleges. The community college students were both female and grew up in large urban areas and attended public high schools. They were enrolled at two different schools within the community college system. For confidentiality purposes, the pseudonyms used in placement of the students' real names were Katarina and Estelle.

Background on Katarina

Katarina was a 26 year old, White woman from a middle class household. She was an Eastern European English language learner and both of her parents had graduate degrees and careers in science. Katarina had no siblings in her family who had completed college. During high school she took three AP science courses and had a GPA of 3.9. Katarina's roommate, a PhD science student, was the person who encouraged her to participate in an undergraduate research experience. She decided to apply because she thought it would be a great opportunity to figure out what it would be like to have a career in bioengineering. She also hoped that the program would help her make more definitive academic and career plans.

Katarina had completed one year of community college before the start of the undergraduate research program. She planned on earning her associates degree and then transferring to a 4-year university. Bachelor degrees she was considering included economics, biostatistics, and/or engineering. At the beginning of the program, she was not sure what her academic plans were after graduating from community college. Her career plans were also not well defined, but she did explain that she wanted a career that involved numbers and real-world problem solving. At the end of the program, her plans did become more defined. She described how she wanted to work for a couple of years after earning a bachelor's degree and then planned on pursuing a doctoral degree in either biomedical engineering or industrial engineering.

The most significant obstacles she identified in her post secondary education was financing her education and having to take several years off from school for a medical condition. Her determination and drive was evident in the fact that during the REU she was also enrolled in a summer class that met three evenings a week. Katarina's undergraduate research project focused on the influence of crosslinker molecular weight on the properties of polyethylene glycol crosslinked dermal extracts.

Background on Estelle

Estelle was a 21 year old, Hispanic woman from a low socio-economic single parent household. Only one parent had graduated from high school and she had no other siblings who had completed college. During high school she did take one AP science class but did not complete it. Her high school GPA was 2.0. Estelle decided to apply to the undergraduate research program to gain research experience, to learn more about diabetes, and help confirm her career path.

Estelle had completed two years of community college prior to starting the undergraduate research program. She planned on earning her associates degree and then transferring to a 4-year university to earn a degree in Biology. For the most part, Estelle's plans for after college did not

change from the beginning of the program to the end. Estelle was considering a master's degree or a medical degree to become either a laboratory technician or a physician's assistant. However, the timings of her plans did change in that she no longer planned on working for several years between obtaining a bachelor's degree and beginning her graduate studies.

Her most significant obstacles in her post secondary education were financing her education, taking math courses, and maintaining the drive to complete academically rigorous classes. She described herself as being a very social person and planned on keeping in touch with her peers from the undergraduate research program. Her determination and drive was evident in her overcoming her math phobia by studying statistics in depth and her spending days taking feedback from her professor and improving her final research Powerpoint presentation. Estelle's undergraduate research project focused on a cell adhesion assay and teaching module.

Data Collection and Analysis

A pre- and post-survey and an exit semi-structured interview gathered data to examine the research question, "What do community college students' gain from an undergraduate research experience?". Items in the surveys asked the students for demographic information (i.e. race/ethnicity, family income status), educational background and plans, and career plans. The semi-structured interview items were: 1) Describe your overall experience with your graduate student; 2) Describe the learning experiences you had with your graduate student; 3) Describe relationship-building experiences you had with your graduate student; and 4) Describe personal development experiences you had with your graduate student. In order to maintain consistency across the interviews, the first author conducted all interviews. Three independent educators established content validity of the assessments. There was unanimous agreement that the assessment items covered content that the research question intended to measure.

The constant comparative method developed by Glaser and Strauss in 1967 was used to analyze the survey and interview data. The constant comparative method is used to analyze qualitative data by constructing themes and/or categories. The interpretations of the emergent constructs constitute the findings of the study. Units of data from the student responses, from the survey and interview, deemed relevant to the study were constantly compared with one another. The reoccurring incidents and patterns in the data were constructed into five main themes. Criteria used to allocate data to one theme or another became more clearly defined throughout the data analysis. Conservative counting was used to not overestimate the prevalence of gains experienced by the students. Only the first statement about a gain experienced by the student was counted in a sentence or interview segment. However, if several different types of gains were mentioned in a sentence or interview segment, each gain was coded separately.

Five main themes emerged from the interviews that describe the community college students' gains from participating in this undergraduate research experience. The five main themes were *self*, *perspective*, *support*, *knowledge*, and *relationship* gains (refer to Table 1). *Self* gains related to the students' recognition what is of value to them, increase in confidence, acknowledgment of self-doubts, and perseverance in the face of difficulty. *Perspective* gains related to the students' views on their own academic and career interests, capacities, and goals; students' awareness of their own and others thinking and learning processes; and the students'

views on the effectiveness and influence of the program. *Support* gains related to the academic, career, and emotional support received from others in the program. *Knowledge* gains related to the students' increased understanding of academia, careers, and research in the science and engineering fields. *Relationship* gains related to bonding with others from diverse backgrounds; experiencing both collaborative and challenging interactions in a work environment; and, building relationships with others who are accessible, approachable, and dependable.

The percentage of the students' comments placed in the five main themes of gains were calculated to rank them in order of how often they were made in the interviews. The percentages were useful information as it provided some indication of how important the gains were to the students. However, higher percentages do not always mean that the gain was more important to the study but could simply mean that they mentioned more often in the interview. Estelle was more talkative than Katarina and this was evident in the length of the their interviews, 50 minutes compared to 23 minutes, respectively. The length of the interview was a factor in the units of data counted in the interviews. In the interview with Katarina, there were 96 units of data that were placed into five themes. There were 24 units of data (26% of the total units) placed in both *self* gains and *perspective* gains, 19 units of data (20%) placed in *support* gains, 15 units of data (15%) placed in *knowledge* gains, and 13 units of data (13%) in *relationship* gains (refer to Table 1). In the interview with Estelle, there were 191 units of data that were placed into five themes. There were 48 units of data (25% of the total units) placed in the *self* gains, 35 units of data (18%) placed in *perspective* gains, 41 units of data (21%) placed in *support* gains, 39 units of data (20%) placed in *knowledge* gains, and 28 units of data (14%) in *relationship* gains (refer to Table 1).

Results

Both Katarina and Estelle experienced many gains in the undergraduate research program. This section presents their *self*, *perspective*, *support*, *knowledge*, and *relationship* gains. Narrative descriptions and quotes made by Katarina and Estelle in their interview are used to describe the results of the five themes.

Self Gains

Self gains related to the two community college students' recognition of how valuable the program was to their own development, increased confidence, acknowledgment of self-doubts, and perseverance in the face of difficulty. In Katarina's interview there were 24 units of data (26%) placed in the theme of *self* gains and in Estelle's interview there were 48 units of data (25%) (refer to Table 1).

Katrina's most prevalent *self* gain related to her recognizing how valuable the program was to her own development. This specific type of *self* gain appears to have been identified in one other previous study that examined the benefits of undergraduate research experiences¹⁰. Specifically, in this previous study 1% of the observations analyzed from the interview data of the 73 undergraduate students (i.e., sample consisted of students attending four-year universities/colleges) were categorized as recognition of the program value. As for Katarina, she felt privileged to have access to the resources available to her in the undergraduate research

program, especially considering her community college background. She highly valued the support she received from her faculty advisor and undergraduate peer. The discussions she had with her faculty advisory about school and career options helped give her a sense of direction. Katarina mentioned feeling genuinely respected and appreciated during the laboratory meetings because her faculty advisor addressed her directly and encouraged her to share her ideas and to ask questions.

Table 1

Definitions and Data on the Five Main Themes of Gains Experienced by the Community College Students in Undergraduate Research Experience

Main Themes of Gains	Definition	Katarina	Estelle
Self	Students' recognizing what is of value to them, building confidence, acknowledging self-doubt, and demonstrating perseverance during difficult times	24 units of data (26%)	48 units of data (25%)
Perspective	Students' providing views on their own academic and career interests, capacities, and goals; recognizing how self and others learn; and, providing views on the effectiveness and influence of the program	24 units of data (26%)	35 units of data (18%)
Support	Students' recognizing the academic, career, and emotional support received from other in the program	19 units of data (20%)	41 units of data (21%)
Knowledge	Students' increasing their understanding of academia, careers, and research in the science and engineering fields	15 units of data (15%)	39 units of data (20%)
Relationship	Students' describing bonds they formed with others from diverse backgrounds; experiencing both collaborative and challenging interactions; and, interacting with others who are accessible, approachable, and dependable	13 units of data (13%)	28 units of data (16%)

Katarina was extra appreciative of the help she received from the other undergraduate student working in the laboratory. She described her undergraduate peer being there for her each step of the way. For example, after Katarina's graduate student mentor would show her how to do a laboratory technique, her undergraduate peer was there at her side to help and reinforce that she was doing a technique properly. The experiences with the undergraduate peer helped her gain confidence, feel successful, and enjoy her time in the laboratory.

Katarina's other *self* gains were related to her self-doubts, perseverance, and confidence. As hard as it was to have her research presentation "*torn apart*" by her faculty advisory, she was able to look back and appreciate the process of receiving feedback. She felt pushed to produce her best possible work in this program and was confident that the knowledge and skills she gained from this experience would help her succeed in school and future career. Many previous studies on undergraduate research experiences have observed undergraduate students (i.e., sample consisted of students attending 4-year universities/colleges) gaining confidence^{10,16-18}.

The increased confidence in these previous studies were described as being either general or related to the undergraduate students' ability to do research. A quote from Katrina's interview that encompassed many of her self gains,

This was definitely a huge confidence builder because while in the program, especially in the initial stages, I felt that perhaps I was under qualified but then when I left and joined the real world I realized how much I learned and just how intense it was but very, very rewarding in terms of research and academics. I learned a lot of new material but also learned about graduate school and what it's like. And I have to say that it's definitely put some thoughts in my head that I didn't think would be there about my future academic plans."

In Estelle's interview, she talked about her own inward battle of struggling, gaining confidence, and valuing the many experiences that she was exposed to this summer. It was her drive that helped her take feedback and be successful in new academic experiences such as learning how to use excel, write lab reports, read journal articles, and other new research experiences. She was able to learn through these experiences to understand and become excited about a future career in science research. This quote illustrated her perseverance and determination to complete the summer program.

"At first I thought, 'Wow. I don't think I should be here [the program].' I don't think I'm on the level that they [other undergraduates in program] are. So I felt kind of little scared. But now I'm like 'Wow'".

Estelle started the summer program with many self-identified academic deficiencies, but she quickly learned about statistical analysis, excel, and reading journal articles that were used for her research project. She adapted quickly and valued every moment, easy and difficult, of the research program.

Perspective Gains

Perspective gains related to the students' views on their own academic and career interests, capacities, and goals; awareness of their own and others thinking and learning processes; and opinions on the effectiveness and influence of the program. In Katarina's interview there were 24 units of data (26%) placed in the theme related to *perspective* gains and Estelle's interview there were 35 units of data (18%) (refer to Table 1).

Throughout the program, Katarina expanded her academic and career goals. She described having the time to think through and refine the direction of her future plans. Katarina described how she planned to pursue a bachelor's degree in engineering and/or biostatistics after earning her associate's degree. This quote described the conversations she had with a graduate student about her future.

"One of the grad students, talked with me extensively about career opportunities and the coursework that she did for her degree. And that was really helpful for me to see just what's out there and what are my options."

At the beginning of the program, Katarina described that she lacked relevant background knowledge that would have been useful to know for her research project. Everything she was exposed to and did in the program was a new learning experience. Her perseverance and

initiative to ask questions when she did not understand or needed clarification helped her succeed. At the end of the program, she recognized that she had expanded her knowledge and skills and solidified her interests in pursuing a science career. This quote described Katarina's realization about her interests. *"This program really made me realize how much I really do like being in the lab"*.

As Estelle reflected about her summer experience, she talked about what she had learned about herself over the summer. In terms of her career, she gained many different perspectives about her future research goals, possibilities, and preferences. Estelle's academic perspective gains related to what would be expected of her in undergraduate and graduate programs. The following quote illustrated how Estelle has synthesized her research experience to apply to her academics for next semester.

"I'm going to stick in my Biology major. I was trying to switch because classes started getting hard. But after, basically, learning that I can learn a vast amount of things in a short amount of time. And that I gained confidence in how I can, like, actually understand things that I normally wouldn't have..."

It was evident that Estelle had become more comfortable with facing academic challenges and had gained the confidence to push through them in order to reach her long-term goals of earning a bachelor's degree, attending graduate school, and working in a research lab. In general, clarification, refinement, and/or confirmation of the education and career plans of undergraduate students (i.e., sample consisted of students attending 4-year universities/colleges) have been identified in many previous studies to be a benefit of undergraduate research experiences^{10,16-18}.

Support Gains

Support gains related to the academic, career, and emotional support received from others in the program. In Katarina's interview there were 19 units of data (20%) placed in the theme of *support* gains and Estelle's interview there were 41 units of data (21%).

Katarina described how receiving feedback on her presentation from her faculty member was an amazing personal experience. No one had ever taken the time or effort to give her such constructive feedback. Receiving edits to improve written work and presentations has been reported in previous studies as a way undergraduate students (i.e., sample consisted of students attending 4-year institutions) benefited from their undergraduate research experiences¹⁰. She explained that she learned a lot from this feedback and it pushed her to improve her presentation.

"The first time he like tore apart my presentation but it made me go back and learn so much more from that and make it so much better. I feel that it was an amazing experience for me personally. The way his criticism was structured it was like a learning experience. It wasn't like you suck at life. It was like these are the areas you could improve and this is how you can make it better. And for me that was really that was really important because I don't have that sort of mentorship where I go for school."

As for Katarina's graduate student mentor, she was always available to help her or answer questions. Katarina emphasized that everything that she learned in the program she learned from her graduate student. Katarina's other *support* gains were related to career advisory and emotional support.

Estelle talked about the academic, emotional, and career support that she received from both her research group and family. The academic support was primarily received from the research group and came in the form of advice, feedback, lab technique guidance, and a push to improve. The support received from her family helped her triumph over academic and research challenges. The following quote illustrated how much support and enthusiasm her family shared with her in her summer experience.

"...I think the first couple of days I took a picture of myself in my lab coat and sent it to my parents and they were super excited and showed everyone else. They [my parents] asked me what I was doing and how I was going to impact society, so I would tell them."

Overall, Estelle internalized the support and feedback she had received from her research group and family and made changes to become a better student and researcher over the summer. Previous studies have suggested that graduate student mentors have the capacity to provide more and a wider range of support to undergraduate students (i.e., sample consisted of students attending 4-year universities/colleges) compared to faculty mentors in undergraduate research experiences^{12,19-21}. The closeness in age and career stages have been suggested to be the reason why undergraduate students feel more comfortable and at ease approaching graduate students with questions or to ask for help^{19,20}.

Knowledge Gains

Knowledge gains related to the students' increased understanding of academia, careers, and research in the science and engineering fields. In Katarina's interview there were 15 units of data (16%) placed in the theme related to *knowledge* gains and Estelle's interview there were 39 units of data (20%).

Every technique Katarina was introduced to in the laboratory was new to her, so she had to rely on the research group to teach her how to perform the techniques. Her graduate student mentor expected her to write laboratory reports on each the laboratory techniques that she learned. As challenging as the laboratory reports were to her at the time, she later reflected on how they helped her really understand what she was doing. She discussed how the laboratory reports were useful to her when she had to prepare her presentation for the program. In addition, she felt that by doing the laboratory reports she was more prepared to take laboratory courses at a four-year university.

"I think I didn't expect the program to be so rigorous to the extent that [my graduate student mentor] made me do lab reports for every technique that I learned. I felt that this was what an upper level collegiate course would be like, with the lab reports due every week. But in retrospect going back, having to use that information in my presentation was really helpful. So I felt that [my graduate student mentor] really put some thought into structuring the experience so that I

was learning every step of the way and was able to build on the knowledge that I learned in the beginning.”

In addition, Katarina learned information about academic programs and careers in the science and engineering fields. She learned about the different types of majors and, specifically, described having extensive discussions with her graduate student mentor about the coursework she had to take for her degree. Through her experiences in the program, she also learned about the realities of laboratory work. In particular, how procedures do not always work out as anticipated and how a lot can be learned by failures. Katarina recognized how much time and effort the research group put into their work. Because of that, she was very appreciative of the time they took to help and show her how to do things in the laboratory. She realized that when they were working with her it was valuable time away from their own research projects.

Under the theme of knowledge, Estelle discussed what she learned in her 10-week research experience in the categories of academia, research, and career. Related to the academia knowledge, she talked about expectations of graduate students, level of rigor in lab reports, and how to transfer from a community college to a four-year university. The research knowledge was about the types of research that was being done and equipment and lab techniques. Career knowledge was about the expectations of a biomedical career and the reality that faculty are often not around because of meetings, conferences, and other projects but are still available via email for consultations. The following quote illustrated the enormous amount of information that she gained over the summer, that she believes was more valuable than an academic class.

“Actually, I think that I learned more statistics in the 10 weeks of the program than I would have ever learned in a class environment [community college]. I’ve never taken a statistics class, and in the 10 weeks I was really pushed to learn something totally new I mean, three things that were totally new to me: the Image Stage, Excel, and statistics (which I’ve heard is not loved and is hard to do).”

The *knowledge* gains identified in this study have all been reported as gains experienced by undergraduate students (i.e., sample consisted of students attending 4-year universities/colleges) in undergraduate research experiences. The previous studies have these gains have been categorized as thinking and working like a scientist, gains in skills, enhanced career/graduate school preparation, and becoming a professional^{10,17}.

Relationship Gains

In Katarina’s interview there were 13 units of data (13.54% of the total units of data in Katarina’s interview) placed in the theme of *relationship* gains. In Katarina’s interview there were 13 units of data (13.54% of the total units of data in Katarina’s interview) placed in the theme of *relationship* gains. Previous research has reported that undergraduate students’ (i.e., sample consisted of students attending 4-year universities/colleges) building collegial relationships was a benefit of undergraduate research experiences¹⁰.

Katarina described her faculty advisor to as approachable and dependable. Her faculty advisor told her she could email him anytime during and after the research program. Katarina did

mention a couple times that she wanted more time to work or meet directly with her faculty advisor, however, she did realize that it was not a realistic expectation due to her faculty mentor's many other responsibilities.

As for the others in the research group, graduate students and undergraduate peers, they were almost always working in the laboratory when she was there. This made them very accessible and available to her. Like Katarina's faculty advisor, the other research group members made it clear that they were there to help and answer her questions. The openness of the research group made her feel very comfortable around them and made her feel like she was part of the group. This quote described Katarina's interactions with her research group during lab meetings.

"But what I thought was really important was that during every meeting he addressed me and the other REU students directly asking us if we had any questions or concerns or if there's anything that we wanted to discuss. Like, he really made himself available. To me that was like a really big deal. He addressed us in such a fashion that I felt really comfortable going and speaking to him if I had any questions or anything."

Estelle discussed the many types and levels of relationships she had developed in undergraduate research experience. The effort she put into building relationships was one of the reasons she thought she was successful in the academically rigorous program that had overwhelmed her in the first two weeks. The different levels of mentoring and bonding came from her graduate student mentor, other graduate students in the research group, faculty that taught the seminars and supervised the overall program, high school students that she mentored, and her own family. All of these people helped her complete the program and pursue her goals in different ways. She had mostly positive interactions with many people, but also talked about the challenges she had working with people, particularly a graduate student in the lab who pushed her to become academically independent. The following quote illustrates Estelle's relationship with the graduate student who was trying to challenge her academically and emotionally to overcome her math block to be able to analyze the statistics.

"And I think that I sort of have a [math] block too. He was trying to get me to over this fear of math. He was like, I know you can do it. You have to get over the block. Because you can't always do lab work on your own, and I can't always be there 100% of the time to guide you in everything you do."

Towards the last half of the summer, she realized how academically independent she was able to become.

Conclusions

The two community college students, Katarina and Estelle, who participated in the undergraduate research program both experienced *self, support, knowledge, perspective* and *relationship* gains. As mentioned, the percentage of comments placed in the themes were calculated and used to rank the themes that were most mentioned in each of the interviews. The rank order of the themes varied between Katarina and Estelle. Comparing the percentages of

comments placed in the *self*, *support*, and *relationship gains* between the two students they differed by approximately 1% percent (refer to Table 1). There were more substantial differences in the percentages of comments placed in *knowledge gains* and *perspective gains* between the two students. Out of the total units of data for each interview, 15% of Katarina's and 20% of Estelle's comments (an approximate 5% difference) were placed in the *knowledge gains* theme and 26% of Katarina's and 18% of Estelle's comments (an approximate 8% difference) were placed in the *perspective gains* theme (refer to Table 1).

The findings suggest that the *self* gains may be one of the more important gains. *Self* gains was the highest ranked theme from Katarina's interview (26% of the total units of data) and the second highest ranked theme from Estelle's interview (25% of the total units of data). At the beginning of the program, both of the students lacked confidence in their abilities and seriously considered dropping out of the program. In the interviews, they compared themselves to the other undergraduate students in the program and felt like they had far less background knowledge and research experience^{22,23}. However, in the end, they demonstrated determination and perseverance to succeed. They sought out academic support by asking questions and often having techniques demonstrated to them more than once by members of their research groups. Both acknowledged that the emotional support they received from their relatives and friends was critical to their success. Our findings and the literature suggests the importance of providing additional academic support and resources to community college students^{23,24}. In addition, undergraduate research programs need to be aware of the likelihood that community college students may feel intimidated and out of their league at the beginning of the program²³. To meet the needs of the community college students, REU program directors may need to check in and advise the community college students more often than the undergraduate students from four-year universities.

The students' *knowledge gains*, *perspective gains*, and *support gains* that related directly to academics and careers was another significant finding of this study. Both students described gaining knowledge about undergraduate and graduate degree programs and careers in science and engineering fields²⁴. It is important that faculty advisors, graduate student mentors, and undergraduate peers who are paired with community college students initiate and take the time to have substantive discussions about academics and careers²⁴. Katarina's experiences allowed her to think through and refine the direction of her future plans. As for Estelle, her future plans were clarified and confirmed through her experiences in the program. These findings suggest that research opportunities for community college student may have the potential influence the success rates of community colleges, including the associate's degree attainment rate, transfer rate, and graduation rate from four-year institutions^{25,26}.

Multilevel Support System

The research group members and the students' families played an important role in the community college students' experiences in the undergraduate research program. Essentially, the community college students were paired with a faculty advisor, graduate student mentor, and an undergraduate peer. The impact of pairing the community college student with another undergraduate student who was in the program was unanticipated, but the literature suggests that community college students are more successful working in groups during classroom science lab

assignments²². The program director intentionally placed the community college students in laboratories that had other undergraduate students who were participating in the research program^{22,24}. The findings related to the interactions between the undergraduate pairs need to be further examined. In addition, the process and criteria used to select undergraduate students to pair with the community college needs be further developed and understood. This would be particularly important information to share with other research universities who may be considering accepting community college students into their undergraduate research programs.

Relatives and friends also played an important role in the community college students' experiences in the undergraduate research program. Katarina did not even know that undergraduate research experiences existed until her roommate, who was a PhD student, told her about it. Katarina's roommate encouraged and supported her throughout the entire duration of the program. He helped with the application process, navigating and understanding the hierarchy of laboratory positions, and preparing the final presentation. Estelle's family was so proud of her and provided her with the emotional support to complete the program. The family shared the photo of her in a laboratory coat to everyone that they knew, and this made Estelle feel special and accomplished. From the existing literature base, there does not appear to be research that focuses on the role of relatives and friends on students' experiences in an undergraduate research programs. However, as mentioned previously, most of the studies that have examined the benefits of undergraduate research were on liberal arts colleges whose student populations are very different from the student populations of community colleges⁸⁻¹².

Implications and Future Research

It is clear from the data that community college students gain extensive valuable positive opportunities in the areas of perspective, relationships, support, self-awareness, and new knowledge. There were many implications from this study to encourage more community college students to participate in the undergraduate research experience^{24,27}. By recruiting more community college students to participating in undergraduate research, it could help increase the success rate of students transferring and graduating STEM majors from four year universities^{25,26}. As suggested by the literature, community college participants could serve as peer ambassadors to help recruit future summer REU participants²⁸.

The mentoring experience at every level from undergraduate peer to the faculty supervisor played a key role in the success of the community college students²⁴⁻²⁶. Hopefully this can begin conversations about the careful placement of community college students and possibly change policy and practices for national placement of community college students in REUs. Hopefully, it will also begin to establish the importance of the role of peer mentoring among the community college students and undergraduate peer mentors. In terms of faculty mentoring, this study shows that, despite the possible academic deficits of the community college students, there was much to be gained in taking risks and selecting students who demonstrated perseverance and determination²⁴.

This case study on two community college students has left a wealth of many different research directions for future studies in terms of students, mentoring, and undergraduate research directors. It would be interesting to follow these two students towards graduation from a four-

year university and track the same themes. Future studies need to include larger sample sizes of community college students in order for the findings to be more generalizable to undergraduate research. Another research route needs to focus on undergraduates who were paired with community college students and learn about how it influenced their academic and career perspectives. In terms of faculty, future studies need to follow the program directors to find out how this case study and other existing research impacted recruitment policies for undergraduate and community college students. Also, interviewing community college professors, administrators, and program coordinators to determine the qualities for a successful undergraduate or community college student in the summer experience would be beneficial.

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