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Exploring the impact of early exposure to research on dual enrollment students: A qualitative single-case study

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Abstract

Embry-Riddle Aeronautical University (ERAU) provides a concurrent enrollment model to high schools across the United States. The concurrent enrollment opportunity offers science, technology, engineering, and mathematics (STEM) college-credit coursework taught by college-credentialed instructors on the student's high school campus. One faculty member transitioned to Embry-Riddle's main residential campus following seven years of service with ERAU's concurrent enrollment program. During his tenure with ERAU's concurrent enrollment program, in addition to instructing a variety of concurrent enrollment courses, he maintained an active research agenda that involved concurrently enrolled students. His transition was preceded by the matriculation of a subset of these students to Embry-Riddle's main campus. Each of these students immediately reengaged in undergraduate research with the faculty member while he continued to serve in a strong mentoring role. This presentation explores the affect this opportunity had on individual members of this tight-knit cohort as they progressed through their concurrent enrollment and undergraduate studies, participated in a long-standing mentoring relationship, and undertook their post-graduation decision-making. The research showcases project-based learning as a scaffolding technique for meaningful undergraduate research and how it may illuminate a pathway for students who do not initially see STEM as a viable option.

Introduction

The Gaetz Aerospace Institute (GAI) at Embry-Riddle Aeronautical University provides a concurrent enrollment model to over 85 high schools across the United States. The concurrent enrollment model offers college-credit coursework taught by college-credentialed instructors, frequently serving in dual roles as high school teachers, on the student's high school campus. This latter characteristic is commonly used to differentiate this model from the dual enrollment model where students leave their high school campus, most often undertaking coursework at their local community college (NACEP, 2020).

Embry-Riddle, through the GAI, specifically offers science, technology, engineering, and mathematics (STEM) oriented coursework for concurrently enrolled students. The coursework administered at the high school reflects the pedagogical, theoretical, and philosophical orientation of Embry-Riddle courses. Further, Embry-Riddle residential faculty provide course-specific training regarding course curriculum, pedagogy, and assessment criteria to the concurrent enrollment instructor.

One faculty member transitioned to Embry-Riddle's Daytona Beach residential campus, following seven years of service with the GAI. During his tenure with GAI, in addition to instructing a variety of concurrent enrollment courses, he maintained an active research agenda that involved concurrently enrolled students. His transition was preceded by the matriculation of a subset of these students to Embry-Riddle's main campus. Upon his arrival at the main campus, one student was enrolled as a sophomore undertaking a meteorology degree program and four engineering physics students were beginning their junior year of study. Each of these students immediately reengaged in undergraduate research with the faculty member while he continued to serve in a strong mentoring role. This unique circumstance, with a relationship that spanned six to seven years for each student, provided an opportunity to investigate how substantive early exposure to rigorous academic research subsequently influences a student's academic and career decision.

Literature review

The positive link between early exposure to research, projects, and real-life experiences and student success across a variety of content areas has been shown repeatedly with various methods (Griffard & Golkowska, 2013; Russell et al., 2007). Field (2002) explored the impact that high school-level exposure to undergraduate level research has on a student's desire to pursue higher education. Student perception of research that lasts several semesters is more influential than a project that last only one or two semesters and that the faculty member involved, "had an important effect on their decision to attend graduate school and in their career choice" more so than their peers who were not involved in research activities at the undergraduate level (Zydney et al., 2002).

However, while much of the current literature addresses the benefits and accessibility to postsecondary research opportunities for dual enrollment students (An, 2013; Pretlow & Wathington, 2014), there is limited research conducted on the longer-lasting impact of early exposures to academic research for such students (Wang et al., 2015). Russell et al. (2007) provided some insight on gender and ethnic influence on mentorship relationships and Lescak et al. (2019) in their *Ten simple rules for providing a meaningful research experience to high school students*, lists a long-term mentoring relationship as their final rule. However, much of the research that exists on healthy relationships with students focuses solely on the teacher-student relationship that existed while the student was in that classroom or course and not on the extended impact of a longer mentoring relationship (Carr, 2005; Claessens, 2016; Hagenauer & Volet, 2014; Wang et al., 2013).

How is research a stepping stone to project-based learning?

According to the Council of Undergraduate Research (n.d.), undergraduate research can be defined as, "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline." In comparison, Project Based Learning Works (n.d.) defines project-based learning (PBL) as, "a teaching method in which students learn by actively engaging in real-world and personally meaningful projects." Both organizations are leaders in their respective fields and strive to achieve the same goal: to encourage the progress of the next generation of experts to continue to ask questions, explore new ideas and contribute to their respective fields of study as lifelong learners. The PBL framework aligns closely with the modality in which the students in the GAI courses experience their education and then correlates to their continued involvement in research or project activities. PBL can be viewed as a scaffolding technique to prepare students for undergraduate research.

In the classroom setting project-based learning establishes what Helle et al. (2006) calls the 'problem orientation' which allows a given question to dictate following activities in which the students are led down a more open-ended learning process. While, in this presentation, the outcome is largely predictable by the faculty/teacher advisor on the project, in a research endeavor the outcome is less understood up front. However, the same principles apply, and the processes present a positive transfer of learning. Feedback from students participating in the ASTER (Access to Science Through Experience in Research) program at Weill Cornell Medical College in Qatar indicated that their exposure to various aspects of research not only helped them make connections between the classroom and subsequent application of problem solving skills in other classes and clubs, but that repeated exposure to research in small doses decreased the associated intimidation factor and made them more likely to return for more research projects later (Griffard & Golkowska, 2013). This confidence factor is acknowledged by many researchers when discussing the impact of undergraduate research and the sooner students engage in the experience the greater the benefit (Field, 2002;

Robnett et al., 2015). Robnett et al. (2015) went on to explain that early exposure to research was essential because the impact of a given experience may not take root for years. Additionally, she gave examples of how to properly scaffold and link classroom learning opportunities to present-day challenges at the undergraduate level. Ward et al. (2016) also advocates that early exposure to research should be developed within the K-12 education system in order to help develop passion and an understanding of how to apply the material outside of the classroom.

Complementing the aforementioned studies, it is recognized that these types of experiences assist students by making them feel more connected to the science and research community and other like-minded individuals (Griffard & Golkowska, 2013). The group of students associated with this work were able to experience project-based style activities while in high school and, subsequently, continue to connect with their faculty advisor from the high school environment throughout their undergraduate experience. This paper explored this group of undergraduate students' experiences as they relate to project-based learning and early exposure to robust academic research during concurrent enrollment. Specifically, it analyzes the factors that they perceived to be the most impactful on their learning experiences.

Methodology

Participants

This case study explores the experiences of a group of five students who were all concurrently enrolled through the GAI at Embry-Riddle Aeronautical University (see Table 1). Following completion of their high school diploma, each matriculated to Embry-Riddle Aeronautical University's Daytona Beach residential campus to earn their bachelor's degree. Four of the five participants chose a major in Engineering Physics, the fifth double majoring in Meteorology and Computational Mathematics. Three of the engineering physics majors also minored in various programs including applied mathematics, aviation law, computer science and computer engineering. Of the group of five, three participants have immediate plans to pursue a graduate level degree. A fourth participant intends to pursue a graduate degree following a year of full-time employment and subsequent enrollment in a Federal Work-Study program.

Table 1: Participants (Pseudonyms)

Pseudonym	Major(s)	Minor(s)
Carson	BS. in Engineering Physics	Computer Engineering
Elijah	BS. in Engineering Physics	None
Jackson	BS. in Engineering Physics	Applied Mathematics & Aviation Law
Liam	BS. in Engineering Physics	Computer Science
Oliver	BS. in Meteorology/Computational Mathematics	None

Procedures

This research aimed to draw conclusions from a purely qualitative research approach. Yin (2014) states that a case study is useful for answering the questions of how and why for a social problem, such as what encourages students to pursue research activities at the undergraduate level of post-secondary education. Moreover, Stake's (1995) exploratory single case study approach was selected because it utilizes a constructivist foundation that complements the educational context of this study. The literature supports a gap in research regarding extended research experiences prior to a student entering a higher education institution (Amaya et al., 2018; Clasessens et al., 2016; Lile, 2017). Data was primarily collected from one focus group interview, comprised of five participants, in which questions were asked of the whole group and the participants led the conversation while also contributing to each other's responses. To achieve triangulation of the data, individual semi-structure interviews with each member were conducted and a digital short narrative was requested (Creswell & Poth, 2018; Stake, 1995). All data collection methods had pre-determined questions to guide the discussion; however, the method gave freedom to the respondents to discuss what they felt was most appropriate. Prior to this data collection, each participant was given an informed consent form which disclosed that the risks associated with participation in this study were no greater than those encounter in daily life activities.

The focus group interview consisted of seven open-ended questions that targeted the high school experience and group interactions of the participants. The group interview lasted approximately an hour and was scheduled during a mutually convenient time for all participants and researchers. The semi-structured individual interviews were composed of six questions which targeted the participants' individual interactions with the mentor and their transition from high school to college. At the end of the interview, the researchers allowed the participants to share any relevant information or experience that was not covered during the interview and that they felt was important to disclose. Each individual interview lasted an average of 20 minutes. Lastly, the narratives probed the experiences that the students had while undertaking research as concurrently enrolled students. Each narrative was between 200-300 words in length. The five participants satisfy both Yin (2014) and Creswell and Poth's (2018) suggestion for employing at least five participants for purposeful sampling. It is important to note that this study was not designed to yield generalizable results but to generate an understanding of the phenomenon and lay a foundation for future inquiries.

Data analysis

The data analysis for the investigation was purposefully undertaken. First, all interviews were transcribed and sent back to the participants for review and approval. After receiving the approval from the participants, the researchers read the transcriptions of the interviews individually and exercised memoing as they immersed themselves in the data. While reading through the transcripts, the researchers

created notes in the margins of the data, beginning with the development of the codes and then the formation of themes from the codes. This strategy of coding the data for its major categories of information is referred to as open coding (Creswell & Poth, 2018). Merriam (2009) suggests that assessing the codes is the initial step in categorizing and gathering meaning from the data. Furthermore, reviewing open codes and grouping similar data together into axial codes created "coding that comes from interpretation and reflection of the meaning of the data" (Merriam, 2009, p.180).

Personal perspectives

The applicable faculty advisor that transitioned from the high school program to the University is one of the paper's authors. Consequently, this individual did not take part in formulating any of the student questions as to not lead the students' answers toward any particular outcome. Further, this member of the research team was removed from the data collection portion of the project as to not influence the students' responses, perceptions and descriptions of the questions during any of the interviews.

Findings

The overarching question that the research team asked was, how does substantive early exposure to rigorous academic research impact students' perception of their learning experience. The two major themes that emerged from the study were mentorship and motivation through industry connection. These themes support arguments made by other case studies that have studied PBL activities at different levels of education (An, 2003; Blumenfeld, 1991; Hagenauer & Volet, 2014). Through the various methods of interviewing, mentorship was coded in every single file and had 64 references, while motivation was also acknowledged in each file with 76 references of the nearly 300 reference points singled-out.

Mentorship. The first major theme to emerge from the data, mentorship, highlights the role that human interaction played between, not only, the faculty member and the students but within the team as a whole. Within the first major theme of mentorship, two subthemes associated with comradery and relationship over time appeared. The comradery found within the team as a whole allowed the students to open up to one another in a family style relationship, and the presence of this continuity over time increased their ability to rely on one another and work together as a cohesive unit. All participants expressed how comradery allowed them to maintain their confidence not only in successfully performing academic research but also in determining their career paths. Elijah articulated this notion when he stated, "just knowing that we have some sort of a support system here [ERAU] already and that we all had individual different [career goals] made the idea of [pursuing my] degree and doing something out of the ordinary [more achievable]." As previously established, because PBL can be conducted in shorter or longer-term commitments and has various aspects of research involvement based on the level of student understanding, comradery adds a depth to the students' willingness to engage in new research. Furthermore, the deeper that these relationships can be built between the students over time, the more encouraged the students are to engage in various research endeavors (Wilkins, 2019). Comradery can assist in establishing the roots for the pursuit of an undergraduate research agenda. Carson solidified this by explaining that having a strong group of like-minded peers, "that we know support each other helped us a lot, especially early on when you are still trying to figure out who your study partners and who your friend groups are."

The relationships between the mentor and mentees developed and further deepened over the course of the time spent conducting the assorted research projects. Each participant relayed that both formal and informal interactions guided how they navigated their undergraduate studies, engaged with the campus community during the course of their studies, and influenced their post-graduation choices. Liam referred to the faculty advisor as an "academic dad" while Oliver expressed the benefit of "having someone you can talk to normally since we knew each other well, something which [he] couldn't do with other professors." This type of relationship brought about reflective conversation that resulted in Jackson having to develop, "an immense level of self-knowledge and a true understanding of one's passion" and resulted in discovering, "a path [that] was truly meant for me" and upon reflection stated, "my career path would not be the same." For Carson, the unique relationship made him feel "important" and afforded him the opportunity to receive "individualized advice." Just as Robnett et al. (2015) found in their research that a student's involvement in research over time helps them develop their identity as a scientist, our students realized that these relationships helped them discover their academic passions and the correct path for the pursuit of these.

The comradery between the team, including the faculty advisor, that was developed over several years and that spanned several seminal milestones in these young people's lives, including the transition from high school to post-secondary studies for the students and the advisor's completion of his terminal degree, brought this group together in a profound manner. In other research investigating the impact of PBL on student's perspective of education, Virtue & Hinnant-Crawford (2019) found students explained the benefit of PBL as, "knowing their work was important to others." Having this relationship with their mentor knowing that he, "treated us like engineers and expected us to come up with a product which eventually got used" was what Carson stated as being the most profound aspect of his research experience with his professor while still in high school. Oliver felt that this mentorship's biggest impact was "the stuff that you cannot see on paper". Oliver and others went on to explain that they gained valuable skills, such as the ability to write a professional e-mail, how to organize thoughts and spreadsheets in a manner that someone else can utilize, and an openness to receiving feedback that was not judgmental or intimidating but in fact came from a nurturing and caring perspective.

Motivation through connection to industry. The second major theme that emerged from the interviews with the undergraduate researchers was motivation through connection to industry. The research projects' open-ended nature provided motivation in that the researchers felt like this better approximated problems that the students' would face in industry. Carson felt "treated like an engineer" due to the "freedom to decide how to get from there to the end product". He found this aspect "really rewarding" and believed that it provided a "sneak peek into the way the world [industry] works." Oliver believed that the research that he undertook "connected the University to the business and engineering of industry." This proxy for industry experience also afforded the students to better assess their desired outcome following completion of their degree programs. Liam indicated that, "undergraduate research allows getting a little bit of a taste of the field without having to fully decide or sign a contract." It was project work that Jackson completed that first opened a door to industry, in the form of an internship. The work ethic that he developed during his research experience brought about "admiration from his first boss in industry despite not having any real experience" and this feedback "changed a bit of the path [he] was looking to take for [his] career." Further, the interdisciplinary nature of the research that he was associated with "pushed me into a career path that I felt would fit with my interdisciplinary interests." After his initial research experiences, Elijah was motivated by the fact he believed his research work products better portrayed his capabilities than his GPA. Elijah shared that at various times during the course of his program of study that, "I was basically told that I should switch degrees or that I was not capable of being an engineer. However, undergraduate research showed me that not only am I capable of solving problems but that I can also excel at it." This success has, "helped [Elijah] to keep going in my undergraduate studies" and "has given me hope to complete my degree" and "shown me that I am capable of being an engineer." The students' ability to stay connected to the industry through their faculty advisor encouraged the above enthusiasm and motivation that Moore et al. (2013) found to be two of their five key "mentor facets" that their mentor embodied in their case study of research mentorship.

Conclusion & future research

This qualitative case study examined a unique group of students who formed a cohort through a unique concurrent enrollment program ripe with substantive research opportunities. They continued their studies at the same undergraduate institution in closely aligned degree programs. When their faculty advisor similarly transitioned to the same residential campus, the previously established cohort resumed its research. This experience created a unique opportunity to obtain insight into the factors that directly impacted their subsequent decisions to continue to pursue research activities during their undergraduate studies despite a heavy course load.

All of the participants in this study realized similar benefits from this experience centering on mentorship and motivation based on the connection to industry. Through the faculty advisor's guidance, the students felt that there was a safe person available to them who had a substantive connection to their industry of interest and who could, consequently, provide them a clear and objective, but personalized, path to achieve their goals. This research adds to the existing body of literature that heavily emphasizes the direct impact that a faculty advisor can have on a student's willingness, eagerness, and confidence to pursue research at any level of education.

It is this research team's recommendation that high schools and institutes of higher education collaborate to establish relationships with faculty who are willing to work with student cohorts on research or applied projects. Student cohort projects could either have a connection with a specific course, preferably, or as an extracurricular activity for the student, outside of class times. Though the uniqueness of the scenario evaluated in this case-study might be hard to replicate, placing faculty members in high school classrooms could provide an opportunity for students to experience the advantages afforded through team bonding and by the mentoring of an actively engaged researcher that is well-connected to industry. School administrators should consider employing a four-year cyclical approach in which they enable a higher education faculty member to work with a high-school student cohort. This cyclical approach will be beneficial for all parties as it maintains the community of mentor and mentees but without the strains of a longer commitment. Integrating this approach could certainly strengthen students' confidence in themselves to pursue higher education, benefitting both high schools as well as institutes of higher education.

Future work will investigate the impact of the aforementioned experience on the students' decisions to pursue additional graduate studies or to proceed directly into their professional careers. While only a limited number of students have the opportunity to work with the same team or faculty mentor from high school through their entrance into graduate school, continuing to evaluate the impact of this connection could prove insightful into the structuring of an analogous program and its potential impact on students' future educational activities and subsequent level of success.

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