CHALLENGE EPISODES AND COPING STRATEGIES IN UNDERGRADUATE ENGINEERING RESEARCH

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ABSTRACT

Higher education institutions are increasingly placing importance on engaging undergraduate students in genuine research, known as undergraduate research experiences (UREs). While the professional and personal benefits that result from UREs have been theorized and researched, the potential challenges students experience when engaging in genuine research remain relatively underexplored. Drawing on a sociocultural understanding of learning, this paper details challenge episodes and coping strategies that engineering students at master level reported while carrying out a research project in biomedical engineering. Data consisted of reflective writing collected at the beginning, middle, and end of the research project.

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A thematic analysis of the data led to the identification of three overarching areas of challenges: (1) organizing, planning, and executing tasks; (2) managing the group and its members; and (3) receiving support from the teachers. We find that while groups often experienced similar challenges, the coping strategies they employed differed and were influenced by the groups' disciplinary composition and the students' previous project experiences. We nuance the discourse around the role of challenges in UREs by making the distinction between "desirable challenges" and "undesirable challenges", and we draw out implications for teachers wishing to involve students in realistic research.

1 INTRODUCTION

Across the globe, higher education institutions are increasingly experimenting with approaches for involving undergraduate students in realistic research, known as undergraduate research experiences (UREs). This surge of interest in UREs is also reflected in the rapidly growing body of research on UREs. The bulk of that research has relied on quantitative methodologies and focused on the professional and personal benefits of UREs [1]. While such studies can provide important insights, they tell us little to nothing about how students navigate their way through UREs, or how students experience being involved in realistic research [1]. Additionally, a quick perusal of three recent systematic reviews of research on UREs [2,3,4] reveals that there is a conspicuous lack of studies attending to the potential *challenges* that students experience while navigating their way through UREs — even though it is widely recognized that cognitive, affective, and social challenges have a significant impact on learning [5].

To redress this knowledge gap in the literature on UREs, this paper reports on a qualitative case study [6] driven by two research questions:

- What challenges do students experience during UREs?
- What coping strategies do students use in response to those challenges?

In examining these questions, we take our theoretical cue from the concept of "situated learning" in "communities of practice" [7], which emphasizes the importance of context — both social and material — for understanding how people learn to become members of a community of practice. Using this theoretical lens to study UREs means attending to how students engage in genuine scientific practices in a real laboratory environment, while interacting with experienced scientists as mentors and other students.

2 STUDY SETTING AND DESIGN

2.1 Empirical setting

The program this study is based on was designed to give undergraduate students an opportunity to participate in genuine research, for which they received payment. There were 14 participants, all of whom were about to begin their fourth year of a five-year master's program. Of the 14 participants, ten were female and four were

male, and they came from a variety of different engineering disciplines. They were divided into four groups, with each group containing one male student. While only some groups were interdisciplinary, each project was designed to be interdisciplinary. The students were expected to work an average of 40 hours per week and each group had one to two scheduled weekly contact hours with their teachers. Each group were assigned their own project, all of which were actual research projects rather than projects with a course-based design. To give an example, one project was on the development of a gel to be used in the testing of medical applications of microwaves for cancer treatment. The students were given a list of criteria that the gel needed to fulfil. The project combined two disciplines: electrical engineering and chemistry.

To ensure the groups had a basic toolbox of skills to allow them to begin the project, one of two approaches was taken for each group. For some their project was based on their group bachelor's project, but at a higher level that took it further in a theoretical sense. The other groups were brought into the labs, trained on the relevant tools and theory, and worked on the same or similar research questions that they would work on in the project.

2.2 Data collection and analysis

As we sought to contextualize the groups' experiences, a qualitative case study design was deemed to be appropriate [6]. The project ran over eight weeks, each participant completed between four and five weeks, and not all participants worked full time on the project. This set up saw the participants finish at different times, which affected the data collection as some had finished before the final wave of collections. Said data was collected in the form or reflective writing, and the collections waves were in the initial stage (one or two weeks in), the middle stage (four to six weeks in), and the final stage (on the last week). Each wave consisted of between one and three questions addressing the participants' experiences and perceptions of the URE during the different phases. Eleven participants responded with their reflective writings in the first wave, three in the second wave, and seven responded in the final wave.

The data was analysed through inductive coding [8] identifying salient challenge episodes and their corresponding coping strategies. In a second step, the identified challenge episodes were grouped into larger themes based on their proximity.

3 FINDINGS

Three overarching themes of challenges were identified: (1) organizing, planning, and executing tasks; (2) managing the group and its members; and (3) receiving support from the teachers. This section describes challenge episodes within each theme and their corresponding coping strategies.

3.1 Organizing, planning, and executing tasks

The project required the students to plan and organise their own work, which raised several challenges. In the initial stages, *the project's unstructured nature* was a

common challenge expressed by the groups. Some of those — but not all — felt that their issues stemmed from a lack of instruction. The coping strategies to face the lack of structure varied, from those that did not begin any work until they received what they felt were better instructions, to those that decided to work in the same vein as they had for their Bachelors project. Other solution strategies consisted of attempting to gain knowledge from examining previous data that was available to them, and simply making decisions under uncertainty on what tasks to perform, despite the lack of the scaffolding or structure they were used to.

Another challenge, *planning project work,* means having to decide which tasks to prioritize and which direction to take. A common strategy utilised by the groups for this was trial and error: they would try something, analyse the results, apply changes they think would lead to improvements and try again, or if needed they would change direction entirely. For one group this challenge led to the emergence of a de-facto leader who appeared to have naturally fit the role and who added structure. This same group would also allow for members to take on the role of an expert when tasks were in their area of study. In these instances, we were told that despite their expert status, the whole group would have to agree before making decisions. It is not known if this joint decision making also applied to the de facto leader.

The length of the project was also listed as a challenge as it was longer than any of the students' previous projects. However, no specific coping strategy for it was mentioned; they simply continued to work and seemed to adapt or became accustomed to it.

Further, the groups faced the challenge of *processing results*. Results needed to be analysed, conclusions drawn, and the reasons for wrong or unexpected results identified. Results could cause a change in strategy or the direction of a group's work. The groups predominantly used cooperative activities as a coping strategy for this challenge, working together to analyse results and try to identify potential improvements. The sharing of results among all group members was recognised as important, especially when obtained by a single individual or a sub-group working on a task. Group discussions were another cooperative activity used as a coping strategy for this challenge. The discussion of and sharing of results was not limited to individual groups as at least one group reported that they shared and discussed results with their teacher. Another strategy employed was the application of previous knowledge and knowledge gained from relevant research papers when analysing results to identify what would have a positive effect in future tasks.

Performing new or unfamiliar tasks was another listed challenge. One group's coping strategy was to seek out and read relevant literature on the topic. They remarked that the knowledge they gained from this coping strategy also proved useful later in the project. Some groups assigned tasks to individual participants and interdisciplinary groups would try to ensure said tasks fell within a participant's knowledge or discipline. This was not always possible, particularly in more homogeneous groups. For these participants, the only solution was for them to learn how to perform the task with the group providing support and help if needed.

An individual *becoming mired in a task*, which includes obtaining unexpected or unexplainable results, was a challenge some faced, regardless of whether it was in their discipline or not. The strategies employed were similar to those for previous challenges: the individual would present the issue to the group, and together they would try to provide help.

Further, *conducting academic tasks* — such as forming hypothesis, developing ideas, and being innovative — was reported as a challenge. Once again, the coping strategies were cooperative in nature as groups would hold brainstorming sessions and group discussions, where they would try to form hypothesis, ideas, plans, perform analyses and share ideas and thoughts.

The final challenge that was mentioned in this theme was when groups received *late task descriptions, goals, or last-minute project changes*. No specific coping strategies were provided; it appears that the groups simply worked to complete said goals and tasks.

3.2 Managing the group and its members

As mentioned previously, the groups had to organise and plan their own work, which led to the challenge of *assigning work within groups*. Groups would employ one of two coping strategies. The first strategy was to work on tasks together when physically possible, and if a group member had expertise or experience in the subject area then they would lead the group. The second strategy was to assign tasks to individuals or sub-groups. Groups tried to ensure that participants would be assigned tasks within their area of expertise or experience when possible. Interdisciplinary groups appeared to have an advantage over more homogeneous groups for both coping strategies.

Dealing with task dependencies, where groups were unable to proceed as planned due to unforeseen circumstances, was another challenge. Examples include delays in receiving vital data or being unable to begin a task until another was completed. These events were beyond students' control as they could not influence the person or task they were waiting on. Thus, they had no way of applying coping strategies directly to ease these bottlenecks. Instead, they often ensured the time spent waiting was not wasted by reading relevant articles about their task or identifying and performing other tasks.

While participants in interdisciplinary groups were positive of their experiences, such groups would sometimes experience knowledge gaps which arose when reviewing literature, or performing a task, or analyse results that were outside of some members' discipline. The challenge then was *addressing knowledge gaps within the group*. One coping strategy was knowledge sharing, where one member would take on the role of an expert and explain concepts or material to the rest of the group. Another strategy was the use of cooperative activities, such as discussions, and the sharing of ideas or experiences. These coping strategies allowed group members to contribute with their own unique knowledge and skills, an experience they found fulfilling.

While most groups reported positive interactions and good social cohesion, one group reported negative interactions which led to *poor cohesion within the group*. These issues were due to the actions and attitude of one group member that worked independently off campus, did not coordinate with the others on task allocation, and communication was either negative or non-existent. As a result, the rest of the group did not know what work that member was doing or how the work was progressing. Ultimately this member left the project before its conclusion and failed to provide work or documentation of his/her work to the other members. Thus, *dealing with a negative member* was a challenge unique to this group. The group did not list any coping strategies employed to remedy the situation. Instead, they worked closely together as a separate group on campus, and after the troublesome member left the project, they worked to complete the outstanding tasks that remained.

3.3 Receiving support from the teachers

While participants generally praised the support provided by the teachers as the project progressed, several felt dissatisfied with the level of support and instruction provided to them at the beginning of the project. The perceived challenge then was *dealing with instructions that were unclear, few, non-existent, or late*. Various coping strategies were employed by different groups. One strategy was to learn more by questioning the teachers, with one group reporting that they did not begin any work until they received instructions that they considered adequate. Other groups were less specific about their strategies, with one group reporting that they did not start working until things became clearer, and another group simply reported that they "figured out" what they needed to do. Some groups did not provide any specific coping strategy that they employed for this challenge.

The project was run over the summer period, which resulted in limited access to teachers due to summer vacation. This, coupled with changes in the campus environment due to the Covid-19 pandemic, meant that groups were often unable to physically meet with their teachers. Adapting to this *lack of physical contact with teachers* was a challenge for the groups. A common coping strategy employed by the groups was to email their teachers. One group did mention having meaningful conversations with their teacher but did not specify if these conversations were in person or digitally, for example a phone call or Zoom. *Limited communication* between groups and teachers brought other issues to the fore; for example, when a group had more than one teacher for their project, who should they direct task specific questions to? Sometimes teachers would respond late or would reply that the group had asked the wrong person. One group employed the following coping strategy for these challenges: they would email as many people as possible that they think may know the correct answer to ensure a quicker reply. If possible, they would attempt to call teachers for an even faster response.

Another issue that arose was when a group received *conflicting facts or answers from different teachers* on the same topic or question. No coping strategy was provided for this issue, but the group reported that teachers tried to answer

questions quickly, so we can speculate that their strategy may have been to send more emails to clarify previous answers. A particular issue highlighted by one student was knowing what questions to ask to ensure they received the information needed. As time progressed the student learned how to pose questions using previous experiences.

4 DISCUSSION AND CONCLUSIONS

This study set out to identify challenges students experience during UREs and the coping strategies they mobilise in the face of those challenges. In the remainder of this paper, we will discuss some of our most significant findings against the backdrop of prior work in the area and their implications for instructional design of UREs.

The first theme of challenges revolves around organizing, planning, and executing tasks. As suggested here and by others [9], students partaking in UREs tend to expect scientific research to be like their previous lab work and projects, with clear guidance and predictable outcomes. These expectations are inconsistent with the messy and iterative nature of doing research, resulting in the expressed challenges. Even though those challenges caused considerable frustration for some of the students, most students were able to develop effective collaborative coping strategies, leading to progress and learning.

The challenges allocated to the second theme relate to internal group interactions, project management, as well as knowledge gaps within the group. This theme is significant since the ability to work in groups has been signposted as a critical aspect of successful UREs [10]. Our findings reveal that coping strategies are largely based on students' previous project experiences, as well as groups' disciplinary make up. Members of interdisciplinary groups could in many cases contribute with their specific content knowledge, either in the role of an expert to share their specialised knowledge, group leader on a task, or specialist completing the task as an individual. This appears to have given interdisciplinary groups an advantage over more homogeneous groups that had to compensate for the lack of expert knowledge by reading articles and taking part in cooperative activities such as group discussions. Consequently, interdisciplinary groups were better equipped to develop coping strategies, which might be connected to the interdisciplinary nature of the projects. These findings suggest that (1) students partaking in UREs can benefit from relevant training in group work or project management prior to or as part of the UREs [10], and that (2) it is important to pay close attention to group composition.

Challenges allocated to the final theme relates to interactions between groups and teachers, including scaffolding, support, instructions, and communication. Students partaking in the URE viewed the teachers as a valuable source of information and guidance. This finding is consistent with prior research on UREs, stressing the importance of teachers as mentors, discussions between students and teachers, and scaffolding if needed [2,10]. The challenges in this theme were caused or exasperated by three factors: (1) the unstructured and open-ended nature of UREs, (2) the fact that the project ran during the summer when there was limited access to

teachers due to summer vacation, and (3) that the project coincided with the pandemic, resulting in restricted campus access for both staff and students. Despite some contextual factors beyond the teachers' control, a lack of presence and interaction between teachers and students seemed to create significant challenges, such as late instructions, lack of physical contact with teachers in the labs, and difficulties to establish communication with teachers when needed. At the same time, we also find that students developed valuable coping strategies in dealing with those challenges, such as learning how to correctly formulate a question, finding out who to ask said question, and working with what they might consider few or unclear initial instructions. These findings suggest that teachers in UREs should ensure that there is an adequate support structure available, and that instructions are clear, adequate, and delivered in a timely manner. Teachers also need to ensure that their students have access to expert performances to build a research identity as part of a community of practice [7,11].

Taken together, our findings point towards an understanding of challenges as a *double-edged sword*. That is, challenges are not inherently good or inherently bad in terms of learning. To nuance the discourse around the role of challenges in UREs, and engineering education more generally, we find it useful to borrow from the concept of "desirable difficulties" [12] and make the distinction between "desirable challenges" and "undesirable challenges". In terms of implications for teachers, we argue that teachers should strive to find the right amount and type of "desirable challenges" — together with support for appropriate coping strategies — while avoiding "undesirable challenges" resulting in a lack of progress, a loss of motivation, or inefficient use of resources (e.g. time). To be able to find this balance, future research on UREs would do well to suggest ways to better connect the research experiences to the students' prior experiences and beliefs, an argument that was brought forward in similar form by Linn et al. [2]. In the presented study, the overwhelming majority of students were overall very positive and enthusiastic about their experience of participating in the URE, despite - or because of - being confronted with the challenges of doing "real" research. Thus, we strongly encourage teachers and universities to offer UREs as part of their portfolio.

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