COLLEGIATE STUDENT ORGANIZATIONS PARTICIPATING IN CHEMISTRY OUTREACH: A CASE STUDY CHARACTERIZING THE COMMUNITY OF PRACTICE

by

Stephanie Santos-Díaz

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STATEMENT OF COMMITTEE APPROVAL

Dr. Marcy Towns, Chair
Department of Chemistry

Dr. George M. Bodner
Department of Chemistry

Dr. Adam Wasserman
Department of Chemistry

Dr. Stacey Connaughton
Brian Lamb School of Communication

Approved by:
Dr. Christine Hrycyna

To my parents, family and friends, for their incredible support. To all those who wanted to but could not.

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ABSTRACT

Outreach initiatives are typically framed as informal learning environments that provide an opportunity to increase the participants' interest in science. Research on chemistry outreach has primarily focused on designing and implementing demonstrations for outreach. Recent studies indicate student organizations are at the forefront of chemistry outreach, describing their outreach practices and facilitators' conceptual understanding of demonstrations. Although leadership has been linked to success of groups and organizations, the leadership structure of student organizations is an understudied aspect of chemistry outreach. Here, we conceptualize student organizations participating in chemistry outreach as a community of practice (CoP) with the goal of expanding the chemistry education community's knowledge of this CoP. Specifically, we aim to characterize leadership styles within the student organization in the context of an outreach event; and, to explore how factors related to diversity and inclusion play a role in boundary processes of the student organization as a CoP. Using a case study approach, we collected multiple sources of data, including the organization's outreach practices, an assessment of leadership style, observations, and semi-structured interviews. Results indicate leaders of the student organization, particularly those in charge of planning outreach events, displayed behaviors associated with the *transactional* and *laissez-faire* leadership styles more frequently than behaviors associated with the *transformational* leadership style. This study also suggested students' prior experiences related to gender, race/ethnicity, education and other outreach events play a role in their reasons for doing chemistry outreach, how they contribute to planning of events and how they interact with the audience of outreach events. As a long-term outcome for this study, the results can be used by national organizations to inform the development of new workshops for leadership training, with the purpose of teaching practices to leaders that can bring success to their chapter or local group.

CHAPTER 1. INTRODUCTION

1.1 Overview of the study

In the field of chemistry, outreach efforts are typically led and coordinated by student organizations (Pratt & Yezierski, 2018a). Previous research links leadership to the success of organizations (Landis et al., 2014). However, the leadership structure of student organizations in chemistry, the organization's success, and the effectiveness of events are understudied aspects of outreach efforts.

Chemistry outreach events are considered informal learning opportunities for everyone involved in these events(Committee on Communicating Chemistry in Informal Settings et al., 2016a). Outreach events have been found to increase the audience's interest in science fields (Casasanto et al., 2018; Metz et al., 2018; Segarra & Tillery, 2018). For undergraduate and graduate students who serve as leaders and volunteers at these outreach events, their participation provides a professional development opportunity for the students to practice science communication skills (Committee on Revitalizing Graduate STEM Education for the 21st Century et al., 2018). Student organizations, such as American Chemical Society (ACS) Student Chapters, are often heavily involved with outreach efforts. The leaders of these student organizations are the ones who plan outreach events, recruit volunteers to participate and potentially engage with the general audience. Given the potential impact of chemistry outreach efforts, discussed in Section 2.1.2, and the role chemistry student organizations play in outreach, the chemistry education community should be interested in studying the behaviors and characteristics of leaders of chemistry student organizations. In doing so, we can inform the community on leadership practices and their outcomes in chemistry outreach events. Student organizations and their leaders might then adopt behaviors leading to favorable outcomes in their outreach event, which ultimately impacts the volunteers and the audience. While there are many understudied aspects of chemistry outreach, the study presented here aims to fill the gap in the literature concerning the leadership of organizations doing chemistry outreach.

This research is framed using a case study methodology, with participants recruited from a student organization doing outreach. The cases to be studied are the leaders of these organizations recruited for the study in the context of chemistry outreach initiatives. The concept of Communities of Practice (CoP) is used as the theoretical framework, discussed in Chapter 3, to conceptualize

student organizations. A CoP is a group of people who share a concern or passion about a specific topic, and they deepen their understanding of the topic by interacting in an ongoing basis (Wenger, 2000). The characteristics taken into account when defining a CoP and the processes involved in CoPs (Wenger, 2000) are present in student organizations doing chemistry outreach events. The work presented herein focuses on leadership and events of the CoP, specifically the relationship between leaders within the student organization and the outreach events they are coordinating.

As a concept, *leadership* can encompass a variety of constructs, which necessitates a clear definition; thus, we adopted Full-Range Leadership Theory (FRLT) as an analytical framework to focus on leadership styles within the CoP of student organizations. FRLT, introduced by Bass and Avolio (Bass & Avolio, 1994), presents three leadership styles, each with their own characteristics: transformational, transactional, and laissez-faire. The FRLT guided data analysis and interpretation to describe leaders in student organizations doing chemistry outreach.

1.2 Providing Context: Researcher's Experiences with Chemistry Outreach and Leadership in Student Organizations

Deciding to investigate leadership in student organizations and outreach was based on the author's sense of commitment and responsibility. Being at the forefront of different local and national initiatives has been part of my trajectory as both an undergraduate and graduate student. In this section, I discuss how my experiences informed the selection of the topic for this project and the design of the study.

As an undergraduate student, I was a particularly active member of the ACS Student Chapter at *Universidad de Puerto Rico - Cayey*. I fulfilled different leadership roles two out of four years I was a member. I vividly remember the leaders, who changed every academic year, and how they led the chapter to success in their own way. Some years were more challenging than others because of the team dynamics and the ambitious goals we would set for the organization. One of the most ambitious goals we set to achieve was to financially support and prepare members to attend an ACS National Meeting, an initiative that a friend and I decided to co-lead. While we succeeded at the leading the initiative, we acknowledged it was a time-consuming and exhausting task considering that we had our own coursework and research responsibilities to tend to as well. Our chapter was also committed to participating in several outreach events throughout the year.

However, I do not recall our chapter having extensive preparation for these events, except that some of us volunteers practiced the demonstrations a few days in advance.

During the last two years as a member of the ACS Student Chapter, I decided to be less active in the chapter and focus my efforts on founding an ACS High School ChemClub at the high school I had attended. This required months of preparation and collaborations with my undergraduate research advisor and my high school chemistry teacher. As part of the ChemClub's activities, we participated in many of the same outreach events our ACS Student Chapter participated in. In preparation for the event, my undergraduate research advisor and I would study the demonstrations weeks in advance to then visit the school a few days before the outreach event. We would then give a short presentation to the ChemClub members on the chemistry behind each demonstration, followed by some free time for members to practice the demonstrations on their own and to practice explaining the chemistry. The day of the outreach event, the ChemClub members acted as facilitators.

As a graduate student, I have participated in yearly outreach events celebrating National Chemistry Week. The preparation provided by the organization planning the event consisted of meeting with the volunteers/facilitators to have us perform the experiments and see what to expect. In terms of outcomes of the outreach event, all my experiences were very different. For one of the most recent events, I partnered up with a chemistry education colleague who took the initiative to reframe the demonstrations and to spend some time rethinking explanations of demonstrations to tailor them to our audience, who were students in elementary school. Based on our interactions with the kids we visited, her ideas worked and kept the audience engaged. That same year, I had volunteered with another colleague to visit a different group of kids. This colleague had no chemistry education background and the way he explained the experiments to the kids led to them not being engaged with the activities. I remember that even I, a graduate student, was not familiar with terminology he was using for his explanations. While his intentions were for kids to learn something, it was poorly executed.

All these experiences were different, from how facilitators prepared for the event to the outcomes of the chemistry outreach event. I have always believed that those who plan outreach events should model those who have successfully planned outreach events. Only recently I understood that we (volunteers, facilitators, leaders, and student organizations) operate and exist in different spaces and contexts. When it comes to planning and organizing outreach events, for

example, perhaps what is a concern for students at a Hispanic-serving institution might not be a concern for students at research-intensive institution. Therefore, modeling those who have been successful might not be enough.

The main lesson I learned from my experiences is that there is more to producing successful outreach events than just recruiting volunteers and performing demonstrations. By being a facilitator of a chemistry outreach event, we are interacting with a community that, whether intentionally or not, is learning about chemistry and science. Reflecting on my prior leadership and chemistry outreach experiences, I believe science outreach events are opportunities for scientists to shape the community's perception about science. As a chemistry education researcher, I have the responsibility to contribute to the field by studying spaces in which scientists are engaged with chemistry outreach. In doing so, we can use research-based evidence to help scientists and student organizations better organize and structure outreach events**.**

1.3 Guiding Research Questions

This study focuses on understanding the relationship between leaders of student organizations and chemistry outreach events. The research questions (RQ) guiding the study are:

RQ1: How can leadership styles and leadership outcomes be characterized within student organizations participating in chemistry outreach?

RQ2: What factors, related to diversity and inclusion, contribute to the student-facilitators' experiences in outreach events in terms of *Boundary Processes* of the student organization as a community of practice?

1.4 Overview of Chapters

The next chapter, Chapter 2, discusses relevant literature that helped situate this study. An overview of the methods used to address the research questions guiding the study is provided in Chapter 3. This discussion includes the guiding frameworks, data collection and data analysis. Chapters 4 and 5 describe the findings addressing RQ1 and Chapter 6 addresses RQ2. Chapter 7 highlights findings from both research questions, the relationship between the two and implications for researchers and practitioners.

CHAPTER 2. LITERATURE REVIEW

2.1 Informal Learning Environments

Informal science learning occurs via activities or events that happen outside of a formal school setting or happen outside of an ongoing school curriculum (Ryu et al., 2019; Stocklmayer et al., 2010). These informal settings include, but are not limited to: museums, after-school programs, summer camps, workshops and one-day outreach events (Brown et al., 2017; Houck et al., 2014; Levine et al., 2015; Schwarz, Frenzel, et al., 2016; Schwarz, Burger, et al., 2016). In recent years, national entities have released reports (Hein, 2009; National Science & Technology Council, 2018) that show an increase level of support for the informal science education community. The National Science Teacher Association (NSTA) has advocated for stronger links between formal and informal science learning, and has called for developing more appropriate measures of learning in informal settings, recommending the expansion of the role of informal science institutions in the design and delivery of professional supports for teachers (*NSTA Position Statement: Learning Science in Informal Environments*, 2019). A report was released specifically for the chemistry education community addressing *Effective Chemistry Communication in Informal Environments* (Committee on Communicating Chemistry in Informal Settings et al., 2016b). This report, further discussed in Section 2.1.2., offers advice and serves as a guide in the design and implementation of "chemistry communication activities", a term that encompasses the majority of the outreach events carried out by the community of scientists.

2.1.1 Outreach in STEM

The general scientific community has placed importance on outreach efforts with the purpose of increasing students' interest in science-related fields (Casasanto et al., 2018; Metz et al., 2018; Segarra & Tillery, 2018), some specifically targeting girls, underrepresented minorities, or underserved communities (Casasanto et al., 2018; Gagnon & Komor, 2017). Others have used outreach efforts as a medium to reach new audiences that would not normally be interested in specific topics, such as earth science or climate change (Casasanto et al., 2018). There are also potential benefits for volunteers carrying out scientific outreach events. Among the benefits for student and teacher volunteers are the possibility of more autonomous and creative learning (McCauley et al., 2018), a feeling of belonging and engagement (Abernathy & Vineyard, 2001;

Gagnon & Komor, 2017), and increasing self-confidence in communicating science (Gagnon & Komor, 2017; Zack et al., 2017). Undergraduate students specifically described the following as outcomes of developing middle and high school STEM clubs: the importance of collaboration and communication in STEM, the need for knowledge outside their major areas of expertise, and the need to persevere through challenges as a STEM student and future professional (Ferrara et al., 2018).

NASA's Ice, Cloud, and Land Elevation Satellite (ICESat-2) mission (Casasanto et al., 2018) introduced some of the considerations to take into account when participating in outreach efforts, such as who are involved in designing the outreach materials and who are the facilitators of the event. For this example, teams at NASA created programs and supported collaborations to design outreach materials (i.e., short films, character designs, interactive activities, and more) to communicate the importance and relevance of the mission. These teams were comprised of students and professors from college art programs, students and professors in STEM fields, and scientists, all who had different roles in designing the outreach materials.

In contrast, other outreach initiatives reported in the literature, such as creating STEM clubs, were led by undergraduate students in STEM fields (Ferrara et al., 2018). Here, the students were tasked with organizing in-school and after-school STEM clubs and teams in middle and high schools. Teachers at the schools helped with publicizing the clubs and teams, assisted with curricular alignment and classroom management, and collected informal feedback from their students. Another outreach initiative aimed to increase content knowledge of physiology by visiting K-12 students during school (Metz et al., 2018). Here, professors and graduate students led the creation of modules and simulations used throughout the visits, as well as facilitating the events.

Further research has brought to light another consideration for doing outreach: interaction with the audience. Segarra and Tillery (2018) introduced primers to undergraduate students who created cell biology laboratory modules for two-hour outreach events with high school students. The primers were meant to prepare the undergraduate students for interactions with their audience by summarizing various aspects of child and adolescent development and behavior to help the facilitators understand what to expect from their population, including ways to connect with the audience and challenges that may come up during the event. Another study reported lecturers and senior lecturers who acted as outreach practitioners tended to transfer a lecturing style of teaching

to outreach initiatives, which has been found to not be effective in engaging audience (Bales et al., 2015) and hinder the opportunity for students and audiences to construct and explain their own ideas (McCauley et al., 2018).

As demonstrated by the examples presented above, there is a wide range of considerations that drive how science outreach initiatives are implemented. These considerations include, but are not limited to: type of audience the outreach is intended for, the setting in which engagement will happen, facilitators for the event, expertise of facilitators, materials needed to address the audience, who creates and designs the materials and the kind of expertise needed to do so, and the available financial and mentoring support available (Stofer & Wolfe, 2018). A review on outreach in chemistry and how these factors are present in chemistry outreach efforts follows.

2.1.2 Outreach in Chemistry

To date, there are no reviews published discussing the literature on outreach in chemistry. In this section, we discuss literature published in chemistry education journals such as *The Journal of Chemical Education* and *Chemistry Education Research and Practice*, classified under the category "outreach" or "chemistry outreach." This provides insight regarding how the scientific community defines chemistry outreach, what aspects of outreach are being discussed, and to what extent these are discussed in the literature. Articles, editorials and commentaries were included in this review.

The overarching themes identified as topics discussed in publications about "outreach" or "chemistry outreach" are the reasons for doing outreach, facilitators, audience, outreach chemistry content, activities or demonstrations and, assessment/evaluation. Most of the authors discuss two to four of these themes, but few authors cover all of the themes. For the purpose of this work, the theme related to facilitators will be discussed in a separate section.

The main purpose of outreach is to inform the audience about chemistry (Brown et al., 2017; Kuntzleman, 2015; Pratt & Yezierski, 2018c), to enhance interest in the sciences in order to address gender gaps (Levine et al., 2015; Levine & DiScenza, 2018) and to increase the presence of minority groups in STEM fields (Wilson et al., 2014). For example, Morais (2015) developed products (i.e., a book with seven stories about chemistry) in Portuguese, English and Spanish to promote scientific activities and experiences in Latin America. The purpose of outreach tends to be more specific to understanding or teaching chemistry content when describing events and an

activity or demonstration. For example, Flynn et al. (2017) published a demonstration with the intention to help the audience learn and understand the difference between hydrophobic and hydrophilic surfaces; and, Schwarz et al. (2016) proposed *Scientifica*, an open, one-day event with short lectures and demonstrations at exhibition stands, with the intention of showcasing specific models for instrumentation.

Given the purpose of encouraging students to join STEM fields, it is no surprise the majority of the outreach efforts are targeting middle school, high school, or young children in general. The nature of events, such as Science Festivals (Gaquere-Parker et al., 2016), camps (Houck et al., 2014; Levine et al., 2015; Schwarz, Frenzel, et al., 2016) or visits to schools (Carpenter, 2015; Morais, 2015; Sewry & Paphitis, 2018), allowed for parents of students to participate in the events. Other demonstrations and activities were designed to be used with the general public, regardless of background or experience with chemistry (Flynn et al., 2017; Jimenez & Bridle, 2015; Schwarz et al., 2016). Interestingly, the camp designed by Houck et al. (2014) and the course created by Sewry & Paphitis' (2018) intentionally targeted two groups, the audience and the facilitators, acknowledging that the facilitators of outreach efforts also benefit from doing outreach.

Assessment of chemistry outreach events presents challenges due to its nature, i.e., it being an informal learning environment (DeKorver et al., 2017). In terms of assessment, only a handful of outreach efforts presented some sort of measure to evaluate whether their purpose was met. Furthermore, most of these measurements that have been made were focused on the affective domain, addressing the influence of an all-day outreach event on desire to attend college (Ting et al., 2017) or participants' attitudes towards science (Levine et al., 2015). The effectiveness of outreach efforts has also been evaluated informally by describing the participants' behaviors and interactions. For example, by stating demonstrations prompted "thoughtful and engaging discussions" (C. L. Brown et al., 2017), activities were "well received" (Flynn et al., 2017), "demonstrations engaged the audience" (Gaquere-Parker et al., 2016), or the overall "atmosphere and motivation was casual and cheerful" (Schwarz, Frenzel, et al., 2016). The use of drawings has also been reported as a method to assess impact of the outreach activities (Morais, 2015). Outreach efforts structured as courses or with chemistry-content related purposes have less informal assessments. Schwarz et al. (2016) designed a university summer camp themed around environmental chemistry and had participants present their findings at the end of the camp. Levine

et al. (2015) had their participants work in group sessions to complete booklets with questions about the science of the demonstrations. Sewry and Paphitis (2018) had the students in their course write reflective journals to use a critical narrative to bring together their experiences doing outreach and what was learned in the course. Overall, there is a spectrum of both what is assessed during outreach event and how it is assessed.

Many topics and concepts have been explored through outreach activities and demonstrations. These topics and concepts include, but are not limited to: polymers (Ting et al., 2017), photochemically responsive materials (C. L. Brown et al., 2017), physical properties of hydrophobic and hydrophilic surfaces (Flynn et al., 2017), molecular structure of compounds in scents (M. K. Brown et al., 2017), the use of analytical methods in environmental chemistry (Schwarz, Frenzel, et al., 2016), ideas associated to inorganic compounds (Gaquere-Parker et al., 2016), chromatography (Houck et al., 2014; Levine et al., 2015), density (Levine et al., 2015; Morais, 2015), ionic compounds (Levine et al., 2015), pH (Houck et al., 2014), sodium reactions (Morais, 2015), color and light (C. L. Brown et al., 2017; Houck et al., 2014), and effect of concentration on time of reaction (Sewry & Paphitis, 2018). The way these concepts are addressed depends on the context of the demonstration, the resources the facilitators have, and the target audience. Some authors only briefly mentioned the concepts addressed, others gave elaborate scientific explanations for the activities or demonstrations, and others discussed how the concept was presented to the audience during the event. Ting et al. (2017), for example, thoroughly discussed how polymers and concepts associated to the topic are presented to high school students. In a similar way, Brown et al. (2017) discussed concepts related to photochemically responsive silicone elastomeric materials and Flynn et al. (2017) differentiated between how to explain hydrophobic and hydrophilic surfaces to the general audience versus appropriate explanations for university students. However, as discussed earlier, there were no formal assessment methods implemented to gauge how the outreach initiatives impacted the audience's understanding of chemistry.

Facilitators

The report *Effective Chemistry Communication in Informal Environments* (Committee on Communicating Chemistry in Informal Settings et al., 2016a) suggests those engaging in informal

science education use a five-element framework when implementing chemistry communication activities:

Element 1: Set communication goals and outcomes appropriate to the target participants

Element 2: Identify and familiarize yourself with your resources

Element 3: Design the communication activity and how it will be evaluated

Element 4: Communicate!

Element 5: Assess, reflect, and follow up

As outlined earlier in this section, most chemistry outreach activities focus on designing the activity (part of Element 3) with content-related goals (part of Element 1) and implementing the outreach activity (Element 4). There is a lack of information on resources, i.e, Element 2; specifically, facilitators of outreach events as resources.

Facilitators as an aspect of outreach has been the least frequently discussed element of outreach activities in the chemistry outreach literature. There was little mention regarding who designed the activities, who carried out the demonstrations, expertise, prior experiences, role in outreach events, etc. Typically, facilitators were described in general terms as scientists (C. L. Brown et al., 2017), tutors (Flynn et al., 2017), graduate and postdoctoral researchers (Ting et al., 2017), or female role models, referring to female professors, postdocs, and graduate and undergraduate students (Levine et al., 2015). While other authors were also vague in describing the facilitators, some were more clear about the role of the facilitators (Schwarz, Burger, et al., 2016; Ting et al., 2017) by stating how the facilitators were involved in the planning or the facilitator's background, for example.

There are some exceptions to the details provided about the facilitators. Carpenter's (2015) work in outreach focused on understanding undergraduate students' perspectives and ideas about science teaching and learning, as facilitators of outreach. These students participated in outreach events throughout multiple years, for a total of over 100 hours. Some outcomes of these students participating in outreach involved developing leadership and communication skills, learning how to teach different populations and increased interest in science. Houck et al. (2014) explicitly stated all aspects concerning the organization of their one-day camp were managed by unpaid, graduate and undergraduate student volunteers who carried out the experiments, attended meetings with safety coordinators, and developed the lesson plans and worksheets. As for the course by Sewry

and Paphitis' (2018), graduate students enrolled in the course carried out the outreach activities at schools, had to participate in debriefing meetings after each school visit, and submitted a reflection.

Diversity and Inclusion in Chemistry Outreach

The *National Science Foundation* (2011) defines diversity as:

> "[…] a collection of individual attributes that together help agencies pursue organizational objectives efficiently and effectively. These include, but are not limited to, characteristics such as national origin, language, race, color, disability, ethnicity, gender, age, religion, sexual orientation, gender identity, socioeconomic status, veteran status, educational background, and family structures. The concept also encompasses differences among people concerning where they are from and where they have lives and their differences of thought and life experiences."

The *Effective Chemistry Communication in Informal Environments* report does not address how themes related to diversity and inclusion (D&I) fit in the five-element framework for communicating chemistry. The lack of information about facilitators' backgrounds and experiences in outreach events is consequential to the lack of information regarding facilitators in chemistry outreach (as discussed in the previous section). Furthermore, the literature on chemistry outreach suggests the aspect of D&I is only considered when implementing activities directly targeting underrepresented minorities in terms of race or gender. Some science outreach programs are part of ongoing initiatives to increase the presence of underrepresented communities in science, technology, engineering and mathematics (STEM). For example, the programs are implemented to enhance interest in the sciences to address gender gaps (Levine et al., 2015; Levine and DiScenza, 2018; Roy et al., 2020) and to increase the presence of minority groups in STEM fields (Wilson et al., 2014; Gagnon and Komor, 2017; Casasanto et al., 2018).

In a broader sense, the concern on recruitment and retention of females, individuals who identify as Hispanic/Latinx and those who identify as African-American in STEM has been widely acknowledged and documented in different forms by researchers and other entities (Peters, 2005; Villafañe et al., 2014; Wilson et al., 2014; Stewart et al., 2017; National Science & Technology Council, 2018; Boateng and Gaulee, 2019; Rocabado et al., 2019). Gender gaps have been studied across different fields of STEM. A study in an introductory physics class, for example, indicated women feel a lower sense of belonging than men, arising from the negative cultural stereotype about women's inferior abilities in physics (Stout et al., 2013). The importance of inclusivity and

belonging was also discussed by female astronomy hobbyists as factors to encourage participation and persistence in STEM (Hite et al., 2019). It has been documented that facilitators benefit from outreach by having a feeling of belonging and engagement (Gagnon and Komor, 2017), having an increase in self-confidence in communicating science (Gagnon and Komor, 2017; Zack et al., 2017) and having the possibility of more autonomous and creative learning (McCauley et al., 2018).

The absence of research pertaining to D&I in Chemistry was recently pointed out by The National Academies of Science, Engineering and Medicine in their *Levers for Change* report (Laursen et al., 2019). This report was a cross-disciplinary review on the status of different fields to present an assessment of the progress on changing STEM instruction. In said report, D&I for Chemistry and Biochemistry is described as "an area ripe for investigations, as little work has been done" and that there is "little momentum on this issue" (p.54). This issue is alarming because it is evident academic institutions and national entities are concerned with increasing presence of, and supporting, traditionally underrepresented populations in STEM and higher education (Committee on Developing Indicators for Undergraduate STEM Education et al., 2018; Committee on Revitalizing Graduate STEM Education for the 21st Century et al., 2018; Laursen et al., 2019). As an example, it is only by having a diverse population that doctoral students can develop the ability to work in collaborative and team settings involving colleagues from diverse cultural and disciplinary backgrounds, a core element presented in the *Graduate STEM Education for the 21st Century* report (Committee on Revitalizing Graduate STEM Education for the 21st Century et al., 2018).

2.1.3 Summary

The degree to which different aspects of chemistry outreach are discussed in the literature varies according to the type of outreach activity or event being discussed. This spectrum might stem from the lack of structure in outreach initiatives (Stocklmayer et al., 2010). While there is a five-element framework addressing that lack of structure in chemistry outreach initiatives, a review of the literature suggests the framework is not being fully implemented when carrying out chemistry outreach events. Pratt and Yezierski (2018a) pointed out that student organizations are leading chemistry outreach efforts, which means these students are the ones acting as facilitators of outreach events and/or recruiting volunteers to act as such. Moreover, Kuk and Banning (2010)

argue that student organizations "… are important components of student involvement, contribute to student learning and development, and can serve as significant agents to advance multicultural and diversity goals of college campuses". For these reasons, it is worth studying the leadership structure these student organizations have, how the structure drives the outreach efforts they participate in, the role of diversity and inclusion in practices pertaining outreach events, and current facilitators' experiences in outreach.

CHAPTER 3. METHODS

3.1 Guiding Research Frameworks

This study aims to expand the knowledge on chemistry outreach efforts by studying the leaders in charge of coordinating outreach events. Specifically, by studying how leaders' behaviors and characteristics, as described by Full Range Leadership Theory (FRLT), influence leader-volunteer interactions, the structure in chemistry outreach events and boundary processes of the student organization CoP. In this section, CoP (Section 3.1.1) and FRLT (Section 3.1.2) are discussed in detail as a theoretical and analytical framework, respectively.

3.1.1 Communities of Practice

Communities of Practice (CoP) has been used as a theoretical framework for studying learning environments, and how knowledge develops and evolves in groups (Bodner & Orgill, 2007). For this study, the adopted definition of a CoP is: "… a group of people who share a common passion or concern and deepen their understanding of the topic by interacting in an ongoing basis," (Wenger et al., 2002). The *Effective Chemistry Communication in Informal Environments* presents the idea of collaborations across different groups –chemists and experts in science communication, for example– to build a CoP that shares common goals and effective practices for communicating chemistry (Committee on Communicating Chemistry in Informal Settings et al., 2016a). To that end, this study is founded on the assumption that student organizations planning and implementing outreach events are a CoP. The remainder of this section provides a general description of constructs associated with a community of practice to support this assumption. Table 3.1 summarizes those constructs relevant to understanding other methodological decisions and findings of the study.

Table 3.1 CoP elements and descriptions informed by Wenger (2000), Wenger et al. (2002) and Smith et al. (2017)

CoP Constructs	Definition Informed by Different Literature Sources	Assumptions on How the Construct Could be Present in a Student Organization
Domain	Shared passion or concern	A student organization with a general passion for chemistry; an organization brought together because of their status as students in chemistry
Community	The process to understand and learn more about the domain that happens by interacting with those who share the passion (i.e., domain)	When the student organization establishes frequent meetings, events or activities to have members interact and discuss "chemistry"
Practice	Tools, resources or processes that facilitate the learning of specific knowledge about the passion or concern (i.e., domain); "a way of acting in the world"	The organization attending a conference to share knowledge on specific research methods/techniques in chemistry; the organization participating of outreach events to better understand chemistry in informal environments
Participation	Core – small group who move the community along its learning agenda; as the community matures, this core group take on much of the community's leadership	Individuals who have extensive experience in the student organization or are passionate in having the organization be involved with a specific topic; maybe a leadership position that has been occupied by the same person for a long period of time
	Active – members that attend meetings regularly and participate occasionally in activities, without the regularity or intensity of the core group	Leaders who limit their participation to fulfilling responsibilities
	Peripheral – members that rarely participate; they might believe their contributions are not appropriate for the whole or carry no authority; they might not have the time to contribute more actively; should not be assumed that it is a passive involvement	Members of the student organization who attend only events of personal interest
	Outsiders – individuals that are not members but express interest in the CoP	Audience members of outreach events, hosted by the student organization, who want to become a scientist (i.e., interest in the science CoP)

Table 3.1 Continued

Boundary Processes	Brokering – happens between CoPs to introduce components of one practice into another; consists of creating connections or establishing personal relationships between members of different CoPs;	A student organization collaboration with education practitioners or researchers to adopt practices that improve outreach
	Boundary Objects – tools, documents, models, language and shared processes that facilitate and support communication or connections between different practices	When different student organizations share processes on how to plan an outreach event
	Interactions – can happen to different degrees and take different forms: (1) to provide direct exposure to a practice and be fully immersed in it; (2) to serve people who need some service, are curious or intend to become members (i.e., Outsiders)	An expert on science communication providing training on how to communicate chemistry; planning event with the intentions of encouraging people to join STEM fields
Leadership	A community need multiple forms of leadership to play their role and help the CoP develop. Examples: thought leaders, networkers, people who document the practice, etc.	Executive board or officers of a student organization; faculty advisors of the student organization

The term CoP was conceptualized to describe a social learning system and is characterized by a domain, the community and the practice. The domain refers to the "shared common passion or concern". The members of a CoP are committed to learn about a specific domain and have a shared competence pertaining that *passion*. The members value the collective competence and learn from each other by engaging in events, joint activities and discussions. The community characteristic refers to "interacting in an ongoing basis". The process of understanding and learning more about the domain from interacting with other individuals is what constitutes the community. Thus, individuals are not necessarily a CoP just by expressing interest in a topic (i.e., domain). There needs to be an exchange of knowledge or collective learning in order for the CoP to exist. Additionally, there needs to be a practice (third characteristic) through the development of a shared repertoire of resources. The resources are tools or processes that facilitate the learning of specific knowledge pertaining the domain (i.e., members "deepen their understanding" of the topic or passion).

The combination of domain, community and practice is what constitutes a CoP. Taking into account these characteristics is what brings a CoP into existence, it is safe to assume a CoP exists in a variety of forms and that one is (or can be) a member of numerous CoPs (Wenger et al., 2002). In the healthcare sector, for example, doctors can be established as a CoP and nurses could be a different community; however, doctors and nurses would be considered members of the same clinical practice CoP when compared to members of the healthcare management CoP (Kislov et al., 2011). In a sports management study, Willem et al. (2019) states athletes, coaches, volunteers and staff of a sport organization are part of a CoP connected to another CoP whose members are employees of governing bodies of sport. In higher education, multiple communities of practice have been identified: undergraduate mathematics lecturers, student-staff across universities, graduate students, and others (McDonald & Cater-Steel, 2017).

Different communities of practice can be similar in structure (i.e., domain, community and practice as characteristics). Individuals' participation, sense of belonging, competence and experience also play a role in delineating and cultivating a CoP but may differ to various degrees across communities of practice. There are tiers of participation in a CoP (Wenger et al., 2002). The first tier is the *core* group, who are those members who actively participate in discussions in the public community, identify projects for the CoP to be involved in, etc. The next tier are *active* members who occasionally participate in activities but not with the same intensity or regularity as

the core group. Another tier is members who are *peripheral*, they rarely participate in activities for a variety of reasons. These members are still part of the CoP because they are still learning and engaging in the practice to their best extent and sometimes in ways the core or active members are not. Lastly, the outsiders are individuals who are not members of the CoP but have an interest in the community.

The degree of participation of a member in a CoP is influenced, and can be influenced by, competence and experience. For members of a CoP, knowing is the interplay between competence and experience (Wenger, 2000). Competence is established over time by the community and experience includes that within the context of a given CoP and beyond. According to Wenger (2000), competence and experience converge in a CoP allowing for a deep expertise on the domain. Wenger argues that not much learning takes place between individuals or within a CoP when competence and experience are too similar. This introduces the construct of *boundaries.* At the boundaries of a CoP, a different learning opportunity presents itself because competence and experience diverge. For example, members of a CoP could be exposed to a new competence by interacting with members outside of the CoP. The processes taking place at the boundary, shown in the outer circle of Figure 3.1, are members acting as brokers (brokering), boundary objects, and interactions among people from different CoPs (Wenger, 2000). Brokering, boundary objects, and interactions are collectively considered *boundary processes*. This study specifically examines these boundary processes, which we continue to operationalize.

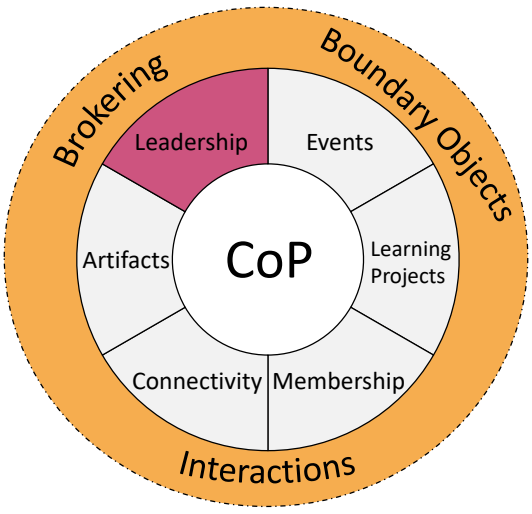

Figure 3.1 Conceptualization of Communities of Practice: Elements and Boundaries

Brokers can introduce elements of one practice into another (S. U. Smith et al., 2017). They create connections across communities of practice and move knowledge. *Brokering* can happen by establishing intentional connections in "exploring new territories" (Wenger, 2000) or it can happen by a personal connection between two members of different CoPs. *Boundary objects* refer to tools, documents, the common language used to communicate across communities and shared processes to coordinate actions. *Boundary interactions* (hereafter, *Interactions*) take different forms depending on the purpose. All are described in Table 3.1; but, particularly relevant to this study is *Peripheries* as a boundary process. This is when communities serve people who need service, are curious or intend to become members of the CoP.

Wenger (2000) pointed out six elements or "doable" actions that characterize a CoP when designing itself: leadership, events, connectivity, membership, projects, and artifacts (inner circle of Figure 3.1). A CoP needs multiple forms of leadership to help it develop, such as members who document the practice, networkers, etc. The community decides what leaders they need, and the forms of leadership may change over time. Events decide the type of activities and its frequency to organize events that bring members together. Connectivity involves brokering relationships between people who need help and those who can offer help. Membership in a CoP includes devising processes by which newcomers can become full members without diluting the community's focus or practice. Learning projects serve to explore the community's knowledge domain and revisit the practice. Last, artifacts such as symbols, documents, tools and websites are produced and maintained by the CoP. To narrow the scope of the study, the element explored in this study is *leadership.* While equally important in a CoP, the rest of the elements encompass other aspects of the community participating in outreach that might not directly involve all facilitators of outreach events.

To contextualize the CoP in this study (summarized in Table 3.1), collegiate science student organizations meet the characteristic 'requirements' to be considered a CoP. The domain of a particular student organization CoP could be chemistry, whose members are brought together by their members' practice as a chemist, a scientist, a student or a researcher or a science communicator. The members of the organization may interact with each other by participating in meetings, social events or private conversations. These modes of participation facilitate the sharing or exchange of knowledge about research methods, techniques, new concepts, etc. In this manner, competence and experience start to develop, cultivating the organization as a CoP. Considering

the concept of multimembership (i.e., being part of more than one CoP), the members of the student organization CoP are acting as brokers by bringing experiences, routines and procedures from one CoP to another. This might happen intentionally or unintentionally; it may be recognizable, or it is unnoticed because it is all part of who the member is and what they do (i.e., identity). As an example, a student who is member of another CoP that participates in a different type of outreach (science or non-science) might have a different perspective on what recruiting volunteers for outreach events entails.

It is important to note communities of practice as a framework is considered highly abstract (Storberg-Walker, 2008) in the sense that it does not describe how the elements of a CoP, or the processes happening at the boundaries, interact with each other. In this study, a CoP lens was used to study leadership in student organizations and their chemistry outreach events, allowing for characterization of the interplay between CoP elements (specifically, *leadership*) and boundary processes.

3.1.2 Full-Range Leadership Theory

Throughout this study it should be clear that even though certain leadership styles might favor mentor-like behavior (Sosik & Godshalk, 2000), the term leadership (the focus of this study) is not intended to be used interchangeably with the term mentorship. For this study, Yukl's (2010, p.8) definition for leadership will be adopted: "the process of influencing others to understand and agree about what needs to be done and how to do it, and the process of facilitating individual and collective efforts to accomplish shared objectives." Similarities and differences between leadership and mentoring are presented in Table 3.2 (Appelbaum et al., 1994; Burke et al., 1991).

Table 3.2 Characteristics of Leadership versus Mentorship

Leadership	Mentorship
Involves a performance-oriented influence process	Involves a long-term role-model relationship
Consists of one leader and one or more followers	Consists of one leader, or mentor, and one protégé
More formal, overt and direct influence process	More informal, subtle and indirect influence process

Given our definition of leadership, different types of leadership styles can be characterized using FRLT. Leadership styles are ways in which leadership is enacted or the "…total pattern of explicit and implicit performed by the leader…" (Newstrom, 2011) The *Full-Range Leadership Theory* (FRLT) assigns behaviors to nine different factors that comprise three different leadership styles, transformational, transactional, and laissez-faire, transactional, as shown in Figure 3.2 (Antonakis et al., 2003). Out of the nine factors, five correspond to transformational leadership, three correspond to transactional leadership, and one corresponds to laissez-faire leadership (Figure 3.2).

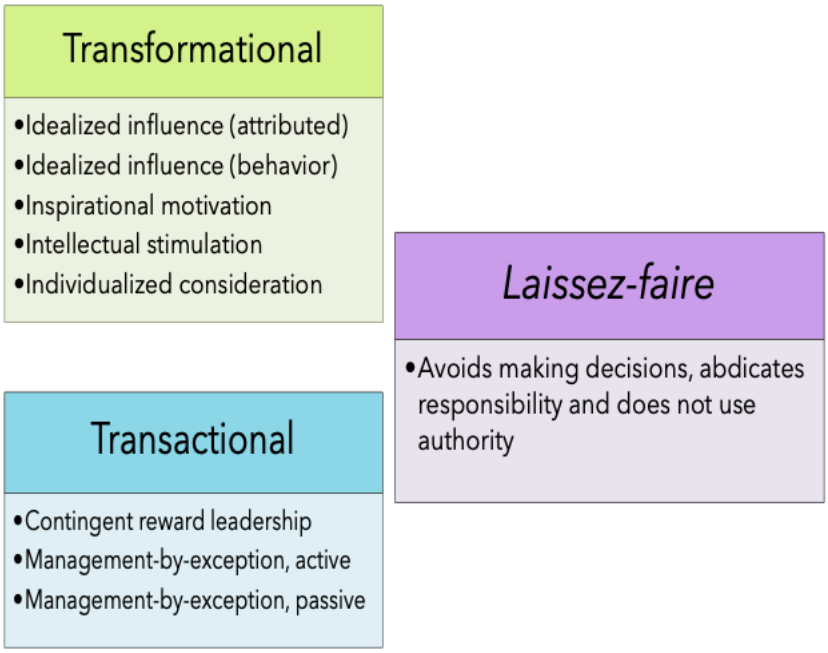

Figure 3.2 Factors for transformational, transactional and laissez-faire leadership styles (Antonakis et al., 2003)

Theories related to leadership styles, such as FRLT, have been used in other fields to describe management dynamics in businesses, religious nonprofit organizations, health authorities, group of librarians, and corporate industries (Chan & Du-Babcock, 2018; Gilbert & Kelloway, 2018; Sosik & Godshalk, 2000; Tarsik et al., 2014). Analysis informed by leadership styles has not yet been applied to student-run organizations, STEM outreach or chemistry education contexts.

FRLT will be used to identify behaviors in leaders and classify them according to the three leadership styles: transformational, transactional, and laissez-faire.

Transformational Leadership Style

Transformational leadership has been found to influence job performance positively (Khan et al., 2014; Pourbarkhordari et al., 2016). Regarding innovation, previous research with Iranian companies shows the elements of transformational leadership style foster organizational innovation (Mokhber et al., 2015). Research in public and private sectors in Dubai also has shown that transformational leadership positively correlates with intra-organizational innovation (Alsalami & Behery, 2014). In general terms, transformational leaders help followers develop their full potential by stimulating them intellectually and enhancing their creativity (Tarsik et al., 2014). Leadership characterized by this style can result in individual and group performance that exceeds expectations. Some behaviors associated with transformational leadership are idealized influence, inspirational motivation, intellectual stimulation and individualized consideration. Antonakis et al. (2013) define the behaviors or factors of transformational leadership as follows:

(a) idealized influence, attributed (IIA): the socialized charisma, whether the leader is perceived and viewed as confident, powerful, focusing on high-order ideals and ethics;
(b) idealized influence, behavior (IIB): the charismatic actions of the leader that are centered on values, beliefs, and a sense of mission;
(c) inspirational motivation (IM): the ways leaders energize their followers by viewing the future with optimism, stressing ambiguous goals, projecting an idealized vision, and communicating to followers that the vision is achievable;
(d) intellectual stimulation (IS): leader actions that appeal to the followers' sense of logic and analysis by challenging followers to think creatively and find solutions to difficult problems;
(e) individualized consideration (IC): leader behavior that contributes to follower satisfaction by advising, supporting, and paying attention to the individual needs of followers, which allows them to develop and self-actualize.

Transactional Leadership Style

Previous work (Sosik & Godshalk, 2000) has showed that a transactional style has no impact on job-related stress and no impact on organizational climate or innovation. As the name implies, a transactional style leader focuses on the follower's self-interest (Avolio & Bass, 2002) and motivates the follower by describing materialistic rewards upon goal achievement (Tarsik et al., 2014). Here, the leader sets goals, clarifies desired outcomes and provides rewards and recognitions for accomplishments when they are deserved (Sosik & Godshalk, 2000). By clearly communicating performance expectations, a transactional style behavior reduces feelings of uncertainty in followers (Sims & Lorenzi, 1992). To summarize, the three characteristics associated to transactional leadership are contingent reward, management-by-exception active, and management-by-exception passive (Antonakis et al., 2003; Tarsik et al., 2014). Antonakis et al. (2013) define these characteristics as:

(a) contingent reward (CR): leaders behaviors focused on clarifying role and task requirements and providing followers with material or psychological rewards contingent on the fulfillment of contractual obligations;
(b) management-by-exception, active (MBE-A): the active vigilance of a leader whose goal is to ensure that standards are met;
(c) management-by-exception, passive (MBE-P): leaders only intervene after noncompliance has occurred or when mistakes have already happened.

Laissez-faire Leadership Style

Lastly, a laissez-faire (LF) leadership style, as defined by Tarsik et al. (2014), is one in which the manager provides minimal direction, giving the employees as much freedom as possible. This style is characterized by delays of action, absence, and indifference (Sosik & Godshalk, 2000). Also known as "hands-off" style (Tarsik et al., 2014), the LF leadership style has been reported to intensify job related stress (Sosik & Godshalk, 2000). These findings align with Avolio and Bass (2002) who described the LF style as resulting in less concentration on work, poor quality of work, as well as low levels of productivity, cohesiveness, and satisfaction. In relation to followers, a leader with LF behavior provides no meaning or clarification of events for followers, which is interpreted as lack of communication, undermining the follower's trust in the leader (Podsakoff et

al., 1990). This type of leader delegates decision-making to the followers (Tarsik et al., 2014) or, in other words, the leaders choose to avoid taking action (Antonakis et al., 2003).

Leadership Outcomes

The behaviors associated with the leadership styles can be described in terms of effectiveness and degree of activity. Behaviors attributed to a transformational leadership style are considered to be more effective and prompts leaders and followers to take action or be more active (Figure 3.3).

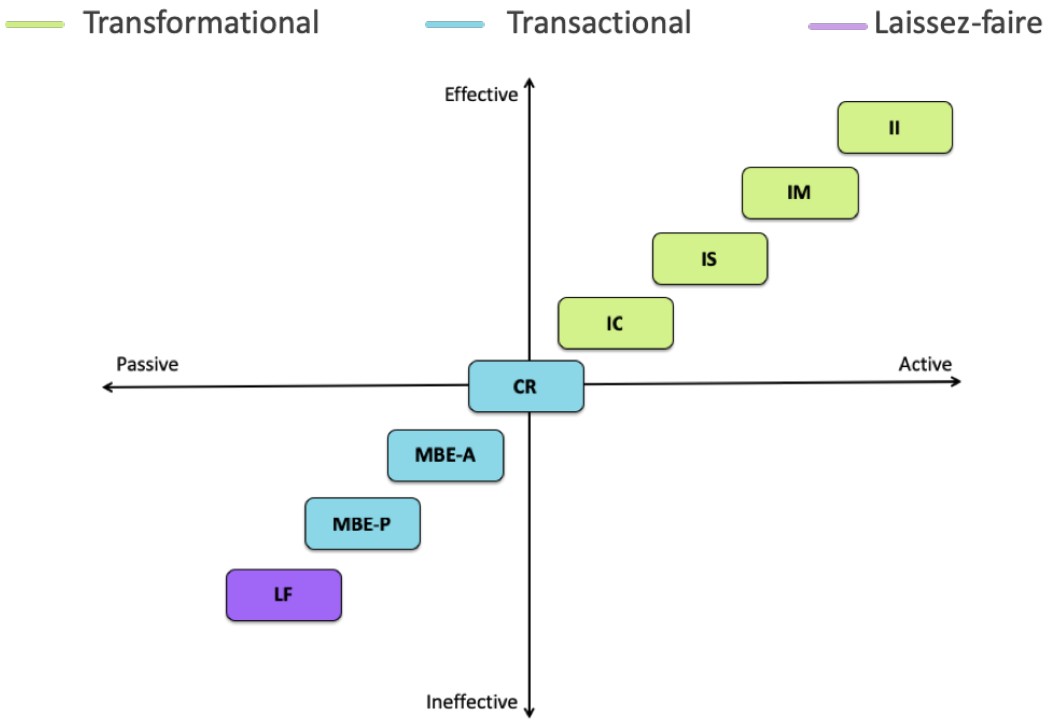

Figure 3.3 Leadership styles factors described in terms of effectiveness and degree of activity

According to the FRLT, the success of a group is determined by outcomes, or results, of leadership behavior (Avolio & Bass, 2004). These outcomes are measured in terms of extra effort, effectiveness and satisfaction. Extra effort entails getting others to do more than they expected to do, heightening others' desire to succeed and increasing others' willingness to try harder. Effectiveness refers to adequately meeting organizational requirements and representing their group to higher authorities and essentially leading a group that is effective. Satisfaction is defined in terms of using methods of leadership that are satisfying and working with others in a satisfactory

way. Based on FRLT and published studies on leadership styles, more effective and active behaviors lead to favorable leadership outcomes. This idea is portrayed in Figure 3.4.

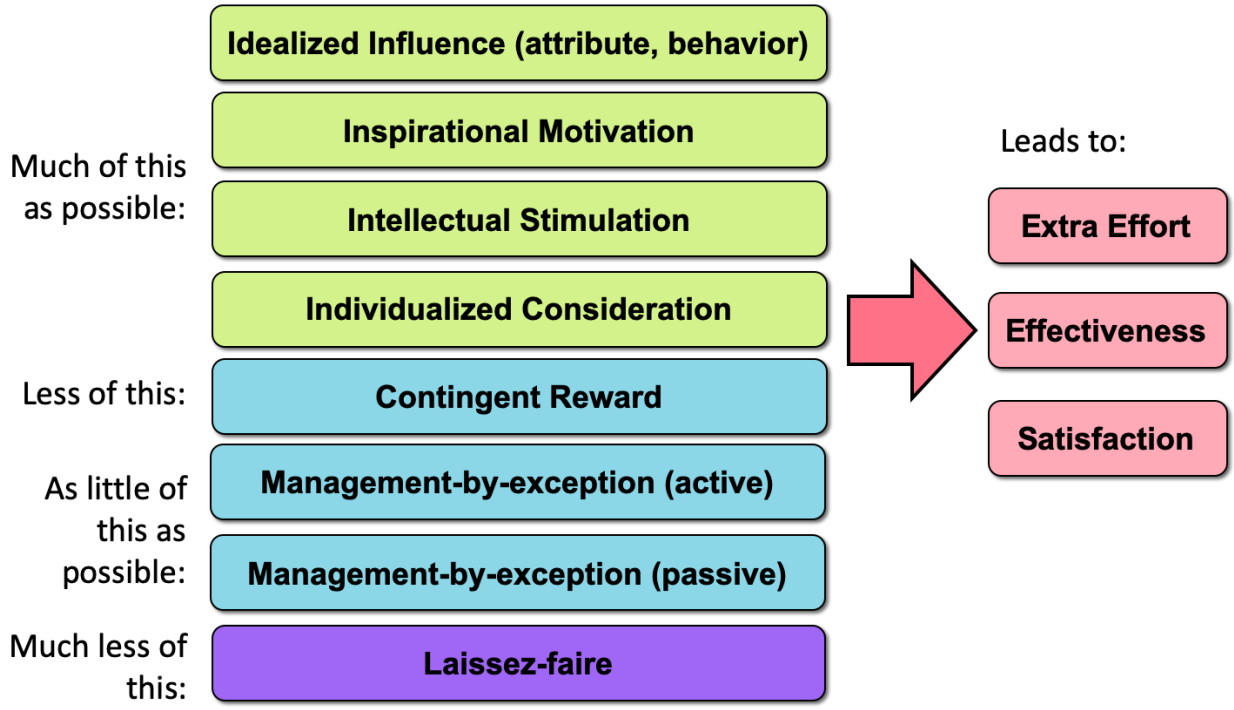

Figure 3.4 Relationship between leadership style behaviors and leadership outcomes

Since many outreach initiatives in chemistry are carried out by student organizations, the interactions between leaders of student organizations and volunteers of outreach events should be investigated. This study aims to expand the knowledge of chemistry outreach efforts by studying the leaders in charge of coordinating outreach events. Specifically, by studying how leaders' behaviors and characteristics, as described by FRLT, are present in the facilitators' interactions chemistry outreach events. As described in the next section, analysis will involve examining cases through the lens of Communities of Practice.

3.2 Research Design

This study was designed within the context of the research questions and the guiding frameworks described above. A case study methodology, discussed below, was deemed appropriate for this study. As discussed later in this section (Section 3.2.1), the descriptive nature of a case study calls

for data collection from multiple sources, employing both qualitative and quantitative methodologies.

3.2.1 Case Study

A case study methodology is recommended when a researcher wants to understand a real-world case and assumes understanding will likely involve important contextual conditions pertinent to the case (Baxter & Jack, 2008; Bodner & Orgill, 2007; Yin, 2014). Given that each student organization and all they encompass is unique (i.e., leadership structure, affiliations, recognitions, membership, leadership styles, etc.), case study is an appropriate approach to address the research questions presented earlier. In addition, Yukl (2010) in *Leadership in Organizations* suggests the use of case study design for leadership studies because of the extensive descriptive nature of this design.

As stated by Yin (2014, p.121), there are five components to define in a case study research design: the research questions, the purpose of the study, the unit of analysis, the logic linking the data to the purpose, and the criteria for interpreting the findings. The research questions and purpose of this study were outlined previously in Chapter 1. In this research project, we were interested in studying the leaders of student organizations participating in chemistry outreach and the impact of their leadership style on *boundary processes* of the CoP. The unit of analysis is the case, which needs boundaries or a context to determine the scope of data collection (Yin, 2014, p.125). Here, the defined case in this study is the leaders of student organizations in the context of chemistry outreach events. Data collection and interpretation will be discussed in the subsequent sections.

3.2.2 Participants and Recruitment

Purposeful sampling is used to select participants the researcher can learn from the most (Merriam & Tisdell, 2016). Therefore, the recruitment of participants for this study took place at institutions that met one of the following criteria:

- The institution had an active ACS Student Chapter that participates in outreach efforts
- The institution had an organization, not affiliated with ACS and with the majority of membership being students, that participated in chemistry outreach efforts

The pool of participants included two student organizations, one for each criterion. These criterions were established in the initial stages of designing the study to serve as a basis of comparison, because organizations affiliated with the ACS may have different membership and access to resources to which those that are not with the ACS may not have access. The participants recruited for the study were students leading outreach efforts and students volunteering to carry out the outreach effort. Those participants who fulfilled both roles as leaders and volunteers were treated as leaders throughout this study. Since there is no standard leadership structure for student organizations, the number of participants per case varied. The students' majors and year in studies may vary across organizations, and while this information could have been relevant during data interpretation, major and year in studies did not limit the recruitment of participants.

The participants for all cases were recruited from chemistry student organizations at a research-intensive (R1) institution in the Midwest. The institution has four chemistry student organizations, one of which agreed to participate in the study. All participation was voluntary as the participants received no incentives for participating in the study. To protect the leaders and volunteers' identities, pseudonyms were assigned to the participants. Specific details for each participant will be discussed in Chapters 4-6, alongside pertinent context for each case. The study was conducted in accordance with the guidelines of Purdue University's Institutional Review Board (IRB). The documentation for approval, recruitment information, and consent forms are included in Appendix F-H.

3.2.3 Data Collection and Sources

Common data sources for leadership studies and case studies include interviews, observations, artifacts, and questionnaires (Yin, 2014; Yukl, 2010). Table 3.3 shows the alignment between research questions and these data sources. A more detailed description for each data source follows.

Table 3.3 Alignment between research questions and data sources

Research Question	Data Sources
How can leadership styles and leadership outcomes be characterized within student organizations participating in chemistry outreach?	Survey MLQ (self-rate and rater) Video recordings/Observations Interviews
What factors, related to diversity and inclusion, contribute to the student-facilitators' experiences in outreach events in terms of *Boundary Processes* of the student organization as a community of practice?	Video recordings/Observations Interviews

Survey

The information collected from the survey *Characterizing Collegiate Organization's Chemistry Outreach Practices* (Pratt & Yezierski, 2018a) informed the context of the study and provided descriptive information (i.e., number of members, affiliations, organizational standing) regarding the participating student organization, their outreach efforts, and general practices. Pratt and Yezierski (2018a) developed the survey used in this study and it was designed for students, faculty, and staff members. For this study, the survey was set up in an online survey platform (Qualtrics) and administered to students, i.e., the leaders and volunteers of organizations. The survey items addressed topics such as the purpose of outreach, specific practices and activities, and success and evaluation (see Appendix A). While no significant modifications were made to the survey, some vocabulary was edited to tailor the survey to this study.

Video Recordings & Interviews

Observations and interviews were used to identify the behaviors of leaders, to compare and examine how well these align with results from the Multifactor Leadership Questionnaire, described in the next section. A video-stimulated recall technique (DeKorver, 2016; Johnson, 2017) was the observation and interview approach used in this project. The participants were recorded at two instances: during any meeting with volunteers in preparation for the outreach event and the day of the event. The video and audio from the recording were used to take observations of leaders' actions and dialogue with the volunteers. From the recordings, certain clips were selected to guide the interview and facilitate questions to yield data related to leadership styles, addressing the

research questions. During the interview, the specific clips were shown to the participant to prompt responses that describe their decision-making and behaviors (Calderhead, 1981). The leaders responded to questions that involved recalling and reflecting about their own actions and interactions, while volunteers provided insight about their interactions with the leaders. The semi-structured interview protocols (Appendix B and Appendix C) were similar to the ones used for a published case study on mentor-student interactions (Johnson, 2017). Due to scheduling conflicts and the location of events, videos recordings were not collected for the second case (Chapter 5). Instead, extensive notes about leader-volunteer interactions were taken at the events and specific instances were addressed during the interview.

Leadership Styles Questionnaire

The Multifactor Leadership Questionnaire (MLQ) was used to identify behaviors associated with different leadership styles in leaders and to determine leadership outcomes. The MLQ was developed by Avolio and Bass (2004) to assess leadership styles and outcomes, through items pertaining to the leaders' interactions with their followers. The Likert-scale format items included in the questionnaire are associated to a specific factor (those described in Section 3.1.2) or characteristics of leadership styles. Specifically, there are four questions per leadership style behavior and nine questions for leadership outcomes, for a total of 45-items. The respondent's scores for specific items are summed and averaged to determine factors scores. A sample of the MLQ is included in Appendix D.

The MLQ, also referred to in the literature as MLQ-5X, has been widely adopted by researchers (Antonakis et al., 2003; Bligh et al., 2018; Eagly et al., 2003; Gilbert & Kelloway, 2018; Sosik & Godshalk, 2000; Toor & Ofori, 2009) because its validity has been well assessed (Antonakis et al., 2003; Sosik & Godshalk, 2000). In addition, the MLQ includes two forms, the leader form and the rater form. The leader form is a self-assessment for leaders, whereas the rater form is completed by volunteers to assess their leaders. In order to make the MLQ accessible to participants, the questionnaire was set up in Qualtrics and administered to the participants after the interviews were finished. The intention in doing this was to use the interview to understand the participants' thoughts on leadership without the influence of the content of the MLQ. Here, the leaders completed the leader self-rate form and the volunteers completed the rater form. The rater form includes the same statements but from a third person perspective.

Artifacts

Understanding what leaders and volunteers are doing at the outreach event can provide descriptive information about their interaction and the context of the case study. Therefore, several artifacts were collected for this study. Specifically, those related to leader-volunteer interactions and the leader's involvement in the event. The artifacts for this study included handouts prepared by student organizations explaining the demonstrations for the event, and written communications sent from leaders to volunteers providing insight regarding how the leaders and organizations operate.

3.2.4 Data Analysis

The manner in which data collection was carried out varied slightly for each case, as discussed in Chapters 4 and 5. The setting for each outreach event and instances of leader-volunteer interactions varied per case, requiring methods for data collection to adapt to the situation. However, data analysis was consistent to what is described below.

Analysis of Observational & Interview Data

The observations (i.e., audio-recordings), the written communications from leaders to volunteers and the interviews were deductively coded (Merriam & Tisdell, 2016) using the leadership styles behaviors presented by Avolio and Bass (2004). The descriptions for each code were created based on reports throughout the literature. Throughout the data analysis process, the code "Absent/Missed Opportunity" emerged inductively from the data. This code described instances in which the leader-participants could have addressed a situation differently or displayed a more effective behavior associated with leadership styles. Inter-rater reliability was carried out with a chemistry education researcher not involved in the design of the study. A set of randomly selected excerpts, from observations and interviews, and the descriptions for each code was sent to the other researcher. After coding the excerpts, these were compared to the main researcher's coding scheme to determine if the codes accurately represent the data. Whenever discrepancies happened, the researchers discussed the coding of excerpts until reaching an agreement.

The pilot study, presented as case one, was used to achieve interrater reliability to then use the same codes to analyze data for case two. Table 3.4 shows all codes used for data analysis, its

description and examples of how codes are present in the data. This table is also included in Appendix E.

Table 3.4 Coding Scheme for Leadership Styles and Data Examples

Code (Abbreviation)	Description	How code is present in data
Idealized influence (attributed) (IIA)	Socialized charisma, whether the leader is perceived and viewed as confident, powerful, focusing on high-order ideals and ethics	*As absent/missed opportunity
Idealized influence (behavior) (IIB)	The charismatic actions of the leader that are centered on values, beliefs and a sense of mission	*As absent/missed opportunity
Inspirational motivation (IM)	The ways leaders energize their followers by viewing the future with optimism, stressing ambiguous goals, projecting an idealized vision, and communicating to followers that the vision is achievable	*As absent/missed opportunity
Intellectual stimulation (IS)	Leader actions that appeal to the followers' sense of logic and analysis by challenging followers to think creatively and find solutions to difficult problems	Interviewer: "Do you think the responses from the leaders or leader helped you figure out--?" Participant: "Not really, but I think in that moment it was kind of the panic of like, "Oh, we changed the experiment, and now it's not working." And then I think the one before that didn't work, so having the first experiments not work, I think there was just a little bit of panic going on and just like, "I don't know why it's not working, but let's move on." So that's why I was trying to explain why it was happening and be like, "Well, even if this doesn't work," I said, "Let's try it with the solids and see if it does anything different. Let's try the unknown." Yeah. "What's baby powder made of?" That's what I was trying to figure out - would it have the same reaction? So just kind of approaching the problem and problem solving through it."

Table 3.4 Continued

Individualized consideration (IC)	Leader behavior that contributes to follower satisfaction by advising, supporting and paying attention to the individual needs of follower, which allows them to develop and self-actualize	[In reference to having another leader explain experiments in event] Participant: "But I also want to give everyone the opportunity to learn and improve. Just because you're not good at something, doesn't mean that you have to stay not good at it forever. We can also work on that. So I try to give everyone an opportunity to step up and improve."
Contingent reward (CR)	Leaders behaviors focused on clarifying role and task requirements and providing followers with materials or psychological rewards contingent on the fulfillment of contractual obligations	[In reference to recruiting volunteers for event] Email communication: "[…] All materials will be provided along with a free T-shirt and pizza party […]."
Management-by-exception, active (MBE-A)	Active vigilance of a leader whose goals is to ensure that standards are met	"[…] we (the board) had to basically choose time slots so that other volunteers could come pick up their materials. I interacted with them. It was just they tell me their name and what school they're going to and I give them a bag. […] I come in, I fulfill my task, my job is done."
Management-by-exception, passive (MBE-P)	Leaders only intervene after noncompliance has occurred or when mistakes have already happened	"The issue is when you plan things so close to milestones, things become even more hectic. Because now you are not able to do your natural functions as part of this group. So a lot of us had to go and reach out to a lot of people outside the board to get the help we needed."
Laissez-faire (LF)	Leader provides no meaning or clarification of events for followers which is interpreted as lack of communication, undermining the follower's trust in the leader; characterized by delays of action, absence and indifference	Participant: "[…] they've (other leaders) been here before and they know what to expect. So I had expected them to give them more of an idea what to do or how to go about planning it, which I don't think they did it. So it was more of a kind of figuring out as you go along."

Table 3.4 Continued

Absent/Missed Opportunity	Instance in which the participant displayed a specific behavior, but the volunteer expected a different behavior; or, the interaction presented an opportunity to display another behavior; or, the participant presented a different approach to a specific situation	"[…] what I think was even more helpful, they didn't really talk about it until I specifically asked them, is what are the steps to take when you go to the school for people who've never been there. […] I was surprised at my first day because I was basically in charge of the classroom. I thought the teachers come and help you and are part of it. […] I was really worried for the undergrads who volunteered who didn't really have much experience doing this." - Missed opportunity to display Individualized Consideration

Analysis of Quantitative Data

The results for the MLQ were analyzed according to the guide published with the questionnaires (Avolio & Bass, 2004). The values obtained from the self-rate forms were compared with the average values obtained by the rater forms using radial plots (see Chapters 4-5), with each line in the radial plot representing a point on the MLQ rating scale. There are two radial plots per participant, one for leadership styles and one for leadership outcomes. Starting at the center of the plot and moving to the outside, the scale is as follows:

0.0 = Not at all
1.0 = Once in a while
2.0 = Sometimes
3.0 = Fairly often
4.0 = Frequently, if not always

As discussed in Section 3.1.2., leaders with transformational behaviors tend to positively impact the organization and their followers, which is represented through the MLQ by scores close to 4.0 for items corresponding to IIA, IIB, IM, IS, and IC. Behaviors associated to transactional and *laissez-faire* leadership styles tend to have less of a positive impact on organizations. Therefore, MLQ scores close to 4.0 for items corresponding to CR, MBE-A, MBE-P and LF are interpreted as negative because it means the participant frequently or fairly often displays those behaviors. These ideas are better illustrated with the radial plot in Figure 3.5. The data line shows an "ideal plot" or trendline, not to be interpreted as data from the study, based on the ideas presented in Figure 3.4. The use of radial plots was specifically developed for this study to visualize the MLQ results and elicit trends.

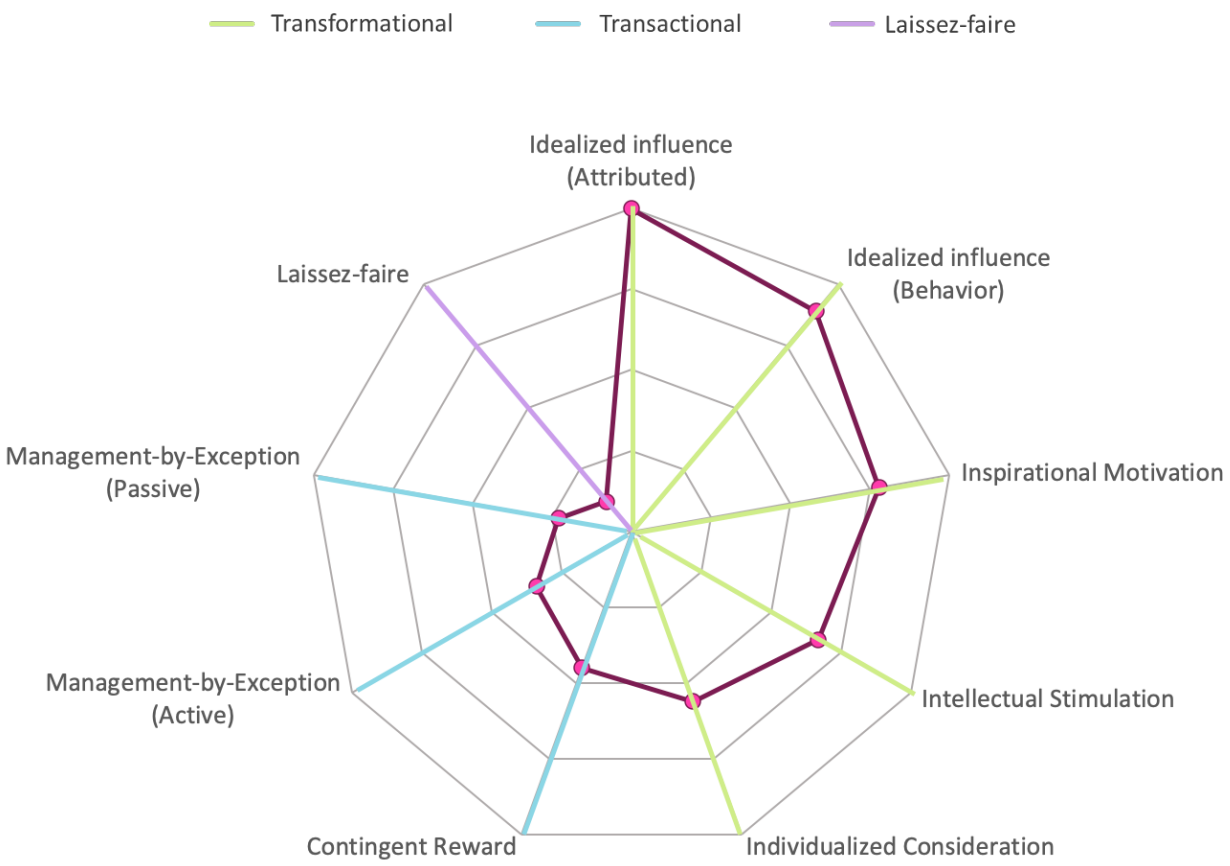

Figure 3.5 Example radial plot to show "ideal results", grounded on the FRLT

Trustworthiness and Authenticity

Both trustworthiness and authenticity were addressed by adopting the strategies suggested by Merriam and Tisdell (2016). Credibility refers to how the findings of the study match the participant's reality (Merriam & Tisdell, 2016). Even though reliability in qualitative work is problematic, as results regarding human behavior might not lend themselves to replication, consistency was addressed (Merriam & Tisdell, 2016). Consistency refers to whether the results are consistent with the data collected. Here, both credibility and consistency were addressed by peer review, triangulation and member check (Merriam & Tisdell, 2016). The first, peer review, was discussed as interrater reliability in the section *Analysis of Observational & Interview Data*. The use of multiple sources of data collection aimed to corroborate findings facilitates triangulation (Yin, 2014). The process for member checks involved sharing preliminary findings with the participants in order for them to give feedback on the researcher's interpretation. The participant's feedback included suggestions to better capture their perspectives with their

statements, which provided an element of authenticity of the data in terms of consistency. An additional strategy to address consistency is an audit trail (Merriam & Tisdell, 2016), which was addressed by the researcher recording memos throughout the process in order to provide a detailed account of how the study was conducted and how data was analyzed.

3.2.5 Pilot Study

The purpose of the pilot study was threefold. (1) to help determine what is an appropriate number of participants for the study, (2) to decide if additional leader-volunteer interactions or other aspects of leadership in chemistry outreach needed to be observed, and (3) to collect interview data that helped modify the interview protocol to better align with the purpose of the study. The study was conducted in accordance with the guidelines of Purdue University's Institutional Review Board (IRB). The documentation for approval, recruitment information, and consent forms are included in Appendix F-H.

The pilot study is presented in Chapter 4 as case one because data collection and analysis methods did not change significantly from one case to another. Slight changes were made to the interview protocol to include event-specific questions. Capturing all possible pre-event leader-volunteer interactions was deemed an impossible task; therefore, the interactions observed throughout the study were only formal interactions, i.e., those facilitated by the student organization.

CHAPTER 4. LEADERS IN GIRL SCOUT CHEMISTRY DISCOVERY DAY

4.1 Participants

The participants for the pilot study (i.e., case one) were recruited from a chemistry student organization at a research-intensive (R1) institution because, as discussed earlier, student organizations are the ones typically leading outreach efforts. Pseudonyms were assigned to each participant. Three leader-participants of a graduate student organization that was not affiliated to ACS agreed to participate in the study: Iris, Caitlin and Cecilia. Felicity and Nora were two volunteer-participants working at the outreach event who agreed to participate in the study. Nora was a member of the graduate student organization, while Felicity was not. The volunteer-participants were recruited after the leader-participants and prior to the event, with no intention of collecting leader-volunteer paired data. While this increased the risk of not having interactions between participants, it reduced the risk of volunteer-participants feeling targeted for recruitment because they interacted with specific leader-participants.

4.2 Context

Iris, Caitlin and Cecilia were members of an all-female chemistry graduate student organization who were part of the "Outreach Committee" within the board of the organization. The student organization participates in one to two chemistry outreach events throughout the Fall and Spring semesters, but does not participate in outreach events during the summer. During the Spring semester, the organization plans *Girl Scout Day;* an outreach event expected to serve around 100 participants: 40-75 girl scouts ranging from 4^{th} to 8^{th} grade and 20-25 volunteers. It is important to note for this year's *Girl Scout Day* 13 girls attended the event and 16 graduate students volunteered as facilitators during the event. Due to the small number of attendees, the leaders changed the *Girl Scout Day* event from being a large group of girls led by a graduate student to a one-on-one structure, in which one girl scout was paired with a "graduate student buddy." Regarding leader-volunteer interactions, the organization did not plan another instance of potential leader-volunteer interactions besides the day of the outreach event. Therefore, communications between leaders and volunteers happened mainly via email.

4.3 Data Collection & Analysis

The leader-participants were administered the *Characterizing Collegiate Organizations' Chemistry Outreach Practices Survey* (Appendix A). The survey was set up using Qualtrics, an online survey platform, and sent to the participants two months before their outreach event. Reminder emails were sent to the participants for them to complete the survey. The volunteer-participants did not fill out the survey because the leader-participants had the most knowledge about the organization. Specific questions pertaining to outreach practices were addressed during the volunteers' interviews, for example, those related to goals for outreach.

The organization only met with volunteers the day of the outreach event. On this day, the leader-participants and their interactions with other facilitators of the outreach event, including volunteer-participants, were audio-recorded. The leader-participants wore a microphone and audio recorder for 4 hours of the 8-hour long outreach event. The volunteer-participants were audio-recorded at the same time as well. While the volunteer-participants are not the focus of this study, their interactions and experiences with leaders in the outreach event are important in describing the leadership in student organizations. All participants were asked to wear the recorder as soon as they arrived at the event; by doing so, the audio was able to capture pre-event interactions between leaders and volunteers. In order to capture visuals of the leader-participant interactions with others, different cameras were set up in the laboratory space where three of the hands-on experiments took place. The first camera was set up in the back of the room to have an overall view of the space and interactions; a second camera was set up in the front of the room to capture leader-volunteer interactions and participants' interactions with the audience; lastly, the primary researcher wore a *GoPro* camera to capture the same interactions, but from a closer and focused point of view. The cameras recorded for approximately 1.5 hours. The audio-recorders captured approximately four hours of observations, which were transcribed using an online automatic transcription service. The audio- and video-recordings were analyzed before moving on with the interview phase. Clips capturing leader-volunteer interactions were selected for the interviews.

The participants were interviewed within one to two months after the outreach event. The clips selected for the interview varied in length, were not repetitive in interactions and there was at least one clip for every significant interaction. In other words, if a leader-participant interacted 10 times with one of the volunteers, the leader-participant would watch only one clip interacting with that volunteer. If a leader-participant interacted with four leaders or volunteers, the participant

would watch a clip for each interaction during the interview. To avoid participant fatigue, a maximum of three clips were shown to the participants. Other interactions were still addressed and discussed during the interview without showing clips. These were semi-structured interviews following the protocols included in Appendix B-C, and participants were given the option of being interviewed in Spanish. The experiment guide was used throughout the interview for reference and to study the chemistry content of it. Data analysis of observational and interview was carried out as described in Section 3.2.4. The codes presented in Appendix E were used in the qualitative data analysis.

The Qualtrics link to the Multifactor Leadership Questionnaire (MLQ) was sent to the participants immediately after their interviews and they had a week to complete the questionnaire. The two volunteer-participants were sent the rater-form of the MLQ for them to evaluate each of the three leaders and the leader-participants were sent the self-rate form to assess their own leadership style. The results for the MLQ were analyzed according to the guide published with the questionnaires (Avolio & Bass, 2019). A complete walkthrough of the quantitative data analysis is described in Section 3.2.4.

4.4 Leadership Styles Characterized

4.4.1 Iris

Out of the three members of the Outreach Committee, Iris was the only member to volunteer as a "graduate student buddy." This was a last-minute decision because more volunteers were needed for the morning session. Iris defined leadership as:

> "A leader is someone who can— they lead the group but not from the front. It's kind of like a shepherd. You're getting everyone together to work towards your goals and get everyone on the same page. You're not making all the decisions by yourself. You're not giving out orders. […] Everything is very democratic. You all get a say and then we split responsibilities."

The radial plot comparing self-rate and rater results for the *Multifactor Leadership Questionnaire* (MLQ) are shown in Figure 4.1 and Figure 4.2.

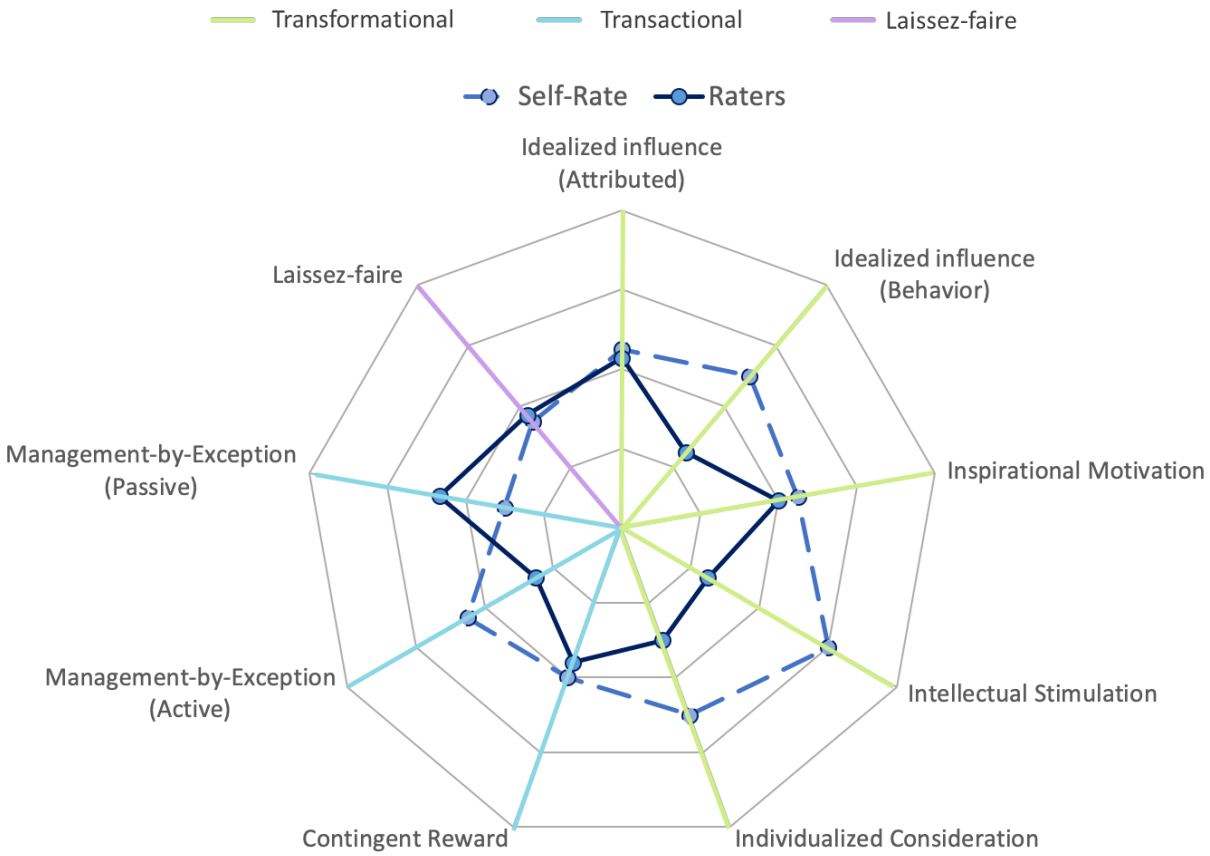

Figure 4.1 Radial plot for self-rate and rater results of MLQ-leadership behaviors for Iris

Figure 4.2 Radial plot for self-rate and rater results of MLQ-leadership outcomes for Iris

Iris' plot for self-rating shows a score close to 3.0 for behaviors associated with a transformational leadership style. Self-rating scores for the other behaviors were lower than the transformational behaviors. The raters' scores for Iris are similar to the self-rate score for behaviors *Idealized Influence, attribute* and *laissez-faire,* which are at opposite sides of the spectrum. Raters assigned lower scores than Iris' self-rate scores for most behaviors, except *Management-by-Exception, passive* (MBE-P). Altogether, the MLQ results indicate the volunteer-participants do not perceive Iris as the leader she believes she is in the context of doing chemistry outreach with the student organization under study. In contrast to the self-rate MLQ results, the behaviors identified throughout Iris' interview were those associated with *transactional* and *laissez-faire* leadership styles. Iris did not display transformational behaviors frequently; therefore, volunteer-participants were not satisfied, remained unmotivated to put in extra effort, and did not view Iris' leadership as effective.

When it came to recruiting volunteers for the outreach event, Iris compared the current experience to experiences in undergrad:

> "… I feel back then it was a lot easier to wrangle volunteers because I knew everyone because they were all in my department. I already knew them because they were either in classes with me or worked in my friends' lab. It was a lot smaller of a community. So, getting people to do things is a lot easier to negotiate because everyone knew each other already. […] Here, I don't have that leverage anymore to get people to help. [..] you're just asking people to help out of the goodness of your heart."

Iris then added:

> "… we get a t-shirt for the volunteers and food to get them to volunteer. That's what we leverage. …"

Iris acknowledged that, in a larger community, material incentives are the go-to for recruiting graduate students to help with the outreach event. While her statement supports Iris' low rating of CR behavior, it is also a missed opportunity to display more *transformational*-like behaviors and explains the discrepancies between self-rate and raters' results for behaviors associated to a *transformational* leadership style.

Iris acknowledged that communication between Outreach Committee members was poor. While this represents a LF behavior on behalf of other members and herself, Iris' actions to solve issues arising from lack of communication and clarity aligned with some transformational behaviors.

For example, the student organization:

> "… invite a university employee to come in the morning of the event and give a safety talk to the kids but they couldn't do it that day. So, the night before I was like 'Did anyone write up a safety talk?' and I was informed 'No, I was going to wing it.' by (another leader) to which I responded 'No, no, no; these are kids in a chemistry lab.' So, we ended up showing them a short video on lab safety I found on YouTube."

With her actions, Iris ensured standards were met which is associated to *Management-by-exception (active)* (MBE-A). Another example is when Iris set up experiment stations, observed the day-of-event. Iris had to find materials in bins prepared by another leader and, in doing so, realized materials were mislabeled or missing. Iris displayed MBE-P behaviors by intervening in issues related to materials when mistakes had already happened.

4.4.2 Caitlin

Caitlin defines leadership as:

> "… a leader leads by example, and they shouldn't ask anyone to do something that they're not willing to do themselves. A leader, at the core of it, is an organizer that also has the ability to discern what everyone's specific talents are and put them to best use. […] It's just someone that steps up to run the show. […] I try to give everyone an opportunity to step up and improve. But, if things aren't getting done, I will step in and do them."

The radial plot comparing self-rate and rater results for the *Multifactor Leadership Questionnaire* (MLQ) is shown in Figure 4.3 and Figure 4.4. Except for IIA, the volunteer-participants rated Caitlin with lower scores than what she perceived herself.

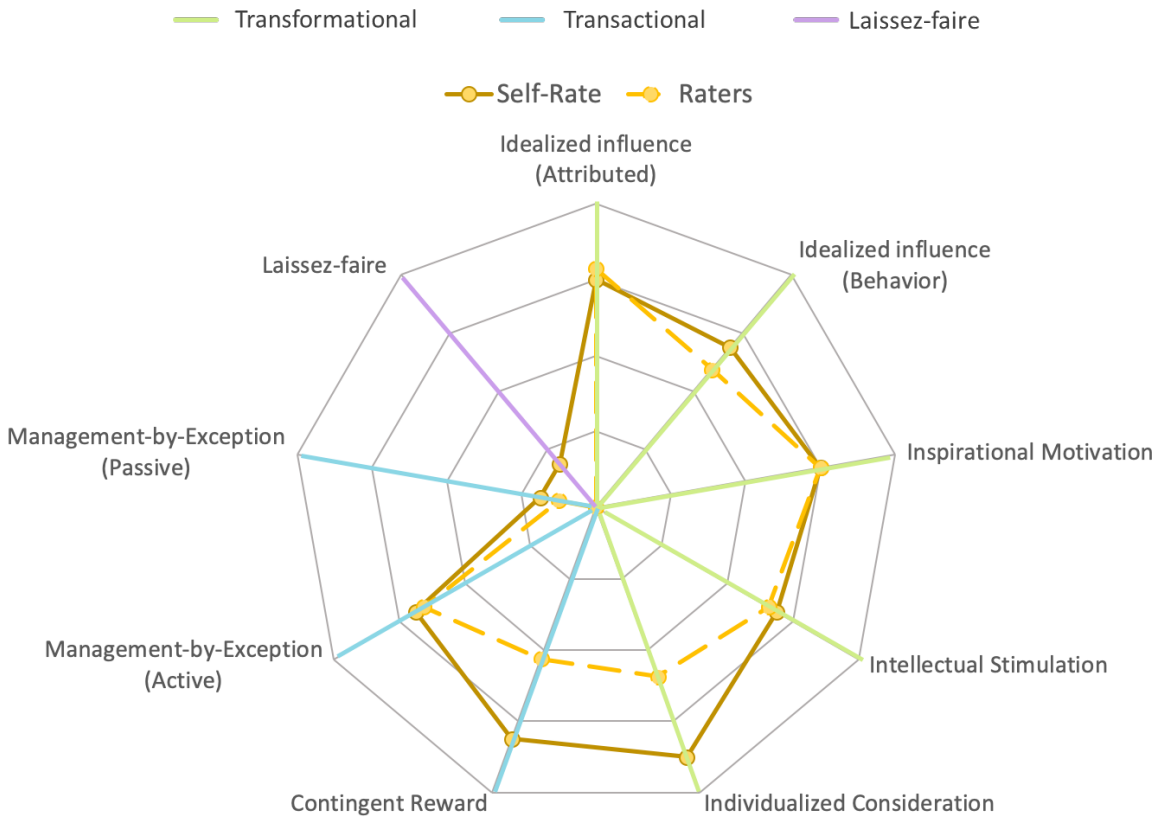

Figure 4.3 Radial plot for self-rate and rater results of MLQ-leadership behaviors for Caitlin

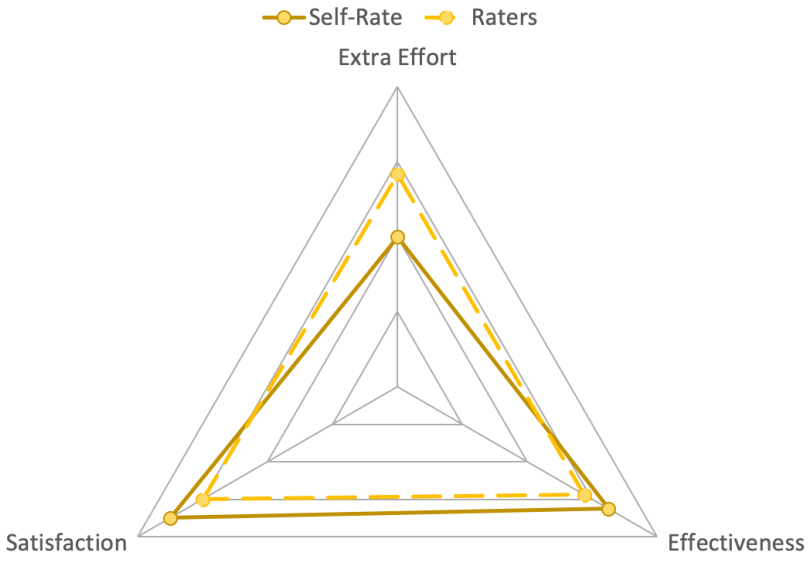

Figure 4.4 Radial plot for self-rate and rater results of MLQ-leadership outcomes for Caitlin

Throughout the planning of the outreach event, Caitlin was the leader who sent out communications to the volunteers. Per observations during the day of the outreach event, Caitlin fulfilled different roles like welcoming volunteers, giving instructions to the volunteers before the event started, welcoming attendees, and led most of the discussions of experiments performed that day.

Email communications, sent on behalf of Caitlin, were mainly an example of *Contingent Reward* (CR) behavior. Aside information pertaining the location and date of the event, the emails stated:

> "… Experiment materials and procedures will be provided along with a free T-shirt and either breakfast or lunch. …"

These materials (i.e., food and shirt) were used as "rewards" to encourage graduate students to volunteer as facilitators of the outreach event. During their interview, volunteer-participants expressed they do not need these rewards to be motivated to participate in the organization's events:

> "[…] I see this event as an opportunity to contribute a little something to a person who might want to study science in the future. For them to realize 'This is cool.', for them to like it and want to pursue it. I don't participate of these events because there's food or free t-shirts or anything of the sort. I wouldn't have woken up at 7:30am to do that. I did it because I want to do something positive for society."

As further discussed on Chapter 6, the facilitators volunteer for *Girl Scout Day,* and other outreach events, to be a role model to younger girls, to give back to the community and to contribute to the efforts of learning through outreach. The misalignment of what leaders think about their volunteers' motivation versus the volunteers' true motivation to participate in outreach is a leader's missed opportunity to exhibit *transformational* behaviors. These behaviors could have been *Idealized Influence (behavior)* (IIB) to have actions be centered on a sense of mission or *Inspirational Motivation* (IM) to energize the followers by communicating to them that their vision is achievable.

Caitlin displayed *Individualized Consideration (IC)* behaviors when she encouraged another leader to explain one of the experiments the Girl Scouts were doing:

> "… I want to give everyone the opportunity to learn and improve. Just because you're not good at something, doesn't mean that you have to stay not good at it forever. We can also work on that. I try to give everyone an opportunity to step up and improve. […] She was kind of on the side, not fully engaged, so I wanted to give her the chance to do that. I know that the talking and explaining is not the

> easiest for her, because she is a little bit more soft-spoken. So, I wanted to give her the chance to do that …"

Caitlin understood the other leader thought of the outreach event as a space for professional development to improve public speaking skills. However, interviews and observations explain the differences observed for *Individual Consideration* (IC) in Figure 4.3. According to MLQ results, Caitlin's leadership influenced the volunteer-participants' effort to be more than expected (Figure 4.4). Yet, based on interviews with volunteers, Caitlin missed opportunities to display more transformational behaviors throughout her interactions with the volunteers. One of these instances was Caitlin's short speech to the volunteers before the Girl Scouts arrived. In her speech, she stated the purpose of the event was to have fun and, in addition to telling the volunteers to not worry about things going wrong, she mentioned:

> "… Oh yeah, so we're just rolling with it today. Okay? Just have fun. That's pretty much it."

Felicity, a first-time volunteer of *Girl Scout Day*, thought this speech was taking a different direction:

> "… I was hoping for clear instructions on what we were supposed to do. I was like 'What the heck? I don't understand any of the things that we're supposed to do today'. I think that before starting the event and before the audience arrived, they [the leaders] should have been like 'Okay, we're in charge of the event, this is what we have to do and this each person's role.' Just give specific details about our roles."

Felicity had no idea of what to expect from the outreach event or what was her role in it, which comes from *laissez-faire* behaviors from Caitlin and other leaders. Paying attention to the individual needs of the follower (IC), energizing the followers by stressing ambiguous goals (IM) or being confident and focusing on high-order ideals (IIA) are some of the behaviors that could have been more readily implemented into the pre-event speech that could have helped first-time volunteers.

4.4.3 Cecilia

For Cecilia, leadership is:

> "… understanding the characteristics/traits and weaknesses of the group you are working with for all of you to reach—to be able to guide the group so everyone can reach a common goal."

The radial plot comparing self-rate and rater results for the *Multifactor Leadership Questionnaire* (MLQ) are shown in Figure 4.5 and Figure 4.6.

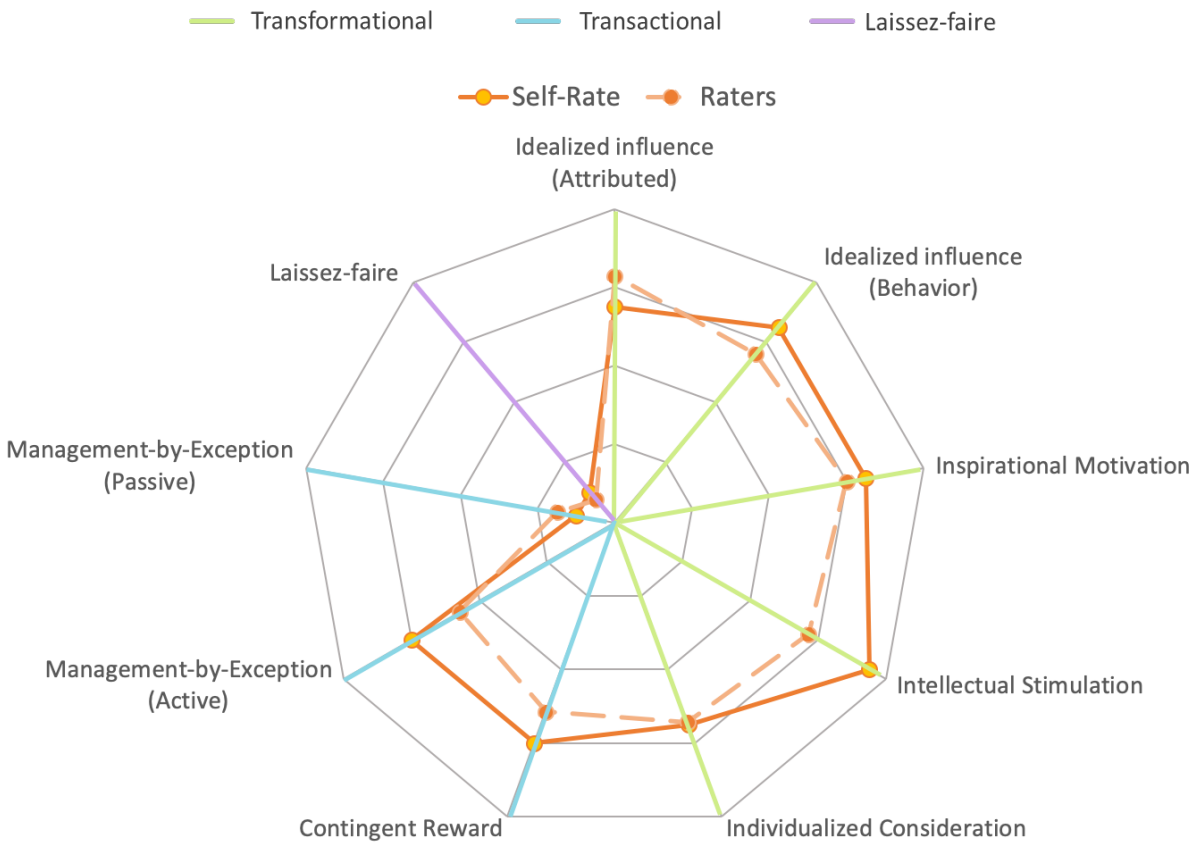

Figure 4.5 Radial plot for self-rate and rater results of MLQ-leadership behaviors for Cecilia

Figure 4.6 Radial plot for self-rate and rater results of MLQ-leadership outcomes for Cecilia

Cecilia's rater scores were lower than self-rate scores, except for *Idealized Influence (attribute)* and *Management by exception (passive)*. Contrary to what was found for the other leader participants, for Cecilia the difference between self-rate and rater score for each behavior is less than 1.0. This means Cecilia and the raters have similar perceptions about Cecilia's leadership styles, but the frequency of these behaviors was perceived as less by the volunteers. The MLQ reflects when, as part of the interview, Cecilia acknowledged:

> "… I wasn't interested in competing for being perceived as the leader of the group. If I felt or noticed someone else wanted to, I would let them do that […] But also, for me it has been more difficult to adapt here or portray myself 100% as I was in my home country. …"

This could also explain why she overestimated the outcomes of her behaviors compared to how she was perceived by volunteers.

Cecilia's highest self-rate behavior was *Intellectual Stimulation* (IS). Throughout the interview, Cecilia shared the following about not having a formal training session for facilitators of Girl Scout Day:

> "There wasn't a specific week for us to train volunteers. I thought that was wrong, I think we should aim to have a detailed and in-depth discussion of the experiments with the volunteers.".

When describing prior science experiences, Cecilia said:

> "… When I was in science academy group, we had girls between 8-11 years old do hands-on experiments about relatively complex topics and the girls were able to complete the experiments. So, based on that experience I do think we're not asking much of the girls [audience]. […] with outreach, we teach them [girls] how to think; they do the experiments, we ask questions and the girls come up with crazy ideas or more questions. Those type of questions I had never asked myself, but the girls do ask. That's why I don't underestimate the girls here [USA, Girl Scouts], because they're also capable of asking the same type of questions. Perhaps we just need a different system for that to happen, I don't know."

Cecilia's perspectives about outreach events, which are informed by her participation in facilitating outreach events in her home country, explains why she thinks of herself as a leader who challenges followers to think creatively and find solutions to difficult problems.

Cecilia had extensive prior experience planning and leading outreach events. Part of the planning included meeting with volunteers prior to the event to instruct them on how to be a facilitator. According to observations the day of the outreach event, Cecilia took the initiative to hand out materials the volunteers needed and walked around the room checking on volunteers. When asked about these interactions, Cecilia clarified she checked on volunteers and their Girl Scout buddy in case they needed help because she was aware preparation for *Girl Scout Day* did not include training the volunteer facilitators. Taking the time to do this shows a form of *Individualized Consideration* (IC).

According to other leader-participants, the experiments guide for the day of the event was a group effort with Cecilia being the main lead on this task. The day before the outreach event, the organization shared via email the experiments guide with the volunteer facilitators which included explanations for each activity the Girl Scouts were expected to complete. This delay of action is associated with a *laissez-faire* leadership style and directly impacted how facilitators taught chemistry throughout the outreach event (i.e., *Brokering*) and how the facilitators interacted with the Girl Scouts (i.e., *Interactions*) as CoP boundary processes. Volunteer-participants mentioned the experiment guide was only slightly helpful for various reasons:

> "Well, really, the board sent the experiment guide the day before. I tried to skim them, but I didn't because I was busy with research. The next day, right before the event, I read it for 10 minutes […] I was lost because the guide they gave the girl scouts did not include the instructions for the experiments but the one they had sent did have the instructions. So, I didn't think that helped much. […] Then, whenever the leaders were discussing the instructions it was really fast. I had to go online, find the instructions and then do the experiment with the girl. Sure, I didn't prepare

> in advance, but I also wasn't counting on the experiment guide not having the instructions. […] Having the instructions on the handout to be used the day of the event would have helped for when students ask questions or if you're trying to explain things to different age groups …"

These statements on behalf of volunteer-participants highlight the importance of portraying behaviors associated to *Individualized Consideration* (IC) and *Intellectual Stimulation* (IS) but being *Absent/Missed Opportunities* in this scenario.

CHAPTER 5. LEADERS IN NATIONAL CHEMISTRY WEEK

5.1 Participants

The participants were recruited from a chemistry graduate student organization at a research-intensive (R1) institution in the Midwest. The organization board consists of nine members, three of which correspond to the "Outreach Committee". Pseudonyms were assigned to each participant Three leader-participants of the graduate student organization agreed to participate in the study: Thea, Shado and Amanda. Only one of these leader-participants was part of the Outreach Committee within the organization. Harrison, non-member of the student organization, is a volunteer-participant working at the outreach event that agreed to participate in the study. Harrison was recruited after the leader-participants and prior to the outreach event, with no intention of collecting leader-volunteer paired data. While this increased the risk of not having interactions between participants, it reduced the risk of volunteer-participants feeling targeted for recruitment because they interacted with specific leader-participants.

5.2 Context

The all-female student organization participating in this study organizes visits to elementary and middle schools to celebrate *National Chemistry Week* (NCW). This year, the organization visited a total of 8 schools and more than 70 classrooms over the course of one week. Volunteers/facilitators visited the classrooms in pairs or groups of three and were able to sign up to visit more than one classroom. In order to prepare the volunteers and facilitators, the board members of the student organization hosted four training sessions. A member of the outreach committee sent a mass volunteer-recruitment email with a sign-up sheet for volunteers to provide information, including which training session they were planning on attending. The low attendance to the first training sessions prompted the organization to plan a fourth training session. There were no repercussions or consequences for not attending training sessions.

5.3 Data Collection and Analysis

The leader-participants were administered the *Characterizing Collegiate Organizations' Chemistry Outreach Practices Survey.* The survey was set up using Qualtrics, an online survey

platform, and sent to the participants 2-4 months before their outreach event, under the assumption preparation for this event would start months in advance. Reminder emails were sent to the participants for them to complete the survey. Only leader-participants part of the outreach committee filled out the survey since they had the most knowledge about outreach practices of the organization. Specific questions pertaining outreach practices were addressed during the other participants' interviews.

The training sessions were facilitated by two to three leaders of the student organization. While the Outreach Committee of the organization was responsible for facilitating the training sessions, external factors interfering with the allotted dates and times did not allow for all members of the Outreach Committee to facilitate the sessions. Therefore, board members not part of the Outreach Committee took on the task of facilitating the training sessions. Due to scheduling issues, observations were collected at two sessions and only one session was video recorded. Two leader-participants were present during the video recorded session and each wore a microphone and audio recorder for the duration of the session. Observations were carried out at school visits where participants were acting as facilitators of the outreach event. All participants wore an audio-recorder and microphone during the event, capturing approximately 30-60 minutes of audio data of participants' interactions. The audio- and video-recordings were analyzed before moving on with the interview phase. Specific instances capturing leader-volunteer interactions were selected for the interviews.

The participants were interviewed within one to two months after the outreach event. These were semi-structured interviews following the protocols included in Appendix B-C, and participants were given the option of being interviewed in Spanish. The observations (i.e., audio-recordings) and the interviews were deductively coded (Merriam & Tisdell, 2016) using the leadership styles behaviors presented by Avolio and Bass (2019). The list of codes is presented in Section 3.2.4 and included in Appendix E.

5.4 Leadership Styles Characterized

5.4.1 Thea

Thea was a member of the Outreach Committee of student organization. She defined leadership as having two-parts:

> "Leadership has to be vulnerable and it also has to be assertive. The vulnerability part comes with being able to accept that you are not always right, but able to listen to other points of view. And then the assertive part is making sure that you are able to communicate, as well as help on the various things that need to be done. So, as a leader, I think you need to have both parts, because I believe that you can't think about yourself. It's not about you, it's about other people. I believe you have to think about how-- it's a lot of-- everybody does not have leadership skills because they're not able to communicate, or they're not able to accept criticism. Because leaders have to accept major criticism, because not everybody sees eyes to eye."

The radial plot comparing self-rate and rater results for the *Multifactor Leadership Questionnaire* (MLQ) are shown in Figure 5.1 and Figure 5.2.

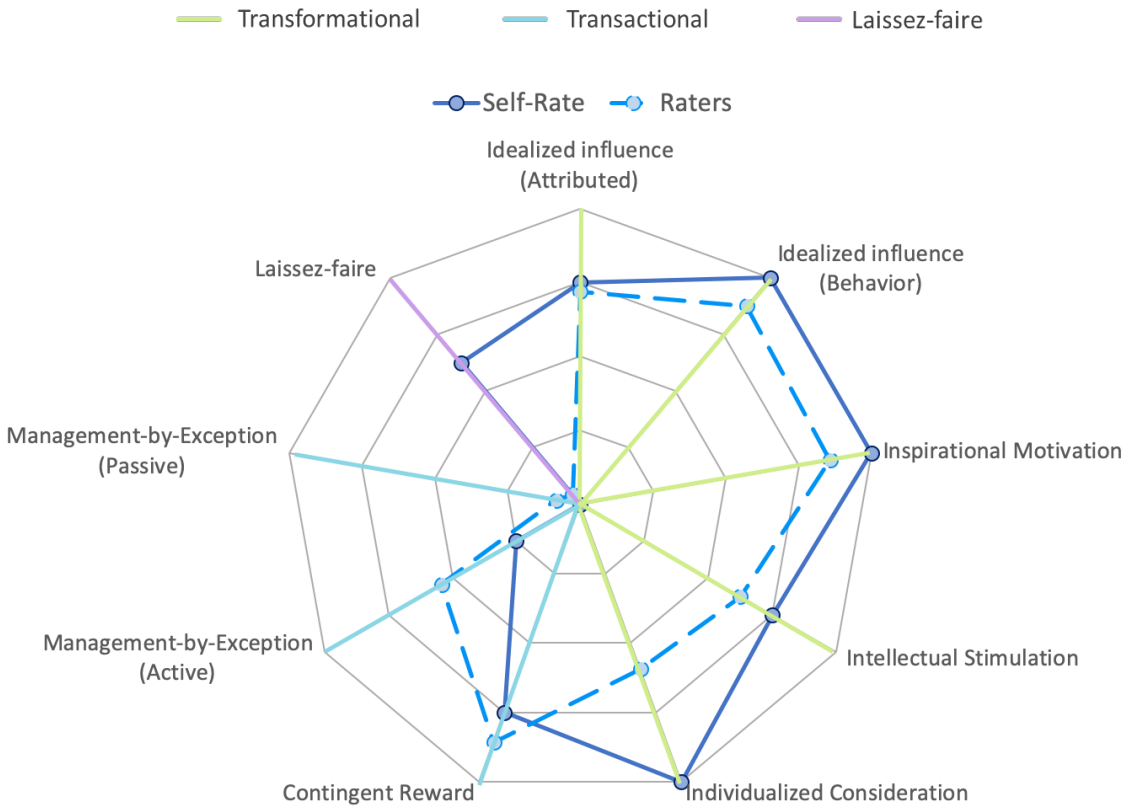

Figure 5.1 Radial plot for self-rate and rater results of MLQ-leadership behaviors for Thea

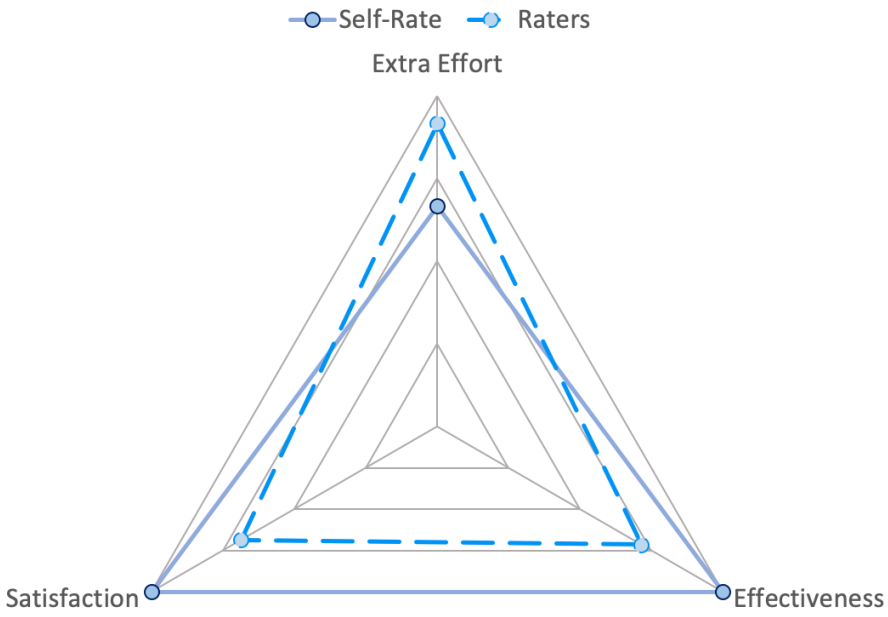

Figure 5.2 Radial plot for self-rate and rater results of MLQ-leadership outcomes for Thea

According to the MLQ results, Thea and followers attributed behaviors associated with transformational leadership style. As part of the Outreach Committee, one of her tasks was to send email communications to the academic community to recruit volunteers/facilitators. Initial email communications stated:

"… All materials will be provided along with a free t-shirt and a pizza party …"

This is a form of *Contingent Reward* (CR), which explains why followers' rating is higher than the self-rate.

An interesting finding is Thea's self-perception about having *laissez-faire* behaviors was rated as more frequent than what followers perceived. Throughout the interview, Thea expressed there was a plan set in place to start preparations for NCW months in advance:

> "NCW goes back to the summer. The purpose of the summer was to talk about our experiments, to trial these experiments and get things off the ground in the summer. This way, when the semester comes, then we don't have to be so flooded with work and school. […] However, no one wants to meet over the summer. So, everyone decides to meet the first two weeks of school which is the most hectic time to meet. Because of that, we were late… we were early but late with getting experiments done. It was late on my approach of doing things, but it was early for what their usual is. …"

According to Thea, she fulfilled many responsibilities not corresponding to her (or rather, meant to be distributed across four leaders) as a consequence of external factors pertaining other leaders (i.e., rigid research schedule, personal milestones, preparation for preliminary exams) impacting their commitment to the NCW event:

> "… The issue is when you plan the event so close to individuals' milestones, things become even more hectic. Because now you are not able to do your natural functions as part of this group. So a lot of us had to go and reach out to a lot of people outside the board to get the help we needed. […] I was the one in charge of recruiting volunteers, so I was the one sending out emails and talking back and forth to friends, students, staff and teachers to convince them to be volunteers. […] I was volunteering at other schools because the volunteers didn't show up. If they don't show up, I have to go to the schools… it was sad if those kids missed the experience. […] For the training workshops, we (leaders) signed up for days but it changed because of the time commitment to their milestones …"

This idea was also discussed by the other leader-participants. While for Thea the timeline shift in planning the event and not meeting that self-imposed expectation might represent *laissez-faire* behaviors, her actions represent more transformational-like behaviors and less *laissez-faire.*

In addition, Thea voiced other challenges she experienced with the preparation of the outreach event and discussed specific changes she would have implemented or things she would have done differently. When discussing the training provided to facilitators, Thea said:

> "… I would make sure that they (the facilitators) understand the purpose of the science. I would make it a real training session where we would go through the science first and then go through the projects."

Thea's concern for the facilitators explains the high self-rating for *Individualized Consideration* (IC) on the MLQ. However, these actions were just thought of rather than implemented, presenting a *Missed/Absent Opportunity* to display a different behavior and a misalignment with the raters' perceptions on Thea's IC behavior.

Among the group of leaders of the student organization, Thea was one of the leaders that responded when volunteer facilitators were not able to attend their selected classroom visit. During her interview, Thea described one her initial classroom visits:

> "When I walked in, I could tell that she was flustered, and she was scared. Another person was supposed to be her partner, but she was expecting that other person to be there to lead it (the event/visit). And I could tell by her personality that she was scared. And I was happy that she was there. I think the reason why I led it's because I know that she was scared. […] She was flustered. I could tell she was happy that I took over. I did that only for her, to help her calm down and be more comfortable

> with it because me and her talked about it outside the school. […] and she was so thankful because she wanted to volunteer and do it so badly. She was so scared when she got there. She was so happy I walked in. But when I saw her I was like, "You did a great job without me being here. If I wasn't here I know that you would still continue to do a great job". So, there were no worries. I thought that she did great job. I just want to give her little things off her back and help her calm down because it's a lot, standing in front of a whole lot of kids. Even though it's not adults it's still intimidating because you don't want to tell the kids wrong. She never interacted with kids before until that day, so it was even more scary for her. She didn't know if she could touch them or anything, so she was happy to see me do that, interact with them and be around them and stuff like that."

In responding specifically to the need of that facilitator, Thea displayed IC and the way she used charismatic and positive actions is an example of *Idealized Influence, behavior* (IIB).

When asked about a second visit, particularly about how Thea and another partner facilitator decided on leading the discussion at the school visit, Thea said:

> "Well, we got there and I asked her 'Which part do you want to do?' She was like 'I don't care.' So, I asked again and when we were putting out materials in the classroom, my partner said 'Okay I'll do this and I'll do this.' To which I said 'Cool, I'll let you lead and then I'll follow' […] I gave them more leeway because I wanted them to have an experience talking to the kids."

This is another example of IC, because Thea's intentions were for her partner to acquire the experience in facilitating an outreach event, complemented by behaviors associated to *Management-by-exception, active* (MBE-A) because the interaction was limited to ensuring the task (i.e., explaining the demonstrations) was completed.

5.4.2 Shado

Shado was part of the board of the student organization but not part of the Outreach Committee. Shado's view on leadership is as follows:

> "I think leadership is a beautiful thing. It's beautiful for someone to be able to guide others in a positive direction. It's not easy. It comes with a lot of stress… and I think it's also within a person. When you lead someone, you become stressed. Everything doesn't go perfectly, and I think it's all about how you deliver. You're stressed but that's not your followers' problems. It takes a lot of self-control and self-discipline to be able to cope with your stress and to be able to still relay in a positive way to the people who are following you and leading with you. …"

The radial plot comparing self-rate and rater results for the *Multifactor Leadership Questionnaire* (MLQ) are shown in Figure 5.3 and Figure 5.4.

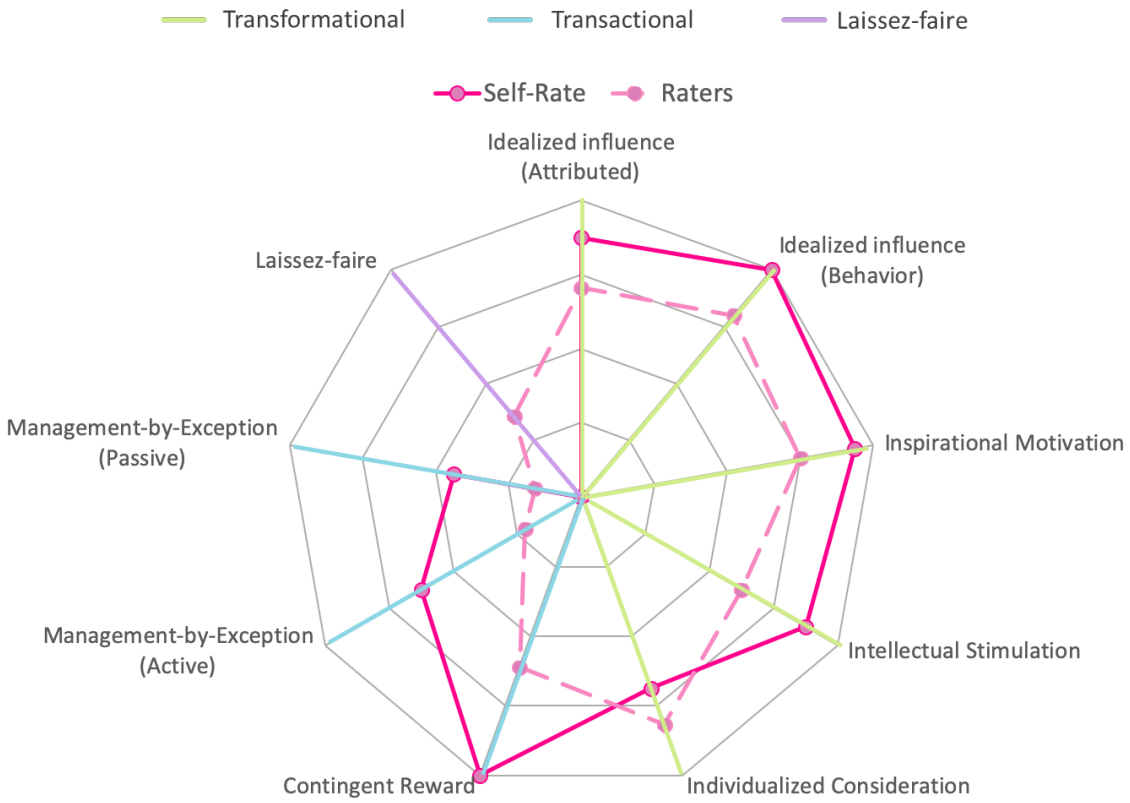

Figure 5.3 Radial plot for self-rate and rater results of MLQ-leadership behaviors for Shado

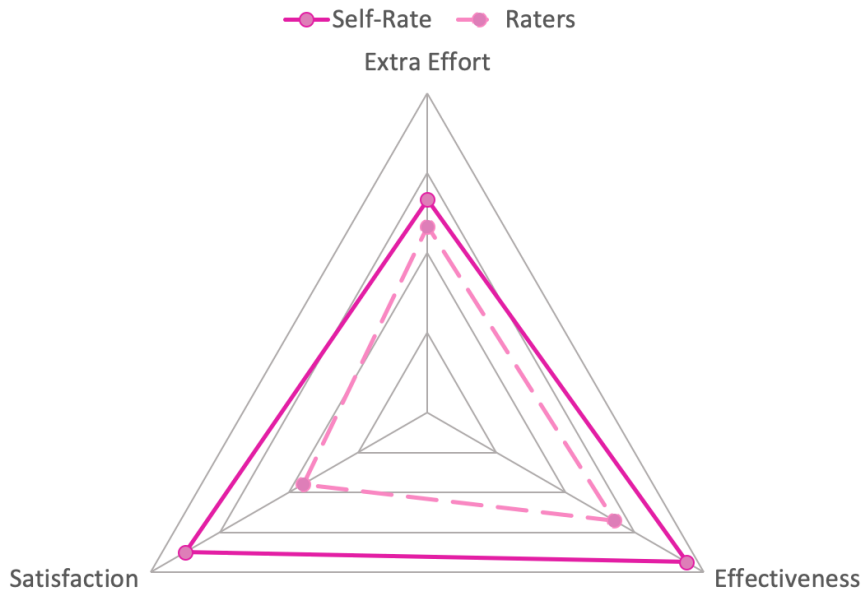

Figure 5.4 Radial plot for self-rate and rater results of MLQ-leadership outcomes for Shado

Both plots show that Shado's self-perceptions about her leadership behaviors and leadership outcomes were overestimated compared to followers' perceptions. Shado had no direct role in planning the outreach event but she was one of the leaders that would fill in for others when necessary. For example, when describing how materials were distributed to volunteers, Shado said:

> "… the board had to sign up for time slots so that the other volunteers could come pick up their materials. It was just they tell me their name and what school they're going to and I give them the materials. That was the extent of my interaction with them."

This represents a *Management-by-exception, active* (MBE-A) behavior. Shado added:

> "… I do my job. I do it well. That's all. I will help if I could help when help is needed. But specifically, I do my role. […] I come in, I fulfill the task, my job is done.".

This view on her position in the organization can be interpreted as displaying a form of Management-*by-exception, passive* (MBE-P) and MBE-A behaviors.

Shado addressed the topic of communication across leaders. Shado attributed the miscommunication to cultural differences, further discussed in Chapter 6. When sharing her experience with communication within the board of the organization, Shado stated:

> "… I feel it got to the point where I don't feel like the outreach committee wanted to do the job themselves anymore, so they needed help. There's four of them, there's one of me, there's one of each other position. Instead of trying to split their job among four… First of all, I feel targeted. Why me? You've got three other people who don't have interactive roles. […] I thought they were trying to ditch their job to other people. And then, as the conversation escalated, I said in a professional and not disrespectful manner: 'It's all about delivery'. If you want something done, nobody has a problem with helping anyone. But you can't just dish it out as a dictator. …"

Shado displayed *Individualized Consideration* (IC) actions as a consequence of identifying the delivery as part of the issue creating the miscommunication. In pointing out the issue, she allows for other leaders to develop and self-actualize. In attributing the miscommunication to cultural differences and acting on it, she (consciously or not, intentionally or not) was supporting other individuals who might have been experiencing the situation from the same perspective. The IC actions could explain the higher effectiveness rating when compared to the other leadership outcomes.

According to observations at the training sessions, the facilitators (mainly other graduate students) were encouraged to explain the chemistry behind experiments as "related to metals" and

placed the responsibility on facilitators to research the explanations of each experiment. Instead of these occurrences, Shado shared:

> "I guess the purpose was to let us know what experiments we were actually doing and explain the experiments to us. I just feel they could've been a bit more thorough, a bit more in-depth. They read the guide to us. What was the point of me going there? […] I feel like we should've had a hands-on experience with the actual experiment. Because if I work with people on the experiment for the first time with the kids… if something goes wrong with them, yeah we're all scientists so we should be able to hypothesize how to fix it, but that doesn't always happen."

Shado's self-rating for *Intellectual Stimulation* (IS) was higher than rater's score; and, this instance is an example of a *Missed Opportunity* to challenge volunteers to find creative solutions to potential complications arising from the demonstrations. While these ideas are reflective of IS, Shado was acting as a facilitator-in-training during the session so there was no explicit space and time for Shado to display these behaviors or put into action her ideas. Shado understood IS actions would have been of benefit to the volunteer facilitators, her position on the board did not allow for her to put into action her ways or ideas.

The lack of transformational-like behaviors explains Shado's low ratings on outcomes as perceived by the raters. According to MLQ results, Shado's self-perception on adopting a *Contingent Rewards* (CR) behavior is frequent, if not always. However, no instances of CR displays were identified for Shado throughout the interview or observations. This was expected based on Shado's views on executing only the tasks associated to her position in the organization.

5.4.3 Amanda

Similar to Shado, Amanda was a leader, part of the board of the student organization but not within the Outreach Committee. Amanda views leadership as:

> "Being in charge or being the one who is accountable for others under you basically. […] That they look like they know what they're doing, and they don't expect others to just pick up the slack, whatever nonsense. You can see when somebody is not well organized and are not sure of how they're doing. A lot of leadership is, even if you're not sure of what you're doing, make it a collaborative effort. Talk to everyone, be open as well. It's a lot of how you talk to people as well, I think is important. A lot of my problems with people, especially with people who are in charge is how they say things to me. I don't mind doing, helping out and doing whatever, but if you say it to me the wrong way, I'm not going to do it. […] Basically, be organized and just good expectations and good communication."

The radial plot comparing self-rate and rater results for the *Multifactor Leadership Questionnaire* (MLQ) are shown in Figure 5.5 and Figure 5.6.

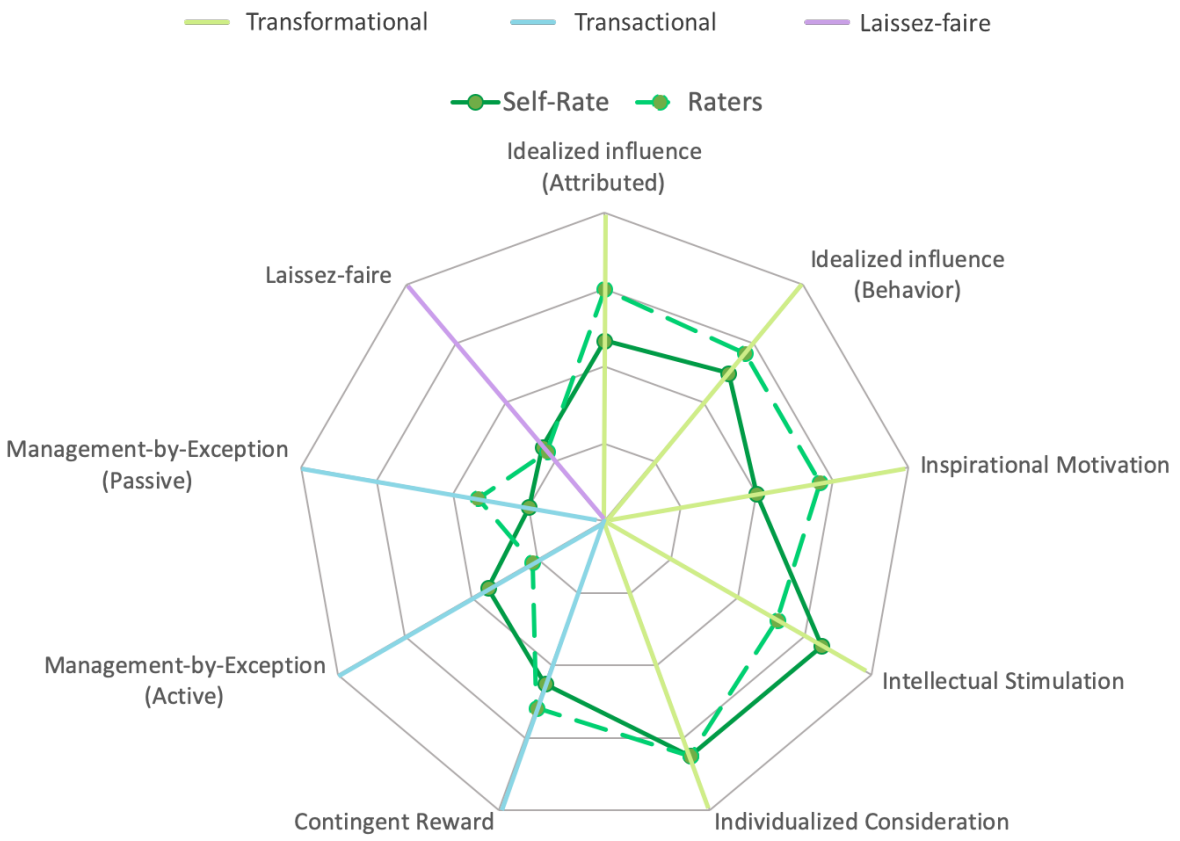

Figure 5.5 Radial plot for self-rate and rater results of MLQ-leadership behaviors for Amanda

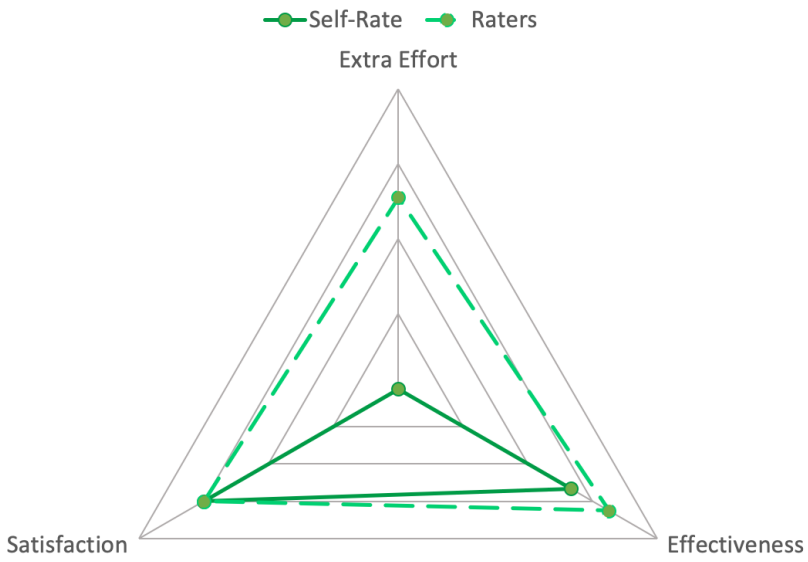

Figure 5.6 Radial plot for self-rate and rater results of MLQ-leadership outcomes for Amanda

While Amanda was not part of the Outreach Committee within the board of the organization, she was still involved with tasks in preparation for the NCW event. This was Amanda's first year in the student organization and first time occupying a leadership position throughout her graduate program. When asked about expectations, Amanda stated:

> "… other board members have been here before, they have been part of the board before and they know what to expect of outreach events. So, I had expected them to give the outreach committee more of an idea of what to do or how to go about planning it, which I don't think they did. It was kind of figuring out as you go along. Everybody was expecting you to just drop everything and do what they say. …"

Both the actions of other leaders in not clarifying expectations and Amanda's inactions are characteristic of a *laissez-fair* style. There is a certain lack of communication and a level of indifference towards the situation around expectations. Furthermore, this situation is an example that supports the argument that *Boundary Objects* and *Brokering* are underdeveloped boundary processes in the student organization CoP. Amanda elaborated on the issue of miscommunication:

> "… I would have a plan the week before everything started. I know they have had their meetings, and they planned amongst themselves what they're supposed to do… Regardless, when asking the rest of the board to help, they needed to make a plan and give us the schedule, what we need to do, when we need to do it. And a report or something we can all fill out what we're needed for… Because, if you do it so late, we're probably signed up for other responsibilities and it conflicts."

While imperfect, not communicating these ideas or acting on them were a *Missed Opportunity* for Amanda to present behaviors associated to a transactional or transformational leadership style. A different situation shows how Amanda exhibited *Individualized Consideration* (IC) as a response to *laissez-faire* behavior on behalf of other leaders:

> "… the training session is the one time with volunteers they meet up. But that was really general. I think it was a demonstration of what they were supposed to do. And you could also see the lack of planning in that as well because it wasn't done well. […] The demonstration was helpful but what I thought was even more helpful that they didn't really talk about until I specifically asked them, is what are the steps to take when you go to the school for people who've never been there. Because I didn't know when you walk in, you have to sign in, talk with the person. And then, when you go to the classroom-- which is also another thing that I was surprised at my first day was that you're basically in charge. I thought the teachers come, and help you, be part of it. But you were just there by yourself. And I was really worried for the undergrads who volunteered who didn't really have much experience doing this. …"

There was a lack of instructions and guidance on behalf of the leaders to the volunteers-facilitators (i.e., *laissez-faire*) but Amanda's actions align with a *transformational* style. By expressing concerns for undergraduate students for who this was their first-time volunteering for *National Chemistry Week* outreach events, Amanda portrayed *Individualized Consideration* (IC). Amanda portrayed *Management-by-exception*, *passive* (MBE-P) behaviors when distributing materials for the outreach events:

> "… I didn't really have much input until they needed people to do the packing of the bags and stuff. That's when they started asking people to volunteer. […] I went because they didn't finish the first time. …"

Amanda intervened only when the leaders in charge of said task did not comply or were not able to complete the task in a timely and organized manner. Amanda also mentioned she recruited a colleague to volunteer as her partner by simply asking the colleague to do so; however, she might have employed actions associated to *Idealized Influence, behavior* (IIB) or *Inspirational Motivation* (IM) to do so, as suggested by the rating score difference between self- and rater (Figure 5.5).

Similar to Thea and Shado, a frequently visited topic throughout Amanda's interview was communication across leaders:

> "… everybody was expecting you to just drop everything and do what they say, when they say. We can't do that because we do have other responsibilities. […] We [other board members] are willing to help, but it's how you go about asking. […]

> some people talk in a really demanding way. If she wants somebody to do something, she says 'I need you to do so-and-so' rather than 'could you do this for me?'. Then saying the rest of the board needs to step up and help. She didn't ask us to do anything in the first place to say that we're not doing our jobs. I was really annoyed by it and the way she spoke to us. … "

Amanda attributed these miscommunication challenges to cultural differences. This is discussed in depth in Chapter 6. Amanda identified this as a problem but displayed *laissez-faire* behaviors, given that it was another leader who addressed the communication problem. Amanda's self-perception on the Extra Effort outcome can be thought of as results of the overall instances in which Amanda displayed *laissez-faire* behavior.

CHAPTER 6. EXPERIENCES OF STUDENT-FACILITATORS IN CHEMISTRY OUTREACH AND BOUNDARY PROCESSES

The cases presented in Chapters 4 and 5 were limited to describing facilitators of chemistry outreach within the community of practice of chemistry student organizations in terms of leadership styles. This was done by using the Full-Range Leadership Theory (FRLT) as a means to understand leadership within the CoP, addressing RQ1. To better comprehend the experiences of facilitators/leaders, however, we cannot reduce what they are to "just leaders and their styles" because we are complex beings. What we are, our motivations, our backgrounds, experiences outside a specific role in a CoP (and more) influence our actions as leaders or facilitators of chemistry outreach events. In this chapter, we address the second research question: *What factors, related to diversity and inclusion, contribute to the student-facilitators' experiences in outreach events in terms of Boundary Processes of the student organization as a community of practice?*

As stated in Section 3.1.1, CoP as framework does not describe how the elements of a CoP, or the processes happening at the boundaries, interact with each other. In addition, the framework does not consider how constructs like gender or race, for example, can influence the design elements of a CoP and its boundary processes. This provides the opportunity to build on and extend the framework by exploring and describing experiences of facilitators, who are leaders of student organizations, in chemistry outreach events, and how these experiences influence boundary processes of the CoP.

6.1 Data Collection & Analysis

For this portion of the study, we reframed the case study methodology to be an exploratory, single case study with embedded units. Here, the case, or unit of analysis, is defined as experiences of student-facilitators participating in chemistry outreach events through a student organization. The embedded units are student-facilitators participating in *Girl Scout Chemistry Discovery Day* and student-facilitators participating in *National Chemistry Week*. These cases are bounded by chemistry outreach events as the context. Figure 6.1 depicts this representation, adapted from Yin (2014). It is important to note the unit of analysis, or the case, focuses on specific experiences of individuals rather than the individuals as a whole. Additionally, it should not be assumed that the

embedded units were compared; the analysis at a subunit level (i.e., leaders participating in specific events) served to inform and better illuminate the case set out to understand (i.e., experiences of student-facilitators) (Baxter & Jack, 2008). Thus, the findings will be discussed holistically and not specific to outreach events or participants.

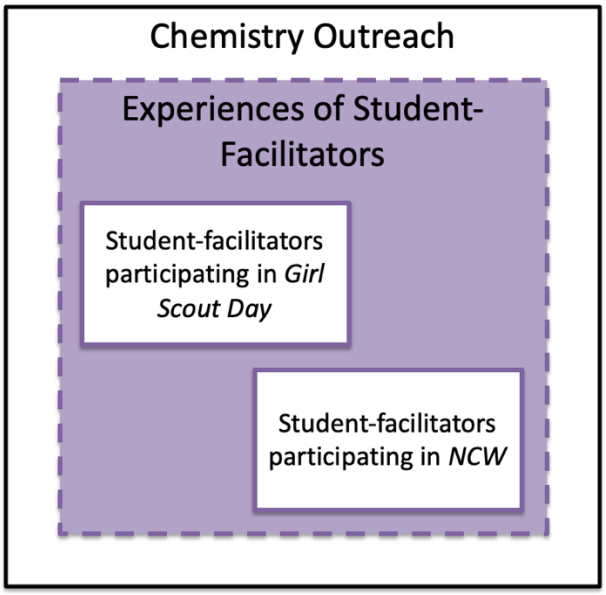

Figure 6.1 Case study design: single case with embedded units

The primary sources of data for this portion of the study are the interviews collected from each participant, which were in-part informed by the survey on outreach practices and observations. Two participants preferred to be interviewed in their first language (i.e., Spanish). Being interviewed in their first language established a common ground between the participant and the researcher (i.e., rapport), it allowed the participant to be more at ease during the interview as they were having a conversation in the language they are fluent in, and it potentially decreased the likelihood of the researcher missing nuances or misinterpreting responses (Merriam & Tisdell, 2016; K. S. Taber, 2018).

The interview transcriptions were analyzed through open-coding (Merriam & Tisdell, 2016) where similar statements or responses were grouped into different themes pertaining to the student-facilitators' experiences. The initial coding scheme resulted in five categories or themes, included in Appendix E. After discussion with another researcher, two of those categories were consolidated in a broader category that better encompassed the participants' experiences. To address inter-rater

reliability, a subset of interview excerpts was randomly selected and assigned to two other chemical education researchers to code with the categories designed by the main researcher. One of the secondary researchers coded responses in English and the other secondary researcher coded responses in Spanish. The main researcher then discussed any discrepancies between codes with the secondary researchers. The discrepancies were minimal and most of them were addressed by refining and broadening the code descriptions. The final coding scheme (Appendix E**)** and examples of codes per category are shown in Table 6.1.

An additional layer of coding was applied to the excerpts coded with the four themes. The excerpts were deductively coded using the three boundary processes described in Table 3.1 (i.e., brokering, boundary objects and interactions). In doing so, the analysis led to insights on how factors related to diversity are present at the boundary of the student organization as a CoP.

Table 6.1 Categories emerged from data or coding scheme and examples

Factor/Code	Description	Example Quote
Outreach initiatives	Participant talked about past experiences with outreach events (own or other people's)	Participant, on why they took charge on explaining experiments the day of the outreach event: "Most of because I knew what I was doing basically. Input. Also, neither of them had done it before, so this would be their first time I think. So, it wouldn't make sense to put them in charge of something when I didn't know exactly what they were going to do. So yeah. That's why."
Educational Background	Participant talked about their own different educational background, differences between education systems across cultures or nations, experiences as instructors, etc.	Participant: "[…] either your goal is to just get kids excited and interested in science and think it's cool and have a good experience, or it's to learn something. And you want them to learn chemistry from what they're doing. Some people are like, "You can do both, which is very hard when you have grad students teaching small children because we're all smart. We (graduate students) have the content knowledge but knowing how to explain chemistry to a 10-year-old-- I was like, "This is difficult. I don't know how smart 10-year-olds are. I don't know what they know." […] We have an entire education college with people who teach pre-service teachers how to teach children […]"
Gender	Participant addressed situations concerning women in science, women in STEM fields and/or other gender issues in STEM	Participant: "[…] especially for Girl Scout Day, since it's women teaching other women, and when you have women of different ethnicities who are in the front taking charge and leading the experience, and then you have the girls that are participating, I feel like that's a lot more inspiring than if you just go to a science camp all by men. Because I feel like women, especially young women, if they don't see themselves represented in the sciences they don't think that that's something that they can do. So I think it's really important to have that representation."

Table 6.1 Continued

Race/Ethnicity (combined language and culture)	Participant alluded to ideas pertaining race, cultural background, experiences as minorities, ethnicity, language, etc.	Participant, on communication across leaders: "I feel like I could adapt to any situation, whatever task, but it becomes a problem when other people, my biggest thing is communication and how people talk. I don't think they were raised to talk in a nice manner and that's just how I've, that's the norm to them. […] I realize it's not even they're trying to be disrespectful, that's just their norm. Where I come from you approach people in a certain manner or certain things go left. So, I think it just comes down to dealing with cultural differences and that's the role of diversity and that can be an issue."

Throughout their interviews, some participants shared concerns about their information being identifiable. For this reason, experiences shared and discussed by URM participants will be presented under the pseudonym Angel and experiences shared by non-URM participants will be presented under the pseudonym Skyler. Angel and Skyler are composite characters across both cases (presented in Chapters 4 and 5). Creating composite characters based on shared experiences is a common practice in qualitative studies when it is necessary to conceal the identity of participants (Allen, 2018; Dwyer et al., 2016; Eisenbach, 2015; N. Taber, 2013). Being labeled, or identified, as an URM is a shared experience in itself. However, this is not to imply, or for the reader to assume, all URMs go through the same experiences. As a technique, creating composite characters is especially relevant when concealing the identities of easily identifiable populations, such as URM students, given that the likelihood of identification of these students is higher based on institutional demographics (Patton & Catching, 2009; Zeller, 1995) as is the case for the institution being studied. In this study, the composite character technique is used solely as a mean to present identifiable information and not as a tool to analyze information provided by participants.

6.2 Factors contributing to experiences in chemistry outreach

Among the themes addressed by the nine participants throughout the interviews are general different experiences with outreach initiatives, educational backgrounds, gender and race/ethnicity. As described in Section 6.1, the discussion is based mainly on interviews which were informed by observations (i.e., field notes and recordings).

6.2.1 Experiences with Outreach Initiatives

The participants all had a varied range of experiences that informed their expectations of the outreach event, how outreach is structured, and how things should be done in order for the event to be considered a success. These prior experiences involved efforts through their ACS Undergraduate Student Chapters and sometimes through other science outreach programs, all events serving a spectrum of audiences. Angel, an URM, used events in their CoP to engage in *Brokering* and *Interactions*. Angel reminisced about previous outreach events they participated in and shared:

> "… back in [my home country] we were all excited about the same thing and wanted to bring science to the general community because science is not something

> highly promoted in a country where there's not a lot of scientific development. […] I differed or disagreed with other leaders here because for me it's important to have the audience learn. Not only tell them the answer, but rather explain or ask questions so they [audience] can generate their own understanding of the concepts…"

These outreach events might have been one of the few times students at their hometown were exposed to science, meaning the event served as an opportunity to hone the audience's critical thinking skills.

Based on their previous experiences, specifically with an award-winning outreach initiative, they also believed having fun with an outreach demonstration and learning from it were not mutually exclusive. This was in contrast to Skyler's simple views on outreach, where the primary goal is for the audience to have fun:

> "I think my goals for volunteering are mostly for the kids to have fun…"

These findings align with previous reports stating that the purpose for chemistry outreach is mainly centered around audience's feelings towards science (Pratt & Yezierski, 2018b). The contrasting views on the goals for chemistry outreach, informed by prior experiences in chemistry outreach, influences the intentions and nature of *Interactions* between facilitators and the audience, future potential members of the science CoP. Facilitators either highlight which concepts explain outcomes of experiments/demonstrations providing a deeper immersion in the science CoP or they limit the exchange to peaking the audience's interest in the CoP by creating an enjoyable experience.

As for the experiments presented during Girl Scout Day, Angel stated:

> "… past experiences in outreach is what allows me to feel more confident in participating of these types of events and understand my role in these events."

For Angel, the confidence was linked to having done the experiments several times for other outreach events. However, Angel heavily relied on Skyler throughout Girl Scout Day to understand the structure of the event because of Skyler's prior experiences with similar outreach events. This is an example of how previous experiences with outreach events positively impact *Interactions* as a boundary process. When discussing National Chemistry Week, Angel stated:

> "… this was their second workshop. So, they knew how things would go. I specifically wanted them to talk because they had experience."

The lack of experience impacts how Angel engages in *Interactions* as a boundary process because they relied on their partner facilitator to do so.

Angel and Skyler have participated in various capacities of outreach events sponsored by the student organization and other organizations at their current institution. Throughout the years, Skyler has planned and led outreach events and also only fulfilled the role of a volunteer. When comparing their experiences as a leader versus experiences as a volunteer, Skyler said:

> "I like being in the leadership position […] I kind of want to step in and help, but at the same time, it's very stressful to plan these events. It's kind of nice to not have to do all the work, but then at the same time, as a leader, you know every single thing that's supposed to happen, whereas as a volunteer, you're kind of in the background. And so, there's only so much you can do to help since you don't know fully what the plan is supposed to be."

Skyler added:

> "… being on the other side of it, outreach, in general, is a very time-consuming thing. So after National Chemistry Week, where you plan all the experiments, and you get funding, and you practice the experiments, and you get volunteers, and it's a week straight, you're just so burnt out by the time the next outreach event comes around."

Throughout their interview about *National Chemistry Week*, Angel alluded to a similar leader-volunteer comparison by stating that they had no desire to pursue a leadership position with an organization planning outreach events because it was a 'triggering' experience. Instead of being related to the workload associated to a leadership position in outreach events, these feelings rose from friction between leaders, which leader-participants attributed to cultural differences (further discussed in Section 6.2.4).

6.2.2 Educational Background

Both Angel and Skyler mentioned having leaders and volunteers with different educational backgrounds influences how the organization prepares for the outreach event. Reflecting back on past outreach events, Angel believed it was easier to guide undergraduate volunteers to use the organization's version on how to explain the chemistry of a demonstration, stating:

> "… at the graduate school level it's more difficult to try to guide student/facilitators in terms of what you want them to teach the audience because each student comes with their own understanding (of the experiments)…"

Angel's perspective aligns with findings of prior research in formal learning environments that show new knowledge is constructed when prior knowledge is elicited and cognitive dissonance happens (Linenberger & Bretz, 2012). According to Angel, graduate students are to more difficult to train on how to explain the demonstrations because they all have their own set of experiences that inform ideas on how something works.

Skyler used a similar reasoning as their argument as to why it is difficult for the student organization to achieve the dual goal of the audience to have fun and to learn chemistry during the outreach event. According to Skyler:

> "Some people say 'You can do both' which is very hard when you have grad students teaching children […]. I was like 'This is difficult. I don't know how smart 10-year-olds are. I don't know what they know.' […] We have an education college who teach teachers how to teach, we should ask people to help us."

Skyler mentioned they would have preferred to take advantage of on-campus resources, which is a form of *Brokering* and *Boundary Objects*, to help graduate students understand "how to teach" in an outreach context. By engaging with other CoPs, the student organization could adopt new practices, routines or establish connections with resources that could better prepare facilitators of chemistry outreach events.

The quality of education and what is covered in each grade level varies across nations. Having been exposed to a different type of education, Angel relied on other leaders and volunteers more familiarized with the American educational system to come up with explanations of the demonstrations. However, they also thought that by designing an event with the sole intention of girls to have fun, the facilitators were underestimating the audience. They believed the event could have served as a learning experience in addition to a fun time.

Skyler briefly mentioned:

> "… So when I did outreach, we always practice the experiments because there's a lot of times that those experiments don't work, and so you don't want the experiment with the audience to be the first time you're trying something in case it doesn't work. But I also know outreach is very challenging and it's very time consuming, so if you don't have the ability to kind of push research off to do those things, then it's very understandable for things to fall through the cracks."

The workload of a graduate student hinders the amount of time and effort that can be put into designing and implementing outreach programs. It is easier and less effort for current leaders of the organization to rely on the prior cohort and mimic what they did in order to implement outreach

activities. Even though participants did not mention the organization having explicit procedures to carry out outreach events, Skyler acknowledged student organizations need these *Boundary Objects* to help structure outreach by stating the necessity of adopting practices from education-oriented CoPs.

In an attempt to address the challenge posed by Skyler, Angel mentioned the goal of the organization was to start planning for *National Chemistry Week* three to four months in advance:

> "… the purpose of the summer was to prepare for National Chemistry Week, to talk about our experiments, to trial these experiments. To definitely get things off the ground in the summer. This way, when the semester comes, then we don't have to be so flooded with work and school. […] so, everyone decides to meet the first two weeks of school which is the most hectic time to meet. […] It was late on my approach of doing things, but it was early for what their (the organization) usual is."

Here, Angel attempted to act as a broker (i.e., *Brokering*) by bringing in their own practices to coordinate actions of the student organization CoP while taking into consideration educational responsibilities, or those associated to being a graduate student.

6.2.3 Gender

Angel and Skyler were part of events planned and coordinated by an all-female organization. For this reason, the discussion of the role of gender in leadership and outreach was expected when asked about diversity during the interview. Angel mentioned:

> "I come from a place that the population is 80% male. So, I am used to working with men; even my closest friends in my group are men. I was sort of disappointed, so I joined the organization to interact with more people."

Since their prior experiences in outreach were within a population that the vast majority were men, Angel saw joining the all-female organization as an opportunity to interact more with women and people from other cultures. However, issues pertaining to language and ethnicity, discussed later in Section 6.2.4, made them feel they were part of a not inclusive environment. This discouraged them from applying their extensive experience in chemistry outreach to this new context, presenting a missed opportunity for the CoP to further cultivate and define their practice and boundary processes. They felt they could not portray themselves as the leader they are.

Additionally, Angel shared:

> "… being in the organization is empowering and it's nice that there's an all-female organization […] because I am in a research group that most of the members are

> men and you can tell they treat you differently because you're a female versus if you were a male. Similar to as they could treat you for being a minority versus if you were white."

For this participant, being part of the organization and participating of outreach events was their way of contributing to society's efforts to inspire younger girls to get excited about science, a form of Interactions. This goal is not uncommon for females and other underrepresented minorities in science, given that there is a persistent underrepresentation of these communities in STEM as pointed out by Angel and reported in the literature (Aschbacher et al., 2010; J. L. Smith et al., 2013).

Skyler thinks of Girl Scout Day as an opportunity to highlight female representation in STEM:

> "… since it's women teaching other women, and when you have women of different ethnicities who are in the front taking charge and leading the experience, and then you have the girls that are participating, I feel like that's a lot more inspiring than if you just go to a science camp run all by men. Because I feel like women […], if they don't see themselves represented in the sciences, they don't think that that's something that they can do."

Angel alluded to the same idea by stating:

> "I think in the role models growing up and I just didn't see a whole lot of people that looked like me doing things that I wanted to do. […] So that was kind of my goal and for the girls to have fun."

In fact, they thought the one-on-one setup for this specific event (i.e., the girl scouts paired with a graduate student) was beneficial in achieving that goal. In the student organization as a CoP, it is through leadership and events that outreach facilitators engage in *Interactions*, to serve those who are curious about science and perhaps intend to become scientists.

Angel shared several negative experiences while planning and preparing for National Chemistry Week. Angel's commented:

> "Everybody wants to be a chief but not Indians. We get a lot of that in the group and it is sad because we women are always known for conflict, chattiness or not having integrity and I saw all of this in the group. And that's not the reason why I joined the organization. So, that makes me very uncomfortable. […] Never in my wildest dreams did I ever expect what I received during this time. If I could go back in time, I would never join the organization. In the future, I would just be a volunteer."

Unfortunately, Angel's experiences reinforced negative stereotypes about females and discouraged them from pursuing opportunities that could contribute to the growth of the CoP.

6.2.4 Race/Ethnicity

Different races and ethnic groups have different languages. Participants described experiences with language that negatively and positively impact boundary processes. Angel shared:

> "[…] For me it has been difficult to adapt here or be 100% myself like I was in (my home country). […] I'm still scared to speak English in public […] I joined the organization to force myself to work on it. […] I feel like language is a barrier to insert myself in conversations. I felt excluded from conversations (during meetings). I didn't feel comfortable."

The language barrier negatively affected their interactions with the audience and with other facilitators at the outreach event. For example, the way Angel thought of the sequence of the demonstrations was different than what others had already discussed and expected. Angel explained it was difficult to keep up with fast-paced conversations. Angel's experience with language as a barrier is consistent with literature that discusses how language and other factors experienced in underrepresented communities impact the overall persistence and motivation along the student's academic journey (Dias, 2017). In addition, as discussed in the *Experiences with Outreach Initiatives* section, Angel had led award-winning outreach initiatives as part of other CoPs. Angel's negative experience with language did not allow for an appropriate exchange of ideas or routines to coordinate actions, hindering *Brokering* and the opportunity for the current CoP to further develop *Boundary Objects.*

Angel also mentioned language is a persistent concern of theirs:

> "I had to think on how to make this accessible to children […] trying to use simple language. Of course, language in my case is also an extra effort because English is my second language, so it was an extra thing I have to think about. [..] Pronunciation is the first thing that always worries and concerns me when I'm teaching, I don't want my pronunciation to cause misunderstanding of concepts. [...] I figure language is more of an issue in my mind that is actually in the class."

While this concern with language did not present an obstacle for Angel to engage in boundary processes, it is still an intrinsic concern that could have surfaced and negatively influenced how boundary processes take place in the CoP.

Angel acknowledged that language could hinder the type of connection you make with the audience, which can influence *Interactions* as a boundary process; however, their own experiences with language in outreach events were positive. They discussed two examples during the interviews, one pertaining a past outreach event, with the same student organization:

> "[…] my partner started explaining the demonstrations and a girl raised her hand to ask if he spoke Spanish. He said: 'Yes.' And she said 'You speak just like my teacher! You have her accent!' […] "

and the other in relation to National Chemistry Week,

> "[…] The children know when English is not your first language, they asked us 'You speak Spanish, right?' and they will say 'Oh, I know how to talk in Spanish too.' […]".

In these two instances, language helped facilitators engage the audience and establish a common ground to engage in *Interactions*. For this participant, differences in cultural background presented more of a challenge than language during Girl Scout Day:

> "It can be complicated in terms of English being my second language, so I don't know if I'm being understood. […] I don't know much about USA, the culture, etc. so asking about which school you went to means nothing to me. So, it (culture) can influence conversations I had with the audience […], it's important for the audience to feel comfortable with me and ask questions."

Angel engages in *Interactions* and *Brokering* by using culture to establish a common ground and trust between themselves and the audience. Not being familiarized with American culture limited their conversation to getting through the experiments of the outreach event. By not knowing how to engage with students, they had difficulties gauging how comfortable the students felt asking questions, which was part of the participant's goal for doing outreach.

Angel self-identified as URM based on their race and ethnicity. Similar to when gender was discussed, Angel mentioned a goal for doing outreach and being involved in *Leadership* is to present themselves as role model because that's what they wished they had when they were younger. For them, outreach events can be used to showcase how underrepresented minorities are scientists and do science.

When discussing experiences related to National Chemistry Week, a common theme addressed by participants was communication across leaders. Angel mentioned:

> "[…] my biggest thing is communication and how people talk. […] I realize it's not even they're (other leaders) trying to be disrespectful, that's just their norm. Where I come from, you approach people in a certain manner or things go left. […] nobody

> has a problem with helping anyone, but you can't dish it out as a dictator. […] I would be more careful when deciding which organization I decide to fulfill the leadership position in. […] I don't have a problem with cultural diversity, but I think I'll need it to be a little bit more than it is now. […] I would just like to be a volunteer and I actually do it with 100% because I think that behind the scenes is where actually triggered me, more so than a volunteer."

Angel used their leadership position to *"[…] give the little kids some type of science experience […]",* a form of *Interactions*. Wise (2019) has reported that even when a student has genuine intentions for being involved in a student organization, the stress of intercultural communication still persists in individuals. In this study, the inability of other leaders to appropriately communicate across cultures discouraged Angel to pursue any other leadership positions in the future, which negatively contributes to developing and cultivating the CoP. Due to this experience, their first time as a leader at their institution, Angel now prefers to act as a volunteer-facilitator rather than be involved in the planning process of chemistry outreach events.

6.2.5 Summary

Race/ethnicity, gender and educational background factors influence boundary processes of the community of practice described in this study. Being unfamiliar with the current educational system might create a barrier for facilitators of outreach events to engage in *Brokering*. The same can be said for differences in languages, which hinders both *Brokering* and *Interactions* as a boundary process. Language and gender guide how facilitators of outreach events interact with the audience and serve people outside of the student organization or community of practice (i.e., *Interactions*).

Leadership takes place in different forms, and diversity is an integral component of leadership. The participant's experiences with ideas related to diversity show these factors play a role in the facilitator's purpose for chemistry outreach, the reasons why they volunteer as facilitators of outreach events and how they interact with the audiences. The discussions of, and experiences with, role models can be described with the mediation model presented by Chemers et al. (2011). In the case of role models through chemistry outreach, 'community involvement' is a support component that influences the psychological process 'identity as a scientist' which affects commitment to a science career.

CHAPTER 7. DISCUSSION AND CONCLUSIONS

The research questions guiding this study were:

RQ1: How can leadership styles and leadership outcomes be characterized within student organizations participating in chemistry outreach?

RQ2: What factors, related to diversity and inclusion, contribute to the student-facilitators' experiences in outreach events in terms of *Boundary Processes* of the student organization as a community of practice?

The Multifactor Leadership Questionnaire, grounded on the Full-Range Leadership Theory, can be used to characterize *Leadership* within the community of practice, that is, student organizations participating in chemistry outreach. A diverse range of behaviors were identified across the leaders of an all-female student-run organization facilitating an event for *Girl Scouts* and school visits to celebrate *National Chemistry Week*. Most behaviors were associated with *Transactional* and *Laissez-faire* leadership styles. Behaviors attributed to a *Transformational* leadership style were scarce but many interactions between leader-participants and volunteer-participants were catalogued as missed opportunities to exhibit a *Transformational* behavior. These behaviors affected *Boundary Processes* that happen in a CoP.

Miscommunication among leaders and not being explicit with volunteers in terms of expectations indicates *Boundary Objects* is an underdeveloped process within the CoP in this study. As presented in Chapter 6, some instances of miscommunication are attributed to cultural differences and leaders' lack of understanding of cross-cultural communication. In terms of communication, language was a barrier for facilitators to establish connections with the audience (i.e., *Interactions*) and for leaders to portray behaviors associated to a *transformational* leadership style. Providing little to no direction to the volunteers/facilitators, associated to a *laissez-faire* style, affected the connections between the facilitator and the attendee (i.e., *Interactions*) because they were not clear on what the facilitators' role was during the outreach event. This is particularly important when taking into consideration those facilitators with no prior outreach experience and those unfamiliar with the local culture and education system. A *laissez-faire* behavior can negatively impact their experiences and hinder the growth of the CoP. For the events presented in this study, facilitators heavily relied on prior experiences with science outreach events to make assumptions on what their role should be throughout the event. Furthermore, delayed actions, lack

of communication and not paying attention to the individual needs of the volunteers did not facilitate *Brokering* and *Interactions* as boundary processes.

According to the findings, it seems *Contingent Rewards* (physical rewards, such as pizza and t-shirts) is the predominant behavior that leaders adopt to recruit volunteers to act as facilitators of outreach events. However, none of the participants acknowledged these rewards as motivation for them to take part of chemistry outreach events. Participants alluded to ideas pertaining being role models, serving underrepresented communities and bringing fun science to kids as motivations to volunteer as facilitators of the outreach events. For *Girl Scout Day,* there was no formal interaction to exchange knowledge on how to explain the chemistry concepts associated to the outreach event. Volunteer-participants explained the activities to the girl scouts using their own understanding of the concepts, which was never assessed for correctness by the leaders or anyone else in the organization. Even though the leaders for *National Chemistry Week* did plan a training session for the facilitators, the experience of participants was similar to that of *Girl Scout Day.* The purpose of understanding the science of the experiments and demonstrations was not achieved with the training session; the attendees simply got familiarized with what they were expected to present at the outreach event. Therefore, *laissez-faire* behaviors and a lack of behaviors associated to a *Transformational* leadership style on behalf of the leader-participants resulted in *Brokering* and *Interactions* being hindered.

7.1 Implications for Research

The MLQ is a tool that provides information on how leaders are perceived and their self-perception which, in this study, most times aligned with their actions. This lends itself to the opportunity of developing a quantitative study, that can be implemented at a national scale. The study could explore leadership styles of ACS Undergraduate Student Chapters, as an example, using their standing in the organization (i.e., outstanding chapters versus non-outstanding chapters) as a basis for comparison. Leadership styles of individuals vary with context: the team they are part of, circumstances outside of the student organization, degree of affiliation to national entities, the academic institution at which they are based, etc. Therefore, a longitudinal study with leaders of student organizations could better describe the dynamic process that is leadership.

Furthermore, as explained in Chapter 6, additional theoretical perspectives should be used to interpret other pieces of information disclosed by the participants to provide more insight on

facilitators' experiences in chemistry outreach. This study sets up a starting point for in-depth studies on the role of diversity and inclusivity in informal learning environments. The use of appropriate frameworks to study abstract constructs of the CoP framework (e.g. belongingness, identity, participation) will expand the CER community's knowledge of student organizations participating in chemistry outreach events. If we set out to understand student-facilitators' experiences in chemistry outreach, researchers can design well-structured training and outreach initiatives taking these into account. Ultimately, the implementation of well-structured outreach events might contribute to the efforts to recruit and retain URM in STEM fields and higher education.

7.2 Implications for Practice

The findings of this study can be used to inform how student organizations plan and carry out chemistry outreach events. The *Characterizing Collegiate Organizations' Outreach Practices Survey* could potentially be modified to include a section about practices pertaining diversity and inclusion (D&I). If properly implemented and used, the organizations could use the survey to evolve as a CoP. For example, leaders completing such survey at the beginning of their term can have an initial assessment on how current organizational practices perpetuate challenges related to D&I; then, as leaders, they can take action to address identified challenges. Furthermore, the leaders can complete the survey throughout, or at the end, of their term to compare with the initial assessment and track how the organization is evolving.

The MLQ is a user-friendly tool that can be implemented across student organizations to assess leadership styles of leaders and their influence on followers' extra effort, satisfaction and effectiveness. Leaders in chemistry outreach, especially those who act as planners of the event, can adopt or keep displaying behaviors associated to a transformational leadership style to positively impact the outreach event and the student organization. For example, adopting *Individualized Consideration* (IC) behaviors can positively impact the *Brokering* process; by understanding how facilitators explain chemistry or what their barriers are, the leaders can decide what is the best way to share knowledge with participants of the outreach event. Considering participants did not address material rewards as the nature of their motivation to participate of chemistry outreach, leaders should instead adopt *transformational* behaviors to recruit volunteers by appealing to high-order ideals and what the volunteer values. In doing so, the leaders can focus

efforts and resources on developing other aspects of the CoP instead of planning a pizza party for the volunteers, for example. Another practice to adopt is to intentionally plan meetings before the outreach event to understand the volunteers' experiences and how these can be used to plan events. While this might be more time-consuming than most outreach practices, it is an effort than can benefit both the volunteer and the organization as a CoP, especially if coordinators plan or meet with a specific purpose. Being aware and understanding the differences amongst members of an organization can influence the organization's performance (Robbins & Judge, 2016). By being more mindful about the facilitators' needs, like language being a barrier or having difficulties engaging the audience at events, can be better addressed. The organization can adopt new practices coming from the facilitator's prior experiences in outreach and their educational background.

The implementation of well-structured outreach events might contribute to the efforts to recruit and retains URM in STEM fields and higher education. However, to quote Hernandez (2020), *"Student diversity must be supported by inclusion throughout the institution through systems of integration and accountability. It is not merely enough to think of diversity as metrics of educational milestones such as enrollment and education."* For faculty and professionals in higher education, findings of the study suggest that minority groups occupying leadership positions currently are not supported in the student organization. Faculty advisors of student organizations should act as champions of implementing new systems, rules, training and policies that work towards fostering an inclusive environment in science student organizations; contributing to the larger goal of increasing diversity in STEM. Additionally, our findings present evidence that being members of student organizations, planning and participating of outreach initiatives is part of the professional development of graduate students. These findings should drive forward a change of culture in academia, one in which advisors and professors treat their students' professional development through informal learning environments equally important as their students' academic development.

7.3 Limitations

Leadership studies have been carried out in formal educational settings, such as schools for example. These studies have identified many different leadership styles in education; including transformational, instructional, distributed, ethical, emotional, entrepreneurial, strategic, sustainable, invitational, constructivist, authentic, dictator, coaching, visionary, servant, autocratic,

laissez-faire, democratic, pacesetter, transactional and bureaucratic (Lynch, 2012). The use of FRLT by itself to identify leadership styles limits the understanding of student organizations' leadership structures, since it only encompasses three out of many leadership styles. To date there is no framework or instrument to measure all possible leadership styles; therefore, this limitation would be present regardless of which leadership theory guided this study.

The use of a questionnaire in leadership studies does not capture the dynamic process of leadership (Yukl, 2010). This limitation is addressed to some extent with data triangulation, as data from the other sources can better inform the leadership process to be described. Also, as with any other statistical measure, a larger sample is preferred over a small sample. While this presents a limitation for this study, it is important to note the results for the MLQ are not used for statistical purposes but as a complement to the qualitative data. The case study methodology has some inherent limitations to it, including the lack of transferability of findings to other settings and contexts (Baxter & Jack, 2008; Merriam & Tisdell, 2016). However, the results of this study can be used to inform leaders on what behaviors are favorable for their outreach events. By only using some elements of the communities of practice framework as a lens, a limitation is introduced, since studying all the areas of student organizations as a CoP goes beyond the scope of the proposed study. In addition, the use of FRLT by itself to identify leadership styles limits the understanding of student organizations' leadership structures, a limitation that would be present regardless of which leadership theory guided this study. Lastly, it is not feasible to reach a full understanding on leadership dynamics in student organizations doing chemistry outreach because (1) it is impossible to capture every single leader-volunteer interaction between the planning and implementation stages of the outreach event and (2) as CoPs, the members decide what kind of leaders they need and when the community needs them, changing the leadership dynamics of the CoP.

APPENDIX A. CHARACTERIZING COLLEGIATE STUDENT ORGANIZATIONS OUTREACH PRACTICES SURVEY

These questions pertain to events planned/led by your group (or at which your group participates) that are aimed at teaching chemistry to the public. These events can be hosted at venues in the community, your own university, or place of business and can be diverse in nature (including demonstration shows at schools, science days at your university, after-school programs, scouting events, etc.). Please consider [insert name of event] as you answer these questions.

Directions: Answer all questions as completely as possible. Please note that you will not be able to navigate backwards.

Demographic Questions

Institution Affiliation: _____

Organization name (Chemistry Club, ACS Student Chapter, AXΣ, etc.):_____

How many years have you been involved with this organization(s)? _____

Position/Role in your organization:

- President
- Vice President
- Secretary
- Treasurer
- Other executive position (please specify)
- Volunteer/No Leadership Position

How many times per semester do you attend/participate in chemistry outreach events? _____

How many times per semester does your group attend/participate in chemistry outreach events? _

Which semester is your organization more active in chemistry outreach events?

- Fall Semester
- Spring Semester
- Equal participation during both semesters

Does your organization participate in these chemistry outreach events during the summer?

Yes / No

If yes: How many events do you/your organization participate in during the summer? _____

Main Survey

1. What is the purpose of doing chemistry activities with the public/children?
2. What do you consider the value of participating in [insert event name] for you?
3. What do you consider the value of participating in [insert event name] for the public/children?
4. About how many participants attend [insert event name]? _____
5. Are there any specific group(s) that your organization typically plans [insert event name] for (schools, scouts, children museums, etc.)? Yes/No
    a. If yes, please describe these groups.
6. Do you have any role in planning your group's event? (yes or no)
    a. If no, who is responsible in your group for scheduling/planning these events?
7. Please describe the events where you/your group teaches chemistry to the public.
8. Describe in more detail the specific activities you use at these events.
9. What is the source of your activities/resources used to plan and run these events?
10. Do you practice demonstrations and/or activities before [insert event name]? (yes or no)
    a. If yes, Please describe how you practice for [insert event name].
11. What are your criteria for a successful [insert event name]?
12. Please describe how you evaluate the success of [insert event name].
13. What skills or resources would help you improve the quality of your group's events?
14. What evidence do you have that participants are learning chemistry during your events?
15. What is the most challenging aspect of communicating chemistry to the public through this event?
16. How does teaching chemistry to others improve your own knowledge of the subject?
17. What resources would help you more effectively evaluate the success of an event?
18. What role (if any) does the American Chemical Society play in planning/implementing your events?
19. Please tell us anything else you would like us to know about communicating and teaching chemistry to the public (optional):

APPENDIX B. SAMPLE INTERVIEW PROTOCOL – LEADER

Sample Interview Protocol - Leader

Introduction

Thank you for agreeing to participate in this study on describing leadership in outreach initiatives. I have two purposes for this interview. First, we will talk about your experience working with volunteers in outreach initiatives. Second, I want to play some video clips of you and volunteers working together and have you reflect on them.

1. How did you begin working with the volunteers for *[insert name of event]*?
   a. Did you know the volunteers before the outreach event?
2. How do you see your role working with these volunteers?
3. Approximately how many volunteers have you worked with before the volunteers at *[insert name of outreach event]*?
4. Please tell me about your experiences carrying out outreach initiatives as a member of:
   a. Other student organizations you have been part of.
   b. Your current student organization.
5. Please tell me about your experiences carrying out outreach initiatives as a leader in your current student organization.
6. What other experiences inform how you lead the outreach event or your volunteer?
7. In what ways did you interact with the volunteers for *[insert name of event]*?
8. What can you tell me about leadership?
   a. What is leadership for you?
   b. How do you "approach" being a leader?
9. How do you think diversity (or lack of diversity) influences:
   a. Your leadership or how you portray yourself as a leader in the organization?
   b. How outreach is being carried out?

Video Clips

I have selected a number of clips that I would like to play for you of different interactions between you and your volunteers. After watching a clip, I would like for you to reflect on the interaction you were having with the volunteers by answering some questions.

Clip 1: Preparation for the event

How would you describe what you and the volunteers are doing in this clip?

What is this volunteer doing?

What are you doing?

What were some challenges you had to face that day as a leader?

How did you address the challenge?

Was your reaction an appropriate response to the challenge?

What would you have done differently?

Thinking back on what you think leadership is and how you approach being a leader, do you think you implemented your ways this day?

Clip 2: Day of event

How would you describe what you and the volunteers are doing in this clip?

What is this volunteer doing?

What are you doing?

What were some challenges you had to face that day as a leader?

How did you address the challenge?

Was your reaction an appropriate response to the challenge?

What would you have done differently?

Thinking back on what you think leadership is and how you approach being a leader, do you think you implemented your ways this day?

Understanding of Chemistry

According to the handouts, the experiments presented at the outreach event were *[insert experiment names]*.

What is the typical age group(s) that you do outreach activities with?

How do you normally perform/do *[insert activity or experiment name]*?

What learning do you expect the participants to gain from this activity?

Pretend that I'm a *[insert typical audience member here from previous questions],* how would you explain the chemistry of this experiment?

What compounds were present?

What are some major concepts the experiment was designed to address?

Do you believe the audience learned these concepts?

What evidence do you have to support the audience did or did not learn the concepts?

What about for a fellow undergrad or graduate student? How would you explain the experiment to them?

Conclusion

1. Is there anything I did not ask in this interview about your experience with the volunteers that you would like to add?

APPENDIX C. SAMPLE INTERVIEW PROTOCOL – VOLUNTEER

Sample Interview Protocol - Volunteers

Introduction

Thank you for agreeing to participate in this study on describing leadership in outreach initiatives. I have two purposes for this interview. First, we will talk about your experience working with your leader in outreach initiatives. Second, I want to play some video clips of you and your leader working together and have you reflect on them.

1. Please tell me about yourself:
   a. What's your major?
   b. Year in school?
   c. Where are you from?
   d. Are you part of any student organizations?
2. Please tell me about your volunteering experience.
   a. What were your goals for volunteering?
   b. Did your participation in *[insert name of the event]* meet your goals or expectations?
   c. What aspects did not meet your expectations?
   d. What role did the leaders of the event/organizations impact your experience as a volunteer?
3. Please describe your interactions with the leaders and organizers of *[insert name of the event/organization].*
   a. How did you begin working with these leaders?
   b. How would you describe your interaction with the leaders?
   c. Did you know these leaders before the outreach event?
4. How do you see your role working with *[insert leader's name]*?
5. Please tell me about your experiences carrying out outreach initiatives as a member of:
   a. Other student organizations you have been part of.
   b. Your current student organization.
6. How would you describe your interaction with *[insert leader's name]*?
7. What other experiences inform how you participate of the outreach event?

Video Clips

I have selected a number of clips that I would like to play for you of different interactions between you and your leader. After watching a clip, I would like for you to reflect on the interaction you were having with *[insert leader's name]* by answering some questions.

Clip 1: Preparation for the event

How would you describe what you and *[insert leader's name]* are doing in this clip?

What is [insert leader's name] doing?

What are you doing?

What were some challenges you had to face that day as a volunteer?

How did you address the challenge?

Was your reaction an appropriate response to the challenge?

What would you have done differently?

Clip 2: Day of event

How would you describe what you and *[insert leader's name]* are doing in this clip?

What is [insert leader's name] doing?

What are you doing?

What were some challenges you had to face that day as a volunteer?

How did you address the challenge?

Was your reaction an appropriate response to the challenge?

What would you have done differently?

Understanding of Chemistry

According to the handouts, the experiments presented at the outreach event were *[insert experiment names]*.

What is the typical age group(s) that you do outreach activities with?

How do you normally perform/do *[insert activity or experiment name]*?

What learning do you expect the participants to gain from this activity?

Pretend that I'm a *[insert typical audience member here from previous questions],* how would you explain the chemistry of this experiment?

What compounds were present?

What are some major concepts the experiment was designed to address?

Do you believe the audience learned these concepts?

What evidence do you have to support the audience did or did not learn the concepts?

What about for a fellow undergrad or graduate student? How would you explain the experiment to them?

Conclusion

1. Is there anything I did not ask in this interview about your experience with *[insert leader's name]* that you would like to add?

APPENDIX D. MULTIFACTOR LEADERSHIP QUESTIONNAIRE – SAMPLE, LEADER FORM

Multifactor Leadership Questionnaire

Leader Form

My Name: _____ Date: _____

Organization ID #: _____Leader ID #: _____

This questionnaire is to describe your leadership style as you perceive it. Please answer all items on this answer sheet. **If an item is irrelevant, or if you are unsure or do not know the answer, leave the answer blank.**

Forty-five descriptive statements are listed on the following pages. Judge how frequently each statement fits you. The word "others" may mean your peers, clients, direct reports, supervisors, and/or all of these individuals.

Use the following rating scale:

Not at all	Once in a while	Sometimes	Fairly often	Frequently, if not always
0	1	2	3	4

1.	I provide others with assistance in exchange for their efforts	0	1	2	3	4
2.	I re-examine critical assumptions to question whether they are appropriate	0	1	2	3	4
3.	I fail to interfere until problems become serious	0	1	2	3	4
4.	I focus attention on irregularities, mistakes, exceptions, and deviations from standards	0	1	2	3	4
5.	I avoid getting involved when important issues arise	0	1	2	3	4
6.	I talk about my most important values and beliefs	0	1	2	3	4
7.	I am absent when needed	0	1	2	3	4
8.	I seek differing perspectives when solving problems	0	1	2	3	4
9.	I talk optimistically about the future	0	1	2	3	4
10.	I instill pride in others for being associated with me	0	1	2	3	4
11.	I discuss in specific terms who is responsible for achieving performance targets	0	1	2	3	4
12.	I wait for things to go wrong before taking action	0	1	2	3	4
13.	I talk enthusiastically about what needs to be accomplished	0	1	2	3	4
14.	I specify the importance of having a strong sense of purpose	0	1	2	3	4
15.	I spend time teaching and coaching	0	1	2	3	4

Continued ➔

APPENDIX E. CODING SCHEME

Characterizing Leadership Styles		
Code (Abbreviation)	**Description**	**Example in data**
Idealized influence (attributed) (IIA)	Socialized charisma, whether the leader is perceived and viewed as confident, powerful, focusing on high-order ideals and ethics	*As absent/missed opportunity
Idealized influence (behavior) (IIB)	The charismatic actions of the leader that are centered on values, beliefs and a sense of mission	*As absent/missed opportunity
Inspirational motivation (IM)	The ways leaders energize their followers by viewing the future with optimism, stressing ambiguous goals, projecting an idealized vision, and communicating to followers that the vision is achievable	*As absent/missed opportunity
Intellectual stimulation (IS)	Leader actions that appeal to the followers' sense of logic and analysis by challenging followers to think creatively and find solutions to difficult problems	Interviewer: "Do you think the responses from the leaders or leader helped you figure out--?" Participant: "Not really, but I think in that moment it was kind of the panic of like, "Oh, we changed the experiment, and now it's not working." And then I think the one before that didn't work, so having the first experiments not work, I think there was just a little bit of panic going on and just like, "I don't know why it's not working, but let's move on." So that's why I was trying to explain why it was happening and be like, "Well, even if this doesn't work," I said, "Let's try it with the solids and see if it does anything different. Let's try the unknown." Yeah. "What's baby powder made of?" That's what I was trying to figure out -

		would it have the same reaction? So just kind of approaching the problem and problem solving through it."
Individualized consideration (IC)	Leader behavior that contributes to follower satisfaction by advising, supporting and paying attention to the individual needs of follower, which allows them to develop and self-actualize	[In reference to having another leader explain experiments in event] Participant: "But I also want to give everyone the opportunity to learn and improve. Just because you're not good at something, doesn't mean that you have to stay not good at it forever. We can also work on that. So I try to give everyone an opportunity to step up and improve."
Contingent reward (CR)	Leaders behaviors focused on clarifying role and task requirements and providing followers with materials or psychological rewards contingent on the fulfillment of contractual obligations	[In reference to recruiting volunteers for event] Email communication: "[…] All materials will be provided along with a free T-shirt and pizza party […]."
Management-by-exception, active (MBE-A)	Active vigilance of a leader whose goals is to ensure that standards are met	"[…] we (the board) had to basically choose time slots so that other volunteers could come pick up their materials. I interacted with them. It was just they tell me their name and what school they're going to and I give them a bag. […] I come in, I fulfill my task, my job is done."
Management-by-exception, passive (MBE-P)	Leaders only intervene after noncompliance has occurred or when mistakes have already happened	"The issue is when you plan things so close to milestones, things become even more hectic. Because now you are not able to do your natural functions as part of this group. So a lot of us had to go and reach out to a lot of people outside the board to get the help we needed."

Laissez-faire (LF)	Leader provides no meaning or clarification of events for followers which is interpreted as lack of communication, undermining the follower's trust in the leader; characterized by delays of action, absence and indifference	Participant: "[…] they've (other leaders) been here before and they know what to expect. So I had expected them to give them more of an idea what to do or how to go about planning it, which I don't think they did it. So it was more of a kind of figuring out as you go along."
Absent/Missed Opportunities	Instance in which the participant displayed a specific behavior, but the volunteer expected a different behavior; or, the interaction presented an opportunity to display another behavior; or, the participant presented a different approach to a specific situation	"[…] what I think was even more helpful, they didn't really talk about it until I specifically asked them, is what are the steps to take when you go to the school for people who've never been there. […] I was surprised at my first day because I was basically in charge of the classroom. I thought the teachers come and help you and are part of it. […] I was really worried for the undergrads who volunteered who didn't really have much experience doing this." - Missed opportunity to display Individualized Consideration
Factors Contributing to Leaders' Experiences		
Factor/Code	**Description**	**Example Quote**
Outreach initiatives	Participant talked about past experiences with outreach events	Participant, on why they took charge on explaining experiments the day of the outreach event: "Most of because I knew what I was doing basically. Input. Also, neither of them had done it before, so this would be their first time I think. So, it wouldn't make sense to put them in charge of something when I didn't know exactly what they were going to do. So yeah. That's why."
Educational Background	Participant talked about their own different educational background, differences between education systems across cultures or nations, experiences as instructors, etc.	Participant: "[…] either your goal is to just get kids excited and interested in science and think it's cool and have a good experience, or it's to learn something. And you want them to learn chemistry from what they're doing. Some people are like, "You

		can do both, which is very hard when you have grad students teaching small children because we're all smart. We (graduate students) have the content knowledge but knowing how to explain chemistry to a 10-year-old-- I was like, "This is difficult. I don't know how smart 10-year-olds are. I don't know what they know." […] We have an entire education college with people who teach pre-service teachers how to teach children […]"
Gender	Participant addressed situations concerning women in science, women in STEM fields and/or other gender issues in STEM	Participant: "[…] especially for Girl Scout Day, since it's women teaching other women, and when you have women of different ethnicities who are in the front taking charge and leading the experience, and then you have the girls that are participating, I feel like that's a lot more inspiring than if you just go to a science camp all by men. Because I feel like women, especially young women, if they don't see themselves represented in the sciences they don't think that that's something that they can do. So I think it's really important to have that representation."
Race/Ethnicity (combined language and culture)	Participant alluded to ideas pertaining race, cultural background, experiences as minorities, ethnicity, language, etc.	Participant, on communication across leaders: "I feel like I could adapt to any situation, whatever task, but it becomes a problem when other people, my biggest thing is communication and how people talk. I don't think they were raised to talk in a nice manner and that's just how I've, that's the norm to them. […] I realize it's not even they're trying to be disrespectful, that's just their norm. Where I come from you approach people in a certain manner or certain things go left. So, I think it just comes down to dealing with cultural differences and that's the role of diversity and that can be an issue."

APPENDIX F. IRB APPROVAL

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	MARCY TOWNS WTHR
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	04/03/2019
Committee Action:	**Expedited Approval - Category**(7)
IRB Approval Date	04/02/2019
IRB Protocol #	1901021544
Study Title	Leadership Styles to Characterize Organizations in Chemistry Outreach
Expiration Date	04/01/2022
Subjects Approved:	40

The above-referenced protocol has been approved by the Purdue IRB. This approval permits the recruitment of subjects up to the number indicated on the application and the conduct of the research as it is approved.

The IRB approved and dated consent, assent, and information form(s) for this protocol are in the Attachments section of this protocol in CoeusLite. Subjects who sign a consent form must be given a signed copy to take home with them. Information forms should not be signed.

Record Keeping: The PI is responsible for keeping all regulated documents, including IRB correspondence such as this letter, approved study documents, and signed consent forms for at least three (3) years following protocol closure for audit purposes. Documents regulated by HIPAA, such as Authorizations, must be maintained for six (6) years. If the PI leaves Purdue during this time, a copy of the regulatory file must be left with a designated records custodian, and the identity of this custodian must be communicated to the IRB.

Change of Institutions: If the PI leaves Purdue, the study must be closed or the PI must be replaced on the study through the Amendment process. If the PI wants to transfer the study to another institution, please contact the IRB to make arrangements for the transfer.

Changes to the approved protocol: A change to any aspect of this protocol must be approved by the IRB before it is implemented, except when necessary to eliminate apparent immediate hazards to the subject. In such situations, the IRB should be notified immediately. To request a change, submit an Amendment to the IRB through CoeusLite.

Continuing Review/Study Closure: No human subject research may be conducted without IRB approval. IRB approval for this study expires on the expiration date set out above. The study must be close or re-reviewed (aka continuing review) and approved by the IRB before the expiration date passes. Both Continuing Review and Closure may be requested through CoeusLite.

Unanticipated Problems/Adverse Events: Unanticipated problems involving risks to subjects or others, serious adverse events, and serious noncompliance with the approved protocol must be reported to the IRB immediately through CoeusLite. All other adverse events and minor protocol deviations should be reported at the time of Continuing Review.

Ernest C. Young Hall, 10th Floor - 155 S. Grant St. - West Lafayette, IN 47907-2114 - (765) 494-5942 - Fax: (765) 494-9911

APPENDIX G. RECRUITMENT INFORMATION

Recruitment Email: Leaders

Dear students,

Dr. Marcy Towns, and her graduate student Stephanie Santos-Diaz (Chemistry Education, Purdue University), are recruiting participants for their research project. The project aims to study the relationship between leadership in student organizations and outreach events. The results from this project could inform student organizations, and its leaders, on practices and behaviors that lead to favorable outcomes in outreach.

As a leader within *[insert name of student organization]*, they kindly ask for your participation in this project. They anticipate you will be in this study for approximately 4-6 hours, over the next 5 months. Participating of this project would require you:

- complete a survey about your organization's outreach practices,
- be video and audio recorded at different instances pertaining the outreach event,
- be interviewed about your experience for approximately 45-60 minutes and,
- complete a questionnaire to assess leadership style.

If you are interested, contact Stephanie directly at ssantosd@purdue.edu.

Recruitment Email: Volunteers

Dear students,

Dr. Marcy Towns, and her graduate student Stephanie Santos-Diaz (Chemistry Education, Purdue University), are recruiting participants for their research project. The project aims to study the relationship between leadership in student organizations and outreach events. The results from this project could inform student organizations, and its leaders, on practices and behaviors that lead to favorable outcomes in outreach.

As a volunteer at the outreach event carried out by *[insert name of student organization]*, they kindly ask for your participation in this project. They anticipate you will be in this study for approximately 4-6 hours, over the next 5 months. Participating of this project would require you:

- be video and audio recorded at different instances pertaining the outreach event,
- be interviewed about your experience for approximately 45-60 minutes and,
- complete a questionnaire to assess leadership style.

If you are interested, contact Stephanie directly at ssantosd@purdue.edu.

Recruitment at meetings: Verbal Script

My name is Stephanie, graduate student with Dr. Marcy Towns in Chemistry Education at Purdue University. My research project aims to study the relationship between leadership in student organizations and outreach events. The results from this project could inform student organizations, and its leaders, on practices and behaviors that lead to favorable outcomes in outreach.

If you plan on being a volunteer at *[insert name of outreach event]* carried out by *[insert name of student organization]*, I kindly ask for your participation in this project. We anticipate you will be in this study for approximately 4-6 hours, over the next 5 months. Participating of this project would require you:

- be video and audio recorded at different instances pertaining the outreach event,
- be interviewed about your experience for approximately 45-60 minutes and,
- complete a questionnaire to assess leadership style.

If you are interested or need more information before deciding, contact Stephanie directly at ssantosd@purdue.edu.

APPENDIX H. CONSENT FORM – LEADERS AND VOLUNTEERS

RESEARCH PARTICIPANT CONSENT FORM

Leadership Styles to Characterize Organizations in Chemistry Outreach

Marcy H. Towns
Department of Chemistry
Purdue University

Key Information

Please take time to review this information carefully. This is a research study. Your participation in this study is voluntary which means that you may choose not to participate at any time without penalty or loss of benefits to which you are otherwise entitled. You may ask questions to the researchers about the study whenever you would like. If you decide to take part in the study, you will be asked to sign this form, be sure you understand what you will do and any possible risks or benefits.

The purpose of this project is to study the relationship between outreach events in chemistry and leadership of student organizations carrying out said events. Outreach events consist mainly on carrying out scientific demonstrations with the general public to engage the community in science. The reason we are conducting this study is to provide science education community a guide on behaviors and characteristics that lead to favorable outcomes in outreach. As a leader of a scientific/chemistry student organization, we kindly ask for your participation in this study. We would like to enroll a maximum of 40 people in this study. We anticipate you will be part of the study for approximately 4-6 hours. Additional explanations may be more detailed in the sections below.

What will I do if I choose to be in this study?

Survey
As a participant, you will be asked to fill out a survey on outreach practices of the student organization you represent. The survey takes approximately 10 minutes to complete.

Observations
Throughout the study, you will be video recorded at 2-3 instances: one or two meetings pertaining the planning of the outreach event and during the outreach event itself. The video recording require you wear a microphone to audio record your conversations with volunteers and the audience at the event.

Interview and Questionnaire
Within a month after the outreach event, the researcher will contact you again to participate in a semi-structured interview which should take 45-60 minutes. During this interview, you will be asked questions pertaining your interactions with volunteers at the instances you were video-recorded and questions about your understanding of the chemistry content behind the demonstrations presented during your outreach event. In addition, you will be asked to complete a questionnaire to self-assess your leadership style. The questionnaire takes approximately 10-15 minutes to complete.

How long will I be in the study?

We anticipate you will be in the study for a total of 4-6 hours, over the next 5 months. The survey takes approximately 10 minutes to complete. The observations may take place for approximately an

hour per instance, which means a total of 2-3 hours of observations. The interview takes 45-60 minutes. Lastly, the questionnaire takes 15-20 minutes to complete.

What are the possible risks or discomforts?

There are always risks associated with research projects. The risks associated with this project are no greater than those associated to everyday life. Breach of confidentiality is always a risk with data, but we will take precautions to minimize this risk as described in the confidentiality section.

Are there any potential benefits?

By participating in this study, you may become more aware of your outreach practices as leader of a scientific student organization and about your understanding of chemistry behind demonstrations presented in outreach events.

Are there costs to me for participation?

There are no anticipated costs to participate in this research.

Will information about me and my participation be kept confidential?

The researcher will follow these steps to minimize the risks regarding the confidentiality of your identity:

(1) You will be assigned a pseudonym as soon as data analysis begins. The pseudonym will be used in all presentations and publications resulting from this study.
(2) Only the research team will have access to the data collected from this project.
(3) All data sources will be deidentified as soon as data analysis begins.
(4) Audio recordings from observations and interviews will be transcribed. Electronic/digital data will be stored on a password-protected computer at Purdue University. Printed or physical data will be kept and stored in a locked office cabinet at Purdue University.
(5) The video and audio recordings will be deleted after a period of 5 years since data collection begins. Printed or physical data will be destroyed after a period of 5 years since data collection begins.

We do not anticipate the data will be used for future research projects. The project's research records may be reviewed by departments at Purdue University responsible for regulatory and research oversight.

What are my rights if I take part in this study?

You do not have to participate in this research project. If you agree to participate, you may withdraw your participation at any time without penalty.

Who can I contact if I have questions about the study?

If you have questions, comments or concerns about this research project, you can talk to one of the researchers. Please contact Marcy Towns (mtowns@purdue.edu, 765-496-1574).

If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Human Research Protection Program at (765) 494-5942, email (irb@purdue.edu), or write to:

Human Research Protection Program - Purdue University
Ernest C. Young Hall, Room 1032
155 S. Grant Street
West Lafayette, IN 47907-2114

To report anonymously via Purdue's Hotline see www.purdue.edu/hotline.

Documentation of Informed Consent

I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research study, and my questions have been answered. I am prepared to participate in the research study described above. I will be offered a copy of this consent form after I sign it.

☐ Yes, I agree to be videotaped.

☐ No, I do not agree to be videotaped.

_____ _____
Participant's Signature Date

_____
Participant's Name

_____ _____
Researcher's Signature Date

RESEARCH PARTICIPANT CONSENT FORM

Leadership Styles to Characterize Organizations in Chemistry Outreach

Marcy H. Towns
Department of Chemistry
Purdue University

Key Information

Please take time to review this information carefully. This is a research study. Your participation in this study is voluntary which means that you may choose not to participate at any time without penalty or loss of benefits to which you are otherwise entitled. You may ask questions to the researchers about the study whenever you would like. If you decide to take part in the study, you will be asked to sign this form, be sure you understand what you will do and any possible risks or benefits.

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Are there any potential benefits?

By participating in this study, you may become more aware of your outreach practices as leader of a scientific student organization and about your understanding of chemistry behind demonstrations presented in outreach events.

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There are no anticipated costs to participate in this research.

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The researcher will follow these steps to minimize the risks regarding the confidentiality of your identity:

(1) You will be assigned a pseudonym as soon as data analysis begins. The pseudonym will be used in all presentations and publications resulting from this study.
(2) Only the research team will have access to the data collected from this project.
(3) All data sources will be deidentified as soon as data analysis begins.
(4) Audio recordings from observations and interviews will be transcribed. Electronic/digital data will be stored on a password-protected computer at Purdue University. Printed or physical data will be kept and stored in a locked office cabinet at Purdue University.
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We do not anticipate the data will be used for future research projects. The project's research records may be reviewed by departments at Purdue University responsible for regulatory and research oversight.

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Who can I contact if I have questions about the study?

If you have questions, comments or concerns about this research project, you can talk to one of the researchers. Please contact Marcy Towns (mtowns@purdue.edu, 765-496-1574).

If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Human Research Protection Program at (765) 494-5942, email (irb@purdue.edu), or write to:

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☐ Yes, I agree to be videotaped.

☐ No, I do not agree to be videotaped.

_____ _____
Participant's Signature Date

_____
Participant's Name

_____ _____
Researcher's Signature Date

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VITA

Stephanie Santos-Díaz

Education

Doctorate of Philosophy in Chemistry — **Expected August 2020**
Purdue University, West Lafayette, IN — **Overall GPA: 3.76**
Advisor: Marcy H. Towns
Committee Members: George Bodner, Adam Wasserman and Stacey Connaughton

Bachelor of Science in Chemistry, Cum Laude — **May 2016**
University of Puerto Rico, Cayey, PR — **Overall GPA: 3.66**

Honors/Awards

National Science Foundation Graduate Research Fellowship Program Fellow — **Fall 2016**
Alliance for Graduate Education and the Professoriate (AGEP) Scholar — **Fall 2018-Present**
2020 ACS Bridge Travel Award — **Spring 2020**
2020 AAAS CASE Workshop – ACS Sponsorship [Postponed due to COVID-19] — **Spring 2020**
Catalyzing Advocacy in Science and Engineering
2020 Emerging Researchers National (ERN) Conference in STEM Travel Award — **Spring 2020**
Periodic Table of Younger Chemists Recognition - Rutherfordium — **Summer 2019**
100th anniversary of IUPAC and International Year of Periodic Table
Special Distinction in Diversity Award — **Spring 2019**
Department of Chemistry, Purdue University
AGEP Mentoring Award — **Spring 2019**
Purdue AGEP Program 2018-2019
2018 SACNAS Travel Award — **Summer 2018**
Society for Advancement of Chicanos/Hispanics and Native Americans in Science
Women in Science Programs Travel Award — **Spring 2018**
Science Diversity Office at Purdue University
Leadership Development Award — **Fall 2017**
Younger Chemists Committee (YCC) from the American Chemical Society (ACS)
Puerto Rico Louis Stokes Alliance for Minority Participation Scholar — **Fall 2015-Spring 2016**
American Chemical Society Scholars Award — **Fall 2015-Spring 2016**
Universidad de Puerto Rico at Cayey Dean's List — **Fall 2011-Spring 2016**

Experience – Diversity & Inclusion

Graduate Assistant at Office of Graduate Diversity Initiatives (OGDI) — **Aug 2019-Present**
Office of Graduate Diversity Initiatives, Purdue University

- Organize events for on-campus diversity related initiatives (i.e. AGEP, SROP and Visitation programs)
- Coordinate meetings with OGDI Scholars
- Develop new strategies to disseminate impact of initiatives

Summer Research Opportunities Program (SROP) Graduate Coordinator — **Summer 2018 & 2019**
Office of Graduate Diversity Initiatives, Purdue University

- Mentored undergraduate students during their summer research experience
- Planned events with other coordinators
- Moderated graduate student panel
- Fostered undergraduate students' effective communication of their research

- Summer Programs Symposium poster judge
- Advised and mentored undergraduate applicants to the NSF-GRFP

Experience – Teaching at Purdue University

General Chemistry Teaching Assistant **2017-2018, Spring 2019**

- Taught laboratory and recitation sections
- Assisted students both on understanding course content and developing effective study skills
- Guided students in developing laboratory practical skills
- Graded laboratory reports
- Designed assessment items
- Encouraged students to develop scientific writing skills

Experience – Chemistry Education Research

Purdue University, Department of Chemistry, West Lafayette, IN **Aug 2016-Present**

Graduate Student: Leadership Styles to Characterize Student Organizations in Chemistry Outreach
Advisor: Marcy H. Towns

- Use theories from organizational leadership to describe chemistry outreach
- Perform statistical analysis to determine leadership styles using a Likert-scale questionnaire
- Analyze participant interviews and observations with NVivo, a qualitative data analysis software

Graduate Student: Undergraduate Students' Goals and Achievement Strategies for Laboratory Coursework
Advisor: Marcy H. Towns

- Designed a survey to study what are students' goals in the laboratory and how they go about achieving said goals
- Performed statistical analysis using SPSS and Excel to compare responses between populations

Graduate Student: Characterization of student understanding of mathematical expressions in chemical kinetics
Advisor: Marcy H. Towns

- Analyzed student interviews with NVivo, qualitative data analysis software, using an open-coding approach and a framework that characterizes patterns of conceptual mathematical understanding

University of Puerto Rico, Department of Chemistry, Cayey, PR **Jan 2014-May 2016**

Undergraduate Research Assistant: Comparison between Dynamic and Static Submicroscopic Activities in Chemistry
Advisor: Zuleika Medina

- Collaboratively developed an interactive dynamic simulation to target limitations presented by an activity that had been previously developed to aid students in the understanding of a Chemistry topic
- Mentored another undergraduate researcher
- Collaborated with other institutions

Undergraduate Research Assistant: Developing an Assessment Instrument Using the Three Levels of Representation
Advisor: Zuleika Medina

- Developed an assessment instrument, based on Johnstone's Three Levels of Representation model, to measure students' understanding of concepts involved in redox reactions and their ability to interconnect the representations

Publications

6. **Santos-Díaz, S.**; Towns, M.H. Chemistry Outreach as a Community of Practice: Investigating the Relationship Between Student-Facilitators' Experiences and Boundary Processes in a Student-Run Organization. *Chem. Educ. Res. Pract.* **2020,** DOI: 10.1039/d0rp00106f.

5. **Santos-Díaz, S.**; Hensiek, S.; Owings, T.; Towns, M.H. Survey on Undergraduate Students' Goals and Achievement Strategies for Laboratory Coursework. *J. Chem. Educ.* **2019**, *96* (5), 850-856.DOI:10.1021/acs.jchemed.8b00984.

4. **Santos-Díaz, S**. When support becomes pressure. *Science*. **2019**, *363* (6430), 1006. DOI: 10.1126/science.363.6430.1006.

3. Rodriguez, J.G.; **Santos-Díaz, S**.; Bain, K.; Towns, M.H. Using Symbolic and Graphical Forms to Analyze Students' Mathematical Reasoning in Chemical Kinetics. *J. Chem. Educ*. **2018,** *95* (12), 2114-2125. DOI: 10.1021/acs.jchemed.8b00584.

2. **Santos-Díaz, S**. Graduate School Through the Eyes of a Student from an Underrepresented Minority. *Graduate & Postdoctoral Chemist*, Mar 2018, p26-27.

1. **Santos-Díaz, S**. Five Reasons To Find Time in Your Busy Schedule To Get Involved. *Graduate & Postdoctoral Chemist*, Aug 2017, p24-25.

Oral Presentations

15. **Santos-Díaz, S.;** Towns, M.H. *Using Leadership Styles to Characterize Student Organizations in Chemistry Outreach.* 2020 Biennial Conference on Chemical Education [Abstract accepted on March 31, 2020; Conference canceled due to COVID-19]
14. **Santos-Díaz, S.;** Towns, M.H. *Investigating Student-Facilitators' Experiences in Chemistry Outreach.* 2020 Biennial Conference on Chemical Education [Abstract accepted on March 31, 2020; Conference canceled due to COVID-19]
13. **Santos-Díaz, S**. *Communities of Practice and Full-Range Leadership Theory: Frameworks to Study Chemistry Outreach*. Methods in Chemistry Education Research 2020 (MICER20 Online) [Invited]
12. **Santos-Díaz, S**. *Research Careers Speaker Panel.* San Diego State University/UC San Diego Cancer Partnership, San Diego, CA. April 2019. [Invited; Canceled due to COVID-19]
11. **Santos-Díaz, S.;** Towns, M.H. *Using Leadership Styles to Characterize Student Organizations in Chemistry Outreach.* American Chemical Society Spring 2020 National Meeting. [Abstract Accepted on February 21, 2020; Conference canceled due to COVID-19]
10. Johnson, K.; **Santos-Díaz, S**.; Reeser, D. *A Panel Discussion on Mental Health in Graduate School.* American Chemical Society Spring 2020 National Meeting. [Abstract Accepted; Co-organized Symposium; Canceled due to COVID-19]
9. **Santos-Díaz, S**. *Investigating Facilitators' Experiences in Chemistry Outreach.* 2020 Emerging Researchers National Conference, Washington D.C., February 2020.
8. **Santos-Díaz, S**.; Hensiek, S.; Owings, T.; Towns, M. H. *Survey on Undergraduate Students' Goals and Achievement Strategies for Laboratory Coursework.* SACNAS National Meeting, October 2018.
7. **Santos-Díaz, S**.; Hensiek, S.; Owings, T.; Towns, M. H. *Survey on Undergraduate Students' Goals and Achievement Strategies for Laboratory Coursework.* 256th American Chemical Society National Meeting, August 2018.
6. **Santos-Díaz, S.;** Rodriguez, J.G.; Bain, K.; Towns, M. *Using Symbolic and Graphical Forms to Analyze Students' Mathematical Reasoning in Chemical Kinetics.* 25th Biennial Conference on Chemical Education, July 2018.
5. Schlatterer, J.; Miller, S.; **Santos-Díaz, S.;** Serrano, K. *ACS Webinar: NSF Graduate Research Fellowship Program.* ACS Webinar, August 2017.
4. **Santos-Díaz, S.;** Álvarez-Rivera, M.L.; Ortiz-Nieves, E.L.; Medina, Z. *Development of an Interactive Dynamic Simulation for the Limiting Reactant Concept,* PR-LSAMP Seminar, Universidad de Puerto Rico en Cayey, PR, April 2016.
3. **Santos Díaz, S**.; Ortiz-Nieves, E. L.; Medina, Z. *The Development of the Redox Assessment Instrument to Measure Students' Understanding and Interconnection of Multiple*

Representations, Primer Encuentro Estudiantil de Investigación, Creación y Servicio Comunitario, Universidad de Puerto Rico en Cayey, PR, May 2015.

2. **Santos Díaz**, **S**.; Obare, S. *Chemical Reduction of Chlorpyrifos Driven by Functionalized TiO_2,* Research Experience for Undergraduates (REU) Student Presentations, Western Michigan University, MI, August 2013.
1. **Santos Díaz, S**.; Choperena, A.; Sobkowiak, M.; Painter, P. *Separating Oil from Tar Sands using Ionic Liquids (IL),* 4th annual Penn State REU Symposium, August 2012.

Poster Presentations

15. **Santos-Díaz, S.;** Towns, M.H. *Using Leadership Styles to Characterize Student Organizations in Chemistry Outreach.* American Chemical Society Spring 2020 National Meeting. [Abstract Accepted on February 21, 2020; Conference canceled due to COVID-19]
14. **Santos-Díaz, S**.; Hensiek, S.; Owings, T.; Towns, M. H. *Survey on Undergraduate Students' Goals and Achievement Strategies for Laboratory Coursework.* Graduate Diversity Fall Banquet, October 2018.
13. **Santos-Díaz, S**.; Hensiek, S.; Owings, T.; Towns, M. H. *Survey on Undergraduate Students' Goals and Achievement Strategies for Laboratory Coursework.* 256th American Chemical Society National Meeting, August 2018.
12. **Santos-Díaz, S**.; Hensiek, S.; Owings, T.; Towns, M. H. *Undergraduate Students' Goals and Achievement Strategies for Laboratory Work: A Quantitative Study.* 25th Biennial Conference on Chemical Education, July 2018.
11. **Santos-Díaz, S**.; Hensiek, S.; Owings, T.; Towns, M. H. *Undergraduate Students' Goals and Achievement Strategies for Laboratory Work: A Quantitative Study.* 12th Annual Graduate Student Education Research Symposium, March 2018.
10. **Santos-Díaz, S**.; Álvarez-Rivera, M.L.; Ortiz-Nieves, E.L.; Medina, Z. *Development of an Interactive Dynamic Simulation for the Limiting Reactant Concept*, 251st American Chemical Society National Meeting, March 2016.
9. **Santos Díaz, S**.; González-Sánchez, A.; Rosario, J.; Caraballo, J.N.; Ortiz-Nieves, E.L.; Medina, Z. *Developing an Assessment Instrument Using the Three Levels of Representation*, 249th American Chemical Society National Meeting, March 2015.
8. **Santos Díaz, S**.; Obare, S. *Multi-electron Transfer Catalyst for Chlorpyrifos Degradation,* 249th American Chemical Society National Meeting, March 2015.
7. **Santos Díaz, S**.; Obare, S. *Multi-electron Transfer Catalyst for Chlorpyrifos Degradation,* Research Initiative for Student Enhancement (RISE) Symposium, August 2014.
6. **Santos Díaz, S**.; Obare, S. *Multi-electron Transfer Catalyst for Chlorpyrifos Degradation,* Western Michigan University Research Experience for Undergraduates (REU) Symposium, August 2014.
5. **Santos Díaz, S**.; Obare, S. *Chemical Reduction of Chlorpyrifos Driven by Functionalized TiO_2,* 247th American Chemical Society National Meeting, March 2014.
4. **Santos Díaz, S**.; Obare, S. *Chemical Reduction of Chlorpyrifos Driven by Functionalized TiO_2,* CUR Conference of REU Student Scholarship, VA, October 2013.
3. **Santos Díaz, S**.; Obare, S. *Chemical Reduction of Chlorpyrifos Driven by Functionalized TiO_2,* RISE Undergraduate Research Symposium, UPR-Cayey, PR, August 2013.
2. **Santos Díaz, S**.; Choperena, A.; Sobkowiak, M.; Painter, P. *Separating Oil from Tar Sands using Ionic Liquids (IL),* RISE Undergraduate Research Symposium, UPR-Cayey, PR, August 2012.
1. **Santos Díaz, S**.; Choperena, A.; Sobkowiak, M.; Painter, P. *Separating Oil from Tar Sands using Ionic Liquids (IL),* 4th annual Penn State REU Symposium, August 2012.

Leadership & Service

Alliance for Graduate Education and the Professoriate (AGEP) Scholar **Fall 2018 – present**
Purdue University, West Lafayette, IN
- Mentor to two undergraduate students from the Purdue LSAMP Program
- Mentor to a scholar from Purdue Bridge Program
- Speaker in workshops *GPS for Grad School* and *How to prepare a scientific poster* addressing Purdue LSAMP Scholars
- Community service volunteer at *Habitat for Humanity* and *Food Finders* food bank
- Volunteer panelist and other events for Graduate Diversity Visitation Program (GDVP)
- Volunteer panelist in Purdue LSAMP meeting

ACS Younger Chemists Committee (YCC) Associate Member **Spring 2018-present**
- Served as reviewer or selection committee of awards given by YCC
- Participated of team efforts to start a liaison program with other ACS Committees
- Liaison to Society Committee on Education (SOCED)
- Member of SOCED team tasked with developing a plan to create Graduate Student Organizations

Diversity Transformation Award (DTA) Team Member **Spring 2017-Spring 2019**
Department of Chemistry, Purdue University, West Lafayette, IN
- Led recruitment efforts for Purdue's Chemistry graduate program, targeting minority-serving institutions
- Lead on building the DTA brand (i.e., website)
- Volunteer panelist for Graduate Diversity Visitation Program (GDVP)
- Part of recruitment team for the Chemistry Graduate Program at SACNAS

Volunteer in Science Outreach Events & Other Leadership Positions

Panelist, DTA Event on Applying to the NSF-GRFP	**Summer 2019**
Volunteer, National Chemistry Week	**2012-2018**
Historian of Plutonium Chapter of Iota Sigma Pi	**Fall 2017-Summer 2018**
Phi Lambda Upsilon Science Discovery Day	**Fall 2017**
Girl Scouts Day with Iota Sigma Pi	**Spring 2017**
Science Fair Judge at Klondike Middle School, West Lafayette, IN	**Spring 2017**

Mentor in *eMentoring program* **Fall 2017**
Department of Chemistry, Purdue University, West Lafayette, IN

Student Advisor of Colegio Bautista's ACS High School ChemClub **Fall 2014-Spring 2016**
Colegio Bautista de Caguas, Caguas, PR

ACS Student Chapter Workshop: *Taller: ¿Cómo redactar y someter un abstract?* **Fall 2015**
University of Puerto Rico, Cayey

Science Education Research Group at Cayey Workshop: *Statistics Worksho: SPSS* **Fall 2015**
University of Puerto Rico, Cayey

Historian of the UPR-Cayey's ACS Student Chapter **2013-2014**
Department of Chemistry, University of Puerto Rico, Cayey

Tutoring for Chemistry Major Freshman Students Program **2012-2013**
Department of Chemistry, University of Puerto Rico, Cayey

Professional Development and Extra Training

Safe Zone Certified	**Summer 2019**
Certificate of Foundations in College Teaching	**Fall 2018**
2018 Chicago ComSciCon Attendee	**Fall 2018**
Communicating Science Convention, an invitation-only event	
ACS Leadership Development System Courses	**Spring 2017**
Collaboration Across Boundaries	
Leading Change	

Laboratory Research Experience

Western Michigan University, Kalamazoo, MI **Summer 2013 & 2014**
Department of Chemistry

Chemical Reduction of Chlorpyrifos (CP) Driven by Functionalized TiO_2

- Synthesized TiO_2 nanoparticles to develop a catalyst for CP degradation
- Characterized compounds using UV-Visible Spectroscopy

The Pennsylvania State University, State College, PA **Summer 2012**
Department of Materials Science and Engineering

Separation of Oil from Tar Sands using Ionic Liquids (IL)

- Performed separations and analyzed the quality of the remaining solids using Fourier Transform Infrared Spectroscopy (FT-IR)

Professional Affiliations

American Association for the Advancement of Science (AAAS)	**Fall 2019-present**
SACNAS Member	**Fall 2017-present**
Phi Lambda Upsilon Member	**Summer 2017-present**
Iota Sigma Pi Member	**Summer 2017-present**
American Chemical Society Member	**2012-present**

Languages

Spanish (native)
English (fluent)

Computer Literacy Skills

Qualtrics
NVivo
SPSS
R [Beginner]
ActionScript 3.0 & HTML [Beginner]
Microsoft Office Suite
Google Suite (Documents, Sheets, Drive, Forms)

LIST OF PUBLICATIONS

Santos-Díaz, S.; Towns, M.H. Chemistry Outreach as a Community of Practice: Investigating the Relationship Between Student-Facilitators' Experiences and Boundary Processes in a Student-Run Organization. *Chem. Educ. Res. Pract.,* **2020**, DOI: 10.1039/d0rp00106f.