In an Era of Soft Skills: Investigating Teamwork Skills in the Geosciences

Samuel Cornelius Nyarko
Western Michigan University, myphlai@gmail.com

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IN AN ERA OF SOFT SKILLS: INVESTIGATING TEAMWORK SKILLS IN THE GEOSCIENCES

by

Samuel Cornelius Nyarko

A dissertation submitted to the Graduate College
in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
Mallinson Institute for Science Education
Western Michigan University
December 2021

Doctoral Committee:

Heather Petcovic, Ph.D., Chair
Matt Reeves, Ph.D.
Megan Kowalske, Ph.D.
IN AN ERA OF SOFT SKILLS: INVESTIGATING TEAMWORK SKILLS IN THE GEOSCIENCES

Samuel Cornelius Nyarko, Ph.D.

Western Michigan University, 2021

Geoscience employers have increasingly called for student competency in three sets of skills – technical, field and soft skills. One major soft skill identified by employers is teamwork, which is critical in laboratory and field-based activities. At the same time, educators seek to inculcate in students a stronger focus on the development of teamwork skills as they are useful for knowledge sharing and problem solving. This interconnected value of teamwork in both the workforce and academia means students’ preparation should include learning teamwork in the geoscience. However, before educators can design strategies that help students learn critical teamwork skills, we need to identify what these specific skills are, and how they are enacted in academic and professional employment settings.

This research was conducted as a series of studies that explored teamwork from perspective of employers and students through the lenses of input-process-output taxonomy of teamwork model by Marks et al. (2001). In study one, the analysis of focus group discussion (N=3) attended by 15 environmental and hydrogeology employers suggested that competency related to team mission analysis, goal specification and planning are the transition skills that
these geoscience employers desire. Action skills identified included metacognition, peer-mentoring/teaching, information synthesis and coordination. Employers also identified key interpersonal skills related to emotional intelligence, communication, organization and time management. A fourth category of teamwork skills that included trust, integrity and humility (teamwork ethics) emerged from data analysis. Results were consistent with prior research and theoretical perspectives, indicating a need for a focused teamwork development approach that teaches students these skills.

Research for studies two and three took place in a hydrogeology field course in a Midwestern university in the United States. In study two, the Geoscience Teamwork Observation (GTO) protocol was developed and validated as a measure of teamwork during fieldwork. The GTO captures the frequency of nine teamwork skills as observed by the user in real time, including: team mission analysis, goal specification, planning, peer-mentoring/teaching, information synthesis, coordination, communication, organization management and leadership. The GTO was developed using observations of two student teams (n= 5 members each) over two weeks of the field course and validated using focus group discussions. The GTO provides a unique framework for identifying teamwork skills as they develop and allows a single observer to simultaneously assess multiple teamwork skills and behaviors.

Study three utilized the GTO instrument to describe how geoscience students developed teamwork skills during the hydrogeology field course using an embedded, single-case study design. GTO data were triangulated against focus group discussions held after each week of team observations. Key emerging teamwork skills demonstrated by students included communication, leadership, peer-mentoring and teaching, and coordination. Skills related to goal identification, information synthesis and organizational management were least often used by student teams.
Participants described the positive role of these skills in hydrogeology fieldwork. This paper provides first-time information on students’ teamwork skills development in the geosciences.

Together, these three studies identified specific teamwork skills essential to the domain of geosciences, provided a novel approach for observing teamwork skills, and described the development of key skills in the context of a hydrogeology field course.
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ACKNOWLEDGEMENTS

I would like to begin by acknowledging the enthusiasm and support from my academic advisor and mentor Dr. Heather Petcovic in putting this research and manuscript together. You have been an inspiration to me throughout my Ph.D. journey. Again, I would like to thank Dr. Matt Reeves and Dr. Megan Kowalske for their suggestions, contributions and effective committee duties. I also acknowledge the efforts of the GeoEd research team at The Mallinson Institute for Science Education, Western Michigan University, and Dr. Cody Williams for their support and contributions. The efforts of these people in helping to refine my research ideas into this substantive manuscript has been immense.

Special thanks also goes to my fellow compatriots I have always looked up to for inspiration, Dr. Benjamin Ofori-Amoah and Dr. Daniel Asiedu. Finally, I would like to thank my wife, Peace Asante and my son, Damian-Heath Nyarko, Agnes Ofori-Amoah, and David Ofori-Amoah. I want to express my sincere appreciation to my parents, Robert and Mary Nyarko, my siblings and the Royal Twidan family of Breman Jamra for their all-round support during the time of this research.

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CHAPTER 1
INTRODUCTION

The geoscience community anticipates that all geoscience careers and occupations will grow at an average of about eleven percent in the next five years (Wilson, 2018), which provides increasing employment opportunities for geoscience students. Geoscience employers are calling for a specific set of skills: knowledge management, technical and field. This means that for students to be competitive for these jobs, they will need training in these skills. Universities and geoscience departments already do a good job training technical and field skills (Jarvis & Dickie, 2010; Viskupic et al., 2020), but often do not embrace teaching the “soft” skills that employers desire.

Employers have emphasized the need for colleges and universities to train students to embrace soft skills such as teamwork (Mosher & Keane, 2021; Hart, 2011; Hughes & Jones, 2011). Similarly, in academia, there is a common theme among employers and educators to inculcate in students a stronger focus on the development of teamwork to meet workforce requirements (Vik, 2001; Viskupic, 2020). Again, current employment and educational requirements suggest that students must have effective teamwork preparation to acquire the skills needed to lead and work in teams to provide effective results (Mosher, 2015; Mosher & Keane, 2021; Viskupic et al., 2020). This has become more important especially with the emergence of teamwork as a standard in both academia and professional work (Kastens & Manduca, 2017).
Furthermore, research supports that teamwork skills are trainable (Ghannam & Ahmad, 2020; Rousseau et al. 2006), hence the need to attach importance to teamwork skill development in students’ academic experience.

Teamwork is a process where members’ interdependent acts convert inputs to outcomes through cognitive, verbal, and behavioral activities directed towards organizing task work (Marks et al. 2001). Members usually play different roles in the team, but these roles are interconnected to achieve a common purpose (Salas et al., 2000). Teamwork occurs in a complex setting and group dynamics such as team leadership, team bonding, and team activities play vital roles in making team learning a success. The multitude of education fields that use teamwork and the positive impact are well documented in the literature (for example Levin, 2005; Griffin, Patterson and West, 2001).

Levin (2005) identified that students working in academic teams in social environment settings improve students’ creativity and problem-solving skills. Also, when students have good team skills, teamwork can effectively be applied in the classroom to provide productive learning (Vik, 2001). Teamwork is also considered to be an important determinant of job satisfaction in industries. Griffin et al. (2001) identified a positive relationship between teamwork and job satisfaction - workers find satisfaction in their jobs when they work in teams. Despite these positive impacts of teamwork in learning, there is an appreciable number of problems associated with teamwork. For example, lack of students’ training in teamwork creates problems for them when they must work in school teams, and lack of empirical research on evaluating and improving teamwork skills among students are problems that have been identified in teamwork learning environments (Vik, 2001).
1.1 Problem Statement

In the natural sciences including the geosciences and ecology, teamwork has become one of the preferred learning strategies (Alwin et al 2020; Viskupic et al., 2020; Yuretich & Kanner, 2015). Also, educational and organizational research supports the inclusion of teamwork curricula in the training of the future workforce (Martin et al. 2005; Mosher & Keane, 2021; Viskupic et al., 2020). Most geology coursework (both in classrooms and the field) and professional activities involve collaboration and teamwork, and learning is usually done in a collaborative environment. This is mostly due to the complex nature of geoscience projects which are such that completing a task in isolation can be very difficult, dangerous and exhausting if one is to rely on their own efforts (Bandura, 1977).

Despite significant thought and research related to teamwork in other fields, the construct has not been explored or implemented in the geosciences. There exist major problems with teamwork advancement in the geosciences. First, these desirable skills are typically neglected in most geoscience undergraduate programs. Most geoscience educators may assume that teamwork are domain general skills and independent of specific contexts which students may acquire in other programs or extracurricular settings (such as organized sports, music, work or community service) and thus see no need to formally teach this skill. Second, geoscience researchers and educators may not consider teamwork as learnable skill and instead regard the skills required to work in teams as personality traits. This has the potential of denying students who do not have these traits or innate skills the chance to learn these skills. Also, studies on teamwork usually include students across majors in multiple Science, Technology, Engineering and Mathematic (STEM) fields. This has the potential of ignoring or masking the differential
knowledge and skills and several other teamwork dynamics at play in specific disciplines such as the geosciences.

Furthermore, researchers have failed to ask from the perspectives of the STEM workforce regarding what practices best constitute essential teamwork and leadership skills needed to work in the STEM workforce. Specifically, in the geosciences, to date, research on skills specific to teamwork is scant. As a field that utilizes collaborative practices both in teaching, learning and professional work, research that examines best collaborative practices such as teamwork is needed. We need to understand what is out there in the geosciences in terms of teamwork in order to transform students’ collaborative practices both within academia and industry. Further research should also focus on how academic colleges or departments attempt to assess and prepare students in best teamwork practices.

1.2 Related Purposes of the Three Studies

Teamwork has proven to be essential skills for both students’ learning and professional growth. In identifying essential skills needed to work in STEM industries, both teamwork and ability to function as part of a team have been mentioned as integral to the STEM workforce (Martin et al., 2005; Mosher & Keane, 2021). This means that students need to be trained and provided with opportunities to build these skills while in school. For students to be competitive for these jobs in STEM broadly and in the geosciences, they will need to learn skills related to teamwork. However, before educators can design instruction that helps students learn critical teamwork skills, we need to identify what these specific skills are, and how they are enacted in academic and professional employment settings. Therefore, in study one, the goal is to identify the essential components of teamwork skills from the perspective of a single sector of geoscience employers, namely environmental geosciences and hydrogeology. Teamwork skills are
characterized using a robust and well-studied theoretical framework, the input-process-output (IPO) and taxonomy of teamwork skills model of Marks et al (2001). This research adds to the ongoing conversation about how to develop students’ essential skill competencies required for full participation in the future geoscience workforce.

Again, a major challenge among teamwork researchers, especially qualitative researchers is the lack of explicit protocols for observing teamwork practices, and how students are developing these skills during learning. To address this issue, I develop and investigate the effectiveness of a qualitative observation protocol based off from study one to assess teamwork during fieldwork in study two. The main purpose of this study is to provide a reliable observation strategy for assessing teamwork during geoscience fieldwork.

Furthermore, Myers and Goodboy (2005) have argued that simply allowing students to work as a team does not guarantee students’ development of teamwork skills. The problem with educational research on teamwork is that studies focus on the benefits of the construct to learning and what students know about the construct, but do not investigate how students develop teamwork skills while going through their education. Study three considers this issue in the context of geoscience fieldwork. I use an embedded, single-case study to investigate teamwork as it occurs during students’ participation in a recognized hydrogeology fieldwork program.

The cumulative results of the three studies build upon one another in several ways to help uncover ways to better understand and train students in essential teamwork skills that will be important for their successful integration and learning in both educational and organizational teams. Ultimately this research is intended to help geoscience educators and researchers transform students’ collaborative practices both within academia and industry. It is through the understanding of teamwork from the perspective of geoscience employers and how students...
perceive and develop the construct that educators and researchers can effectively design training programs such as curricula and teaching plans to teach these essential skills.

The remaining chapters of this dissertation are organized to present each study as a peer-reviewed journal article, with the final chapter providing a synthesis and summary of overall findings. At the time of submitting this dissertation, study one (Chapter 2) is in review with the Journal of Geoscience Education. Studies two and three (Chapters 3 and 4) are in preparation for submission to this journal. I am the lead author on all three papers, and my advisor, Dr. Heather Petcovic, is the second author. The papers generally use “we” to refer to both authors, however, in some cases where it is important to distinguish my contributions the papers use “I” or “lead author.”

1.3 Theoretical Framework

The theoretical foundation for this study is embedded in the Input-Process-Output taxonomy of teamwork skills model by Marks et al. (2001). The model describes teamwork as a multidimensional process that involves two or more people (input) performing cognitive, behavioral, and interactive activities (process) in order to produce outcomes or products (output). Input describes properties of teams such as individual attributes, team attributes and the environment in which the team is operating. Team processes describe the interdependent activities that combines transition, action and interpersonal processes to accomplish a task. Output refers to team outcomes as a result of input and process orchestration and includes team effectiveness, learning outcome or product outcome. In summary this theory defines teamwork as two or more people performing interdependent cognitive, behavioral, and interactive activities to produce outcomes.
Marks et al. (2001) propose that team processes are episodes/stages of transition, action and interpersonal processes. Transition processes involves planning and evaluation activities that sets up the team to take actions. During team transition processes, skills related to analysis of team mission, goal specification, task design and setting alternative pathways for task completion are important for effective team outcomes. Action processes involve activities that directly impact task completion. Skills essential for team action processes include effective team coordination and monitoring. Interpersonal processes support the team processes through effective management of the affective domain. This is when team members manage conflict, build confidence and motivation, and ensure that individuals feel part of the team. According to Marks et al. (2001), interpersonal processes are not direct and fixed but are emergent and are geared towards regulation of team performance to promote team task accomplishment and team maintenance to foster team cohesion and coordination.

The IPO taxonomy of teamwork skills model provides a critical lens to investigate teamwork. It provides a linear but complex teamwork model that can easily be attributed to both educational and organizational teams. Again, as a result of the repetitive cycles of teamwork episodes (output from transition processes serve as the input for team action processes, and vice-versa) described by the model, it provides a comprehensive method for delineating the processes of teamwork as they occur under functional (problem-solving teams) and multitasking (multiple functional) conditions.
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CHAPTER 2

ESSENTIAL TEAMWORK SKILLS: PERSPECTIVES OF ENVIRONMENTAL GEOSCIENCE EMPLOYERS

2.1 Abstract

Geoscience employers have increasingly called for the future workforce (students) to demonstrate competence in non-technical skills, including teamwork. This descriptive qualitative study contributes to ongoing efforts to identify the specific practices, skills, habits, and knowledge that make up these desired teamwork competencies in the geosciences. We collected data from three online focus group discussions centered around teamwork. Focus group participants were hydrogeology and environmental geology employers and team managers from government, private industry, and non-profit organizations in the United States. Using the teamwork taxonomy model as our conceptual framework, we generated three categories of teamwork skills specific to environmental geoscience teams. First, our data indicate that these employers value team transition skills related to specifying goals, interpreting team tasks, identifying resources, and planning. The second category of desired teamwork competencies included action skills such as metacognition, coordination and mentoring. These skills directly impact successful task completion. The third category captured interpersonal skills such as emotional intelligence, proactive communication, and organization. A fourth category of desired teamwork competencies emerged from data analysis and include ethical skills related to trust, integrity and humility. This study provides a detailed description of teamwork.
competencies desired by environmental geoscience employers and suggests implications for how to prepare students for this workforce.

2.2 Introduction

The geosciences are an actively growing field of employment, with all geoscience careers and occupations anticipated to grow at an average of about eleven percent in the next five years (Wilson, 2018). One goal of geoscience education is to prepare students for current as well as future employment (Viskupic et al., 2021). Over the past few years, the Future of Undergraduate Geoscience Education initiative has shared outcomes of a series of workshops and surveys in which academic geoscientists and geoscience employers identified key knowledge, skills, and habits of thinking critical to success in the geoscience workforce for both undergraduate (Mosher, 2015; Mosher & Keane, 2021) and graduate students (Mosher & Ryan, 2019).

The ability to work in teams – to lead and/or follow as part of a team – was considered by geoscience employers to be an essential non-technical skill (Mosher, 2015; Mosher & Keane, 2021; Wilson, 2018). Similarly, teamwork has long been highlighted as a critical science, technology, engineering and mathematics (STEM) workforce skill requirement (Martin et al., 2005; Stasz, 1997), as organizations embrace the idea of knowledge sharing through teamwork (Retna & Ng, 2011). For example, in the United States, about 95% of employees work in teams and about 91% of team experts and consultants believe that teams are central to an organization’s success (Van Velsor & Wright, 2015; Martin & Bal, 2006). As a learning tool in organizations, teamwork promotes the learning of complex concepts, knowledge and skills. In STEM workforce such as the health sciences, there is enough evidence suggesting a direct positive relationship between effective teamwork and patient safety. Van Schaik et al., (2014) identified that effective teamwork among health teams is critical in ensuring the wellness of patients in
emergency settings. Also, prior research by Fearon, (2012) indicate that teamwork promotes the process of active learning and participation in organizations through social processes.

For students to be competitive for these jobs in STEM broadly and in the geosciences, they will need to learn skills related to teamwork. However, before educators can design instruction that helps students learn critical teamwork skills, we need to identify what these specific skills are, and how they are enacted in academic and professional employment settings. The Future of Undergraduate Geoscience Education initiative identified personal awareness and behavior monitoring, conflict resolution, time and project management, goal setting, and the ability to work with diverse individuals as important teamwork skills (Mosher, 2015; Mosher & Keane, 2021). Our goal is to build on this initial work by identifying the essential components of teamwork skills from the perspective of a single sector of geoscience employers, namely environmental geosciences and hydrogeology. Our study used an approach similar to that of the Future of Undergraduate Geoscience Education initiative in that we solicited specific teamwork skills directly from employers. However, we characterized these skills using a robust and well-studied theoretical framework, the input-process-output (IPO) and taxonomy of teamwork skills model of Marks et al (2001). This research adds to the ongoing conversation about how to develop students’ essential skill competencies required for full participation in the future geoscience workforce.

2.3 Theoretical Framework

Teamwork involves two or more people combining their knowledge structures and behaviors in an interdependent environment to accomplish a task. Marks et al. (2001) argue that teamwork is a social learning process that involve members’ cognitive, verbal and negotiation skills. As described by Decuyper et al. (2010), teamwork is a compilation of processes that
circularly generate change or improvement for teams, members and organizations. Similar to a feedback loop in an earth system, teamwork is a compilation of interdependent processes that together generate change or improvement for teams, individual members, and organizations.

Figure 1 Conceptualization of teamwork in the Input-Process-Output (IPO) model.

The Input-Process-Output (IPO) model (Marks et al., 2001) (Figure 1) is generally recognized as a robust and accessible conceptual framework of teamwork. The model proposes that teamwork involves two or more people (input) performing cognitive, behavioral, and interactive activities (process) in order to produce outcomes or products (output). Team input (“I” in IPO) involves the personal attributes of individual team members as well as team characteristics, and the context in which the team operates.

Team processes (“P” in IPO) involve the phases of transition, action and interpersonal processes that team members employ to accomplish a task. According to Marks et al. (2001), these processes are not direct and fixed, but instead develop over the life of team. The transition
phase of team process is when the team reviews itself, identifies goals, and designs an agenda for the way forward. Teamwork during the transition phase includes skills that promote goal identification, analysis of team mission and tasks, and scheduling and evaluation of team plans.

The action phase of team processes involves application of skills that directly impact task completion. This is when teams work towards the main goal through effective team coordination and monitoring. According to Marks et al. (2001), skills related to member monitoring, resource monitoring, and collective construction of knowledge are important for the team action phase. Team transition and action phases can happen concurrently, although the consistency and length of both action and transition phases are dependent on team objectives, environment, expertise, and leadership (Marks et al., 2001). However, Rousseau et al. (2006) suggest that the phases of teamwork during team processes interact at different times, and they operate in a hierarchy to regulate team performance and management. These authors argue that under ideal team settings, teams will first perform transition processes before action processes.

Interpersonal processes support the team processes through effective management of the affective domain. This is when team members manage conflict, build confidence and motivation, and ensure that individuals feel part of the team. Interpersonal skills that promote team management and maintenance include leadership, empathy, and communication. The interpersonal phase of teamwork can occur in both the transition and action phases of team processes.

Team output (O) are the outcomes of team input and processes, which could include reaching a goal, completing a project, or team learning. Marks et al. (2001) suggest that team outputs are the final products of a team, and they define the effectiveness of the input and team
processes. Both team input and output are connected by feedback mechanisms and the support of interpersonal skills.

The IPO model, despite its wide acceptance in educational research, is not without criticism (Huang, Sun and Law, 2021). Ilgen et al. (2005) argue that the IPO model is too narrow to depict the complex nature of teamwork, which limits its application in research. They suggest an input-mediation-output-input (IMOI) model that embraces the complex mediation and interaction processes, with all of the teamwork dimensions connected by feedback loops. However, the IMOI model provides a rather complex organizational model of teamwork that has proven difficult to apply in education research (Knapp, 2010). The stages of formation and other processes do not reflect higher education learning models, hence, while appropriate to research on teamwork in professional organizations, it is difficult to apply to educational and school teams. On the other hand, the IPO model provides a simpler teamwork model that can easily apply to education research.

The IPO model has proven to be useful in both education and organizational teamwork research. Yu (2005) used the IPO model to investigate the development of team cohesiveness, effectiveness, and leadership among undergraduate business students. Similarly, Mathieu et al. (2006) used the IPO model to investigate how team empowerment emerges among service technician teams in business management. Recently, Varela and Mead (2018) used the IPO model as a framework to develop an assessment instrument to measure teamwork competencies of business students. The results of the factor analysis by Varela and Mead (2018) yielded factors similar to the processes and phases of teamwork identified in Marks et al. (2001).

Because we want to identify the teamwork skill competencies desired in a specific community, we conceptualize teamwork as the interdependent verbal, cognitive and interactive
behaviors a group of community members apply to accomplish a common task. Hence, teamwork skills are the team attributes that members within the community employ to orchestrate community effectiveness and ensure their common purpose of obtaining effective outcomes.

2.4 Research on Essential Teamwork Skills

Globally, teamwork skills essential in the STEM workforce outside of higher education have not been well documented in the research literature. The few empirical studies on teamwork in the workforce have been concentrated in the fields of business management and healthcare. For example, prior research on workplace skills in engineering has identified task orientation (explaining and making a task clear to team members), application of knowledge to make decisions and solve problems, sharing of knowledge and skills, and interpersonal skills as important for the workplace (Katzenbach & Smith, 1993). Again, having good coordination skills and creating positive relationship with team members, as well as leadership have been identified as essential teamwork skills in business management teams (Yan, Huang & Wu, 2011). Also, Levin (2005) emphasize the importance of creativity and critical thinking as important for working in teams. Though it might sound easy, teamwork is a complex process and group dynamics such as team leadership, team cohesiveness and team activities play vital roles in making it a success (Miller, Riley and Davis, 2009).

In their review of the teamwork literature, Salas et al. (2000) identified that teamwork is characterized by set of common behavior and motivation among team members, cognitive capabilities, and attitude of team members toward teamwork. Others include member monitoring and support, concise communication, and coordination of collective actions. The rest are leadership, and the context and task requirements of the team. Similarly, Tannenbaum et al.
(2012) identified that diversity in membership, technology and distance, and empowering team members to take ownership of the team through task delegation affect teamwork. In summary, the broader literature demonstrate that teamwork involves the use of both technical and non-technical skills.

In STEM, prior work documents competency gaps in teamwork skills among students, especially when it comes to leading teams (Lang et al., 1999). In a study of chemical engineering majors’ perceptions of their preparation to work in professional teams, majority of students believed there was insufficient practice and activities to learn teamwork during their undergraduate education. They felt inadequately prepared to take up roles in professional teams (Martin et al., 2005). Humphreys and Davenport (2005) found that undergraduate liberal education students, especially freshmen value teamwork skills and the ability to work in teams as important to their education. However, they believe that teamwork skills are not direct outcomes of their college curriculum. Furthermore, how teamwork is applied and practiced in the workplace differs from teamwork in college classrooms in terms of elements such as putting teams together, team goals, and available resources (Berge, 1998; Barak et al. 1999). For example, whereas organizational teams involve selection of team members based on expertise, educational teams are formed with available students. The literature also emphasizes the lack of explicit teaching of teamwork skills (Levenburg, 1996).

In the geosciences, teamwork skills such as goal setting, motivation to take ownership of learning, coaching, leadership and conflict management have been identified as essential workforce teamwork skills (Mosher & Keane, 2021). In their literature review on the perspectives of skills that geoscience employers desire, Viskupic et al. (2020) identified that experience working in interdisciplinary teams and in different team cultures are skills that
geoscience employers value. Again, 88% of 1013 geoscience instructors surveyed by Viskupic et al. (2021) described that development of teamwork skills is very important to students’ preparation, hence, they use teamwork strategy at least once in their courses.

2.5 Research Questions

As described by Ellis et al. (2014), to effectively teach skills such as teamwork to students, educators and researchers need to examine from the perspectives of what employers want and then compare with what is being taught. The purpose of this study is to characterize teamwork process (the P in IPO) skills essential to the geosciences as viewed through Marks et al. (2001) framework. We are specifically interested in teamwork processes because it is the stage of teamwork where interdependent skills of team members are adequately utilized for task completion. During teamwork processes, members convert transition, action and interpersonal processes into outcomes. We seek to address the following research questions:

1. What team transition skills do environmental geoscience employers report as most important for students/employees to have?

2. What team action skills do environmental geoscience employers report as most important for students/employees to have?

3. What interpersonal skills do environmental geoscience employers report as most important for students/employees to have?

2.6 Methods

2.6.1 Research design

The study employed a descriptive, basic qualitative design (Merriam and Tisdell, 2016) as we wanted to identify and describe desired teamwork skills from the perspective of geoscience
employers. We collected data through online focus group discussions hosted and recorded on the synchronous web conferencing tool, WebEx. A focus group is a carefully planned interactive discussion that considers a specific topic with a predetermined group of people who know the most about that topic (Hennink & Leavy, 2014). Whereas interviews can deeply probe individual perspectives, a focus group design offers the opportunity to obtain a socially constructed, collective narrative. By including environmental geoscience team managers as participants, we could identify a range of perspectives on what constitutes best teamwork practices. Furthermore, a focus group methodology is embedded in social construction of knowledge, allowing for the moderator to obtain consensus on ideas and check the quality of information provided (Hennink & Leavy, 2014).

A synchronous online focus group offered the added opportunity for real-time discussion among participants from multiple locations, and the capacity of the moderator and participants to see each other. As a practical concern, an online focus group also allowed the research to continue with little to no impact from COVID-19 restrictions. Lastly, the procedure also facilitated an active moderator role, in which the moderator participated in the discussion (Hennink & Leavy, 2014; Tuttas, 2015). The first author coordinated and moderated all focus groups.

2.6.2 Participant recruitment and selection

The participants for this study are hydrogeology and environmental geology team and project managers. Although there are many geosciences industry sectors (e.g., mining, geotechnical, oil and gas, etc.) that uses teamwork, we specifically targeted hydrogeologists and environmental geologists for three main reasons. First, these two sectors include the greatest number of employees, especially employees with undergraduate degrees in the geosciences labor
force in the United States (Wilson, 2018). Second, we thought we would get more consistent results by limiting the study to one employment section, and that future research could expand on this research to compare results against other sectors. Third, we also had the practical reason that we know a lot of environmental geologists.

We used two email-based strategies to recruit potential participants for the focus groups. First, we put out an open call for research participants through geoscience professional organization member listservs (the Geological Society of America, the American Geophysical Union, and the National Groundwater Association). Second, we directly invited individuals using our own networks of geoscience professionals, faculty, industry advisory boards, and others. The second snowball recruitment strategy also asked focus group participants to recruit additional participants through their own personal contacts.

The recruitment email was sent together with informed consent documents and a link to an online Qualtrics survey requesting professional information. The survey was intended to screen participants and identify those who met the qualifications of five or more years’ experience managing and supervising teams in hydrogeology and environmental geology organizations. Participants (Table 1) were selected from government, private and non-profit organizations.

Table 1 Participant information by focus group (because the moderator assumed a participatory role, he is included in the participant count for each focus group).

<table>
<thead>
<tr>
<th>Gender</th>
<th>Focus Group 1</th>
<th>Focus Group 2</th>
<th>Focus Group 3</th>
<th>Position held by participants.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>n = 6</td>
<td>n = 5</td>
<td>n = 4</td>
<td>Environmental Manager; Chief Executive Officer; Section Head; Vice President; District Supervisor; Hydro Consultancy manager; Senior Scientist; Project Manager; Technical</td>
</tr>
</tbody>
</table>
2.6.3 Instrumentation

The study used two data sources: a survey and the focus group interview. The Qualtrics survey contained both closed and open-ended questions about participants’ job title, years of professional experience and a brief description of their job. The primary purpose of the survey was for participant selection; however, demographic data of all focus group participants was retained in order to describe the characteristics of each group. The focus group script (see online supplement) included open-ended questions that allowed participants to describe what teamwork looks like in their organizations. It also prompted participants to share the specific teamwork skills, habits, and competencies that they deem essential to the workforce, and to explain why these skills are important.

2.6.4 Data collection

Following Tuttas’ (2015) criteria for selecting online web conference tools, we selected WebEx as it: supports meetings attended by participants of up to six and above; supports real time video and audio imaging and recordings; requires only moderate technical competency; is easy for invited participants to join without accounts; allows the moderator to mute participants; and restricts access to recordings to only the researchers. Each focus group meeting was audio and video recorded using the WebEx conference recording option.

<table>
<thead>
<tr>
<th>Work experience of participants</th>
<th>5 -50 years; Mean = 24 years</th>
<th>5 – 33 years; Mean = 12.5 years</th>
<th>12 – 30 years; Mean = 19 years</th>
</tr>
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<tbody>
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<td></td>
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</table>

Table 1 - continued
Focus group meetings took place between October and December 2020, and each focus group discussion lasted about 90 minutes. Each of the focus group sessions began with a “share and tell” that served as an icebreaker to quickly prompt conversation (McNeal et al., 2017). The script was designed to stimulate conversation and discussion. Questions and follow-up prompts were structured to promote group interaction and varied with each focus group. After each round of questions, participant comments were summarized by the moderator and put in the online chat box for participants to see, respond to, elaborate on, or corroborate.

After the third focus group interview, we observed saturation in the data as we did not identify any different perspectives from the three focus group discussions for further exploration.

2.6.5 Data analysis

Focus group data analysis followed the category construction model described by Merriam and Tisdell (2016). Data transcription followed a two-step process. First, an automated transcript was generated from the WebEx recording. Second, the first author performed manual cleaning and de-identification of data to remove participant names, references to companies or organizations, or other potentially identifying information.

The unit of analysis was each focus group conversation. Using the research questions, conceptual definition of teamwork, the theoretical framework, and the focus group transcripts, the first author developed a priori codes. We used a priori codes because the dimensions of teamwork described by Marks et al. (2001) are well-established in the literature and we expected them to arise in the data. The initial coding scheme included three categories related to Marks et al.’s (2001) team processes: transition skills, action skills and interpersonal skills. The a priori scheme was tentative and subjected to redefinition and modified to fit the focus group conversations. Through this process, a fourth set of codes, which we refer to as teamwork ethics,
emerged from data analysis as we found ideas that did not fit into the Marks et al. (2001) framework.

The first and second authors then independently coded one focus group transcript using the revised coding scheme. We then compared our codes to create a final coding scheme (Table 2). The first author then applied the finalized coding scheme to all focus group data. We compiled codes that represent each category using QSR NVivo 12, and generated interpretations that explain teamwork skills. In this paper, we use focus group quotes that represent our findings and interpretations.
Table 2 Teamwork skill categories and examples of coded texts.

<table>
<thead>
<tr>
<th>Category of Teamwork Skills</th>
<th>Description of code</th>
<th>Example of code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition Skills:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skills that promote</td>
<td>Interpretation of</td>
<td>Most of the work that our staff does is generally</td>
</tr>
<tr>
<td>team task evaluation and</td>
<td>team mission: Ability to clearly describe</td>
<td>independent, but within, all the staff is available</td>
</tr>
<tr>
<td>planning.</td>
<td>to the team, what the team task is and its scope, and to</td>
<td>as a team to help every member understand what we are</td>
</tr>
<tr>
<td></td>
<td>identify material resources.</td>
<td>doing [task] – FG3</td>
</tr>
<tr>
<td></td>
<td>Identification and prioritization of goals: Ability to</td>
<td>So, one of the pivotal foundations of being able to</td>
</tr>
<tr>
<td></td>
<td>identify specific goals, delegate work, make sure all</td>
<td>move a project forward is being able to identify goals</td>
</tr>
<tr>
<td></td>
<td>members are on the same page.</td>
<td>and identify who's doing what. You must be a good</td>
</tr>
<tr>
<td></td>
<td></td>
<td>delegator. One of the things that I see so often is</td>
</tr>
<tr>
<td></td>
<td></td>
<td>people can't delegate downward to their junior staff.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>You've got to delegate and don’t keep the work for</td>
</tr>
<tr>
<td></td>
<td></td>
<td>yourself. Delegate or talk to somebody to help them</td>
</tr>
<tr>
<td></td>
<td></td>
<td>take over and that give them the opportunity for task</td>
</tr>
<tr>
<td></td>
<td></td>
<td>management – FG2</td>
</tr>
<tr>
<td>Planning: Skills that promote</td>
<td>You must be willing to change or be accepting or adaptive.</td>
<td></td>
</tr>
<tr>
<td>task/goal accomplishment such</td>
<td>if one plan doesn’t work you accept that and use alternative</td>
<td></td>
</tr>
<tr>
<td>as budget issues and task</td>
<td>plans. So, you must be ready to adapt to the conditions</td>
<td></td>
</tr>
<tr>
<td>design, and development of</td>
<td>that you have when you put the shovel to the ground, if</td>
<td></td>
</tr>
<tr>
<td>alternative pathways for</td>
<td>you will – FG1</td>
<td></td>
</tr>
<tr>
<td>team goal attainment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action Skills: Skills and</td>
<td>Metacognition: Skills related to self-drive, problem</td>
<td>We’re looking out for lots of the self-initiative</td>
</tr>
<tr>
<td>behaviors that directly</td>
<td>solving and willingness to learn, personal development</td>
<td>problem solving in our teams and willingness to try</td>
</tr>
<tr>
<td>impact task</td>
<td>and personal motivation.</td>
<td>things on their own – FG2</td>
</tr>
<tr>
<td>accomplishment</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mentoring: Serving as a mentor in the team that members</td>
<td>It's important for us to mentor, train and educate our</td>
</tr>
<tr>
<td></td>
<td>can learn from, training and coaching members.</td>
<td>team members at the various levels to understand the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>role that they play, how their role impacts the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>overall project because</td>
</tr>
<tr>
<td>Skill Category</td>
<td>Description</td>
<td>Statement</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td>Information synthesis:</td>
<td>Skills related to ability to analyze and interpret information</td>
<td>I think that leads to better outcomes from a standpoint of our employees and our team members – FG3</td>
</tr>
<tr>
<td>Coordination:</td>
<td>Skills that brings whole team ideas together such as taking ownership of team, accept and acknowledge the ideas of others, coordinating technical skills and inscriptions</td>
<td>We want them to be curious and critical thinkers. We want them to be able to analyze the data we give them and understand that what they're doing fits into the bigger picture of what we're trying to accomplish on the project or as a company - FG1</td>
</tr>
<tr>
<td>Interpersonal Skills:</td>
<td>Emotional intelligence: Ability to identify and manage one’s own emotions as well as the emotions of others.</td>
<td>Yea, respect for people’s knowledge. You're going to work with people from all kinds of backgrounds, and you need to respect their knowledge - FG1</td>
</tr>
<tr>
<td>Communication:</td>
<td>Ability to receive and relay information proactively including both oral and written forms and persuade people.</td>
<td>The ability to integrate their everyday experiences with their technical abilities and the emotional intelligence pieces of it is really important. Because whether or not, your everyday experience, if they're necessarily relevant to you they still give you a paradigm from which to view the world -FG2</td>
</tr>
<tr>
<td>Organizational and time management skills:</td>
<td>Personal organization skills and the ability to influence team organization and time management.</td>
<td>Be a good listener during communication with team members. Because [name redacted] might have a better idea than me, and I got to be able to listen to him to make sure that we're delivering the right job – FG2</td>
</tr>
<tr>
<td>Teamwork Ethics:</td>
<td>Trustworthiness: ability to build trust around and within the team</td>
<td>I think what this comes down to is to life and organizational skills. To be a decent and respectful person that cares about themselves and other people, and organizes the team and takes care of their situations – FG2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>You got to be genuine, right. Because people in your team want to trust whatever you say or do. If there is a problem, you have to let them know – FG2</td>
</tr>
</tbody>
</table>
Table 2 – continued

<table>
<thead>
<tr>
<th>principles in teamwork</th>
<th>Integrity: being truthful, ensuring probity and accountability</th>
<th>We always need to do the right thing. There’s all the pressure in the world to do the wrong thing to be a people pleaser and give people the answer that they want to hear. But it’s our job, we always need to do the right thing. And if you do the right thing then tend to turn out better in the long run and you do your job and you stay out of jail - FG3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Humility: accepting responsibility, putting team success over individual success</td>
<td>Be humble, because as geologists, we are frequently wrong. And we must always know that we are going to be wrong - FG1</td>
</tr>
</tbody>
</table>
2.6.6 Validity and reliability

We conceptualized validity as a methodological rigor that assessed trustworthiness in our study (Merriam & Tisdell, 2016). First, we assessed validity through member checks and adequate engagement during data collection. After each round of questions, comments relating to teamwork skills were summarized by the moderator and put into the online chat for participants to modify and/or verify. Verbal participant responses to the summaries were preserved in transcribed data and coded. Second, during data analysis, we ensured that we captured all the important ideas in the data by discussing and comparing codes.

We approached reliability as “the extent to which research findings can be replicated” if the study is repeated (Merriam & Tisdell, 2016, p.250). We engaged in an inter-coder agreement process between both authors and with a third geoscience education researcher external to this project to ensure agreement in how the coding scheme was applied to the data. We achieved an initial inter-coder agreement (measured as % of identically coded text passages out of total coded passages) of 91% between the two authors, and 82% between the first author and external research associate, which are both higher than the 80% value suggested by Miles and Huberman (1994). The authors also discussed and resolved all disagreements until we achieved an agreement of 100%.

2.6.7 Researcher positionality

The researcher is a geoscience educator with experience in science education theory and research, including qualitative research. I align with the social constructivist theory (Vygotsky, 1978) of knowledge creation, and believe that diversity in knowledge creation is the closest we can go to achieve accurate knowledge. I am an active member of the geoscience education community, have worked in teams, and have taken team leadership roles in academia. As a result
of these beliefs and experiences, I am predisposed to think positively about teamwork, and this might bias my interpretations during this research. However, keeping researcher journals and critically reviewing the findings with peers are techniques that I employed to identify and mitigate any hidden biases.

2.7 Interpretation and Discussion of Results

Here, we organize and present our results based on our research questions. However, we interpret and discuss our results in the context of our theoretical framework (Figure 1) and our conceptualization of teamwork. We then synthesize our results with findings of the Future of Geoscience Education report (Mosher & Keane, 2021).

2.7.1 RQ 1. What team transition skills do environmental geoscience employers report as most important for students/employees to have?

Marks et al. (2001) refer to transition skills as interdependent teamwork behaviors that promote team task evaluation and planning. Collectively, these skills are utilized to set the team up for action. The first specific competency within the broader transition skills described by our focus groups are skills that promote interpretation of team mission and task. Focus group discussions pointed to the idea that team members should be able to understand the mission of the team and the task at hand. Focus Group Two (FG2) shared that “we expect that the project manager is going to effectively tell the rest of the team members what our goals and objectives of the project are”. Similarly, FG1 described that

*It’s important we challenge our team members at all levels to ask questions about the work [task] we are doing. We challenge them to make sure that they understand what we are doing and what they are going to do.*
The second competency within transition skills described in the focus group discussions referred to skills that promote identification and prioritization of goals. Team members should be competent in identifying specific goals and what should be accomplished at what time, be able to delegate work, and ensure that all members are on the same page with regards to specific team goals. FG2 shared that

*Another thing that is essential is the ability to identify specific goals, pass work off to delegate, share the workload and you know, at times the ability to say no and set healthy boundaries in teams in terms of what goals is to be achieved and who is doing what. So, really the ability to set boundaries and share the workload is also very important.*

Similarly, FG1 emphasized that

*Being proactive about where you are with the project [goals], where you are with your team and making those lines of communication really strong.*

The third competency within transition skills that emanated from focus group discussions related to effective planning. These skills are essential to ensuring that the team is well resourced and prepared for uncertainties. Planning skills include task design, finding alternative pathways for solving problems, and budgeting. FG3 indicated that

*You have to have a schedule scope and budget, and then be able to identify how to execute those things. And then, once you can execute the scope schedule and budget, you recognize what type of resources you need and then you can build your team from there.*

FG 2 discussions also heavily emphasized the ability of team members to develop alternative pathways for team goal attainment.
As team members, we need to always find ways to do things differently if the current way is not working. We don’t have to expect the same method to work all the time, so we need our team members to have in mind that they can always come up with new ways of doing things.

In the Marks et al. (2001) framework, team transition phases are periods in which the team evaluates and plans activities to guide team actions. In the geoscience community where teamwork is usually focused on problem solving, how to effectively plan tasks, design possible task accomplishment strategies and consistently evaluate plans and strategies are very important. These skills encompass both cognitive and behavioral performances that seek to ensure effective teamwork planning and evaluation for positive team outcomes. The skills identified from our focus group discussion are also similar to Martin et al. (2005) who describe that understanding team mission and task goals, task delegation, and critical analysis of the team environment are necessary skills for effective problem-solving teamwork in engineering.

2.7.2 RQ 2. What team action skills do geoscience employers report as most important for students/employees to have?

During action phases, teams focus on activities that directly apply to task completion through effective team coordination and monitoring (Marks et al., 2001). We identified four main competencies related to team action skills: metacognition, mentoring, information synthesis, and coordination. Metacognitive skills include those that enhance self-learning. All focus groups heavily emphasized the ability of team members to be self-driven, independent problem-solvers and willing to learn. FG3 participants shared “the hungry part is having enough ambition to be able to do your work independently”. Similarly,

Another important one for teamwork is the ability to problem solve [independently]. I’ve noticed with a lot of new hires they’re really great at coming to me with problems, noticing
things that aren't working, but what works better is when that same new hire comes, says, ‘here's this problem, I thought through the problem and here are some possible solutions that I've thought of.’ - FG1.

Focus group discussions also emphasized action skills related to mentoring. During the task completion phase of teamwork, team members should have mentoring skills in order to train, assist, and substitute for each other, for example

One of the things that was mentioned by several participants was mentorship. When you bring in new people, the success of teamwork has to involve mentorship. You have to be able to serve as a learning guide to team members – FG2.

Also, FG1 shared that:

It's important for us to train and educate our team members at the various levels to understand the role that they play, and how their role impacts the overall project because I think that leads to better outcomes from a standpoint of our employees and our team members.

Competency in skills related to information synthesis were also described by focus group participants as important during action phase of teamwork. Team members should be able to analyze and interpret information related to the task.

It's important that the information that's collected or distributed amongst the team members... they can understand and interpret the information that is being collected, so we try to stress that importance – FG3.
Codes from our focus group discussions about action skills included coordination skills that brings whole team ideas together. These skills included the ability to take ownership of the team as described by FG3.

The other part that I think is very important that is been indirectly alluded to by several people is the fact that you want the team members to feel a sense of ownership, rather than they [are] being just dictated to. And that means that you've collaborated, and you've involved them in the decision process to the extent you can.

Similarly, FG1 emphasized the need for the ability to accepting and acknowledging the ideas of other team members. They shared that

*Accept others’ ideas and acknowledge other people and their thoughts and views on things and still allow the team to proceed and work through things to get to that common endpoint.*

Participants in FG 3 also described skills related to coordinating team efforts through tasks such as notetaking, report writing, and data collection are important to geoscience teamwork. Tasks such as note-taking and collecting information is important for teams to stay organized.

*Team skills are important from a standpoint, and making sure that the note taking, data collection all that is important. Because as much as I would like to say, in our firm, we can’t just say, okay, you are part of this team, and you won’t do anything else until this project is done.*

The responses from geoscience employers suggest that interpretive skills, independent problem-solving skills, positive behavior towards learning, and coordinating skills are important for the success of geoscience teams. Being self-aware of what one can do independently and
coordinating it with the efforts of other team members enhances diversity in outcomes and promotes both individual growth and team effectiveness.

2.7.3 RQ 3. What interpersonal skills do environmental geoscience employers report as most important for students/employees to have?

Marks et al. (2001) define interpersonal skills as those that promote management of human resource interactions in teams. Interpersonal skills are important to teams during both transition and action phases – they support transition and action skills to enhance team cohesion while maintaining standards. We identified three key sets of interpersonal skills: emotional intelligence, communication, and organization. Under this category, discussion highlighted the importance of emotional intelligence – the ability to identify and manage one's own emotions, as well as the emotions of others.

*And then again, that high emotional intelligence of being able to kind of read things in the teams, and when they are in them and understand what the temperature of the group is and find a way to fit into that that mold for themselves and that group is really important – FG1.*

Similarly, participants also shared the importance of being able to integrate into the group and recognize team dynamics to ensure effective participation.

*Teams are made of people, and we disagree on things and there's nothing wrong with that in teams. But when you have these skills [emotional intelligence] they all build into everybody recognizing that the team is dynamic, it's different, but we are all working towards a common goal – FG2.*

Second, skills related to proactive communication also featured prominently in focus group discussions. Participants described that the ability of team members to effectively
communicate information verbally and in writing helps promote team cohesion and understanding of tasks. FG1 shared that:

*I think with teamwork; communication is going to be extremely important. How you want to work as a team if you're operating in separate silos, if you're not talking to each other, collaborating, so I think that one sort of self-evident. If we're not communicating, we're not being effective at all.*

Similarly, communication skills that persuade and motivate people, and bring people together in the team were emphasized by focus group participants.

*When you really start an initiative, say in the geosciences, then you really hope for that you would have members in the community that would be able to convince people to follow and convince people that this is in the best interest of the community and communication is very important* – FG2.

Finally, participants described that organizational and time management skills are crucial to effective performance of teams. Personal organization skills and the ability to influence team organization promote team effectiveness and timely completion of tasks.

*Organizational skills and time management are critical. You need to build a framework and have an infrastructure in which these people can actually work together* – FG 3

In summary, focus group participants perceived that building effective relationships in teams is crucial to the success of teamwork. Our data suggest that these relationships are effective when team members are able to appreciate their own emotions and that of others while maintaining effective communication and organization. As discussed by Rousseau et al. (2006), a lack of positive interpersonal skills can reduce the efficiency of teamwork.
2.7.4 Emergent skills from data: Teamwork ethic skills

Similar to every workforce team, high moral standards and principles are required in geoscience teams for effective functioning. These skills do not only enhance team performance, but also promote mutual benefits for teams and their clients (Harell & Daim, 2009). Although not part of the Marks et al. (2001) framework, three codes related to ethical conduct during teamwork - trustworthiness, integrity and humility – emerged from our analysis. Trustworthiness involves the ability to build trust around and within the team.

*If you don't trust your management, and you don't trust your team members and the only reason you will trust them is if you know that they have your best interest in mind. So we tend to look at it from a little bit more of a less technical, less business minded perspective and more about what actually makes a teamwork and building trust is one – FG1.*

Similarly, FG 3 described the importance of integrity, such as being truthful, ensuring probity and accountability in building trust within teams. They shared that

*Because we’re scientists and we’re making judgments based on data, I think we can take that a little deeper - that honesty and integrity has to extend into how we do our work, how we document our work, the openness by which we make decisions. So honesty and integrity are very important.*

Humility refers to skills that promote inclusion within the team by ensuring that one person, or ideas of one person, is not considered as more important than others. Thus team members must humble themselves to the ambition of the whole team rather than individual ambitions.
Being humble is the most critical. When we are trying to do hiring, I look for humility because if we can't ask our team to put the good of the team before themselves, or their own self-interest, or their own thing we can't have effective teams and we can't have effective communication. So humility is very important. – FG 2

Our participants recognized the moral responsibilities of geoscientists in discharging their duties during teamwork. To ensure ethical teamwork, geoscientists must understand that they are working with other individuals and clients who may have different functions, strengths and limitations. Hence, skills that ensure high moral responsibility such as trust, integrity and humility are essential for maintaining human relationships and communities. Our results are consistent with those of Mogk and Bruckner (2020), who considered geo-ethics important in promoting diversity in the field of geoscience, and with Harell and Daim (2009), who emphasized the importance of trust and integrity in information technology teams at the workplace.

2.8 Summary and Synthesis of Findings

Overall, our results align well with desirable teamwork competencies described by geoscience employers (Mosher & Keane, 2021). Mosher and Keane (2021) describe relevant skills and competencies within two constructs – teamwork and essential non-technical skills. Because our a priori coding scheme was derived from the Marks et al. (2001) framework, we place all of these competencies within teamwork skills. Mosher & Keane identified several teamwork competencies that did not emerge in our study, such as risk management and business acumen, having a global perspective, and being dependable. Conversely, the entire category of ethical skills was not captured by the Marks et al. (2001) framework but did emerge in our study and in the work of Mosher & Keane (2021). Based on this synthesis, we theorize that in
geoscience workforce teams, skills related to planning and evaluation of tasks, metacognitive and coordination skills, mentoring and coaching, and interpersonal skills related to emotional intelligence, communication, and ethics are essential for effective teamwork.

Table 3 Essential teamwork skills described in current study and other studies.

<table>
<thead>
<tr>
<th>Teamwork Process Skills</th>
<th>Identifying Teamwork Competency Skills</th>
<th>Marks et al., 2001</th>
<th>Mosher &amp; Keane, 2021</th>
<th>Present study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition Skills</td>
<td>Mission analysis; Goal specification; Strategy formulation; and planning</td>
<td>Goal setting</td>
<td>Business acumen; Risk management</td>
<td>Mission analysis; Identification of resources; Goal specification; Planning and Budgeting</td>
</tr>
<tr>
<td>Action Skills</td>
<td>Monitoring progress toward goals; Systems monitoring; Team monitoring and back up; Coordination</td>
<td>Metacognition; Coordination; Coaching; Identify and resolve problems as they arise</td>
<td>Having a global perspective (versatility)</td>
<td>Metacognition; Mentoring; Information synthesis; Coordination</td>
</tr>
<tr>
<td>Interpersonal Skills</td>
<td>Conflict management; Motivation and confidence building; Affect management</td>
<td>Lead or be a follower in a team; Manage conflict; Work effectively with diverse individuals</td>
<td>Emotional literacy: Communication; Time management</td>
<td>Emotional intelligence; Communication; Organization and time management</td>
</tr>
<tr>
<td>Ethics</td>
<td>--</td>
<td>--</td>
<td>Ethical awareness and conduct; Being responsible, dependable, and honest; Understanding and appreciating diversity, equity and inclusion</td>
<td>Trustworthiness; Integrity; Humility</td>
</tr>
</tbody>
</table>
2.9 Limitations and Future Work

A major limitation of this study is the small number of participants who are project managers from only one sector of the geosciences, though they included government, regulatory, private, and non-profit organizations. Hence, it is unclear how the findings can be generalized to geoscience organizations outside of hydrogeology and environmental geology, or to organizations where most work is done independently without teams. Furthermore, the nature of a focus group itself is a limit – it reflects the perceptions of the individuals who participated. Hence, we cannot generalize the findings to all hydrogeology or environmental geology employers everywhere. The alignment of our findings with those of Mosher & Keane (2021), who did include a wider range and greater number of geoscience employers, suggest that our findings may be broadly applicable.

To address these limitations and expand the findings from this study and given that students are supposed to be competent in the range of teamwork skills described by geoscience employers, future work should examine the perceptions of geoscience students regarding their familiarity with teamwork skills, and how they develop these skills during their education. For example, a comparative study that examines students’ teamwork skills and desirable geoscience workforce skills is needed.

2.10 Implications for Education

Findings from this study suggest several implications for geoscience education. As described by Myers and Goodboy (2005), simply allowing students to work as a team does not guarantee students’ development of teamwork skills. Again, Viskupic et al. (2020) identified that geoscience faculty report having students work in teams, but are those students actually learning
teamwork skills? Hence, we suggest that educators need to be intentional about teaching teamwork as a learnable skill.

Also, experiential learning that uses teamwork is known to promote students’ learning in STEM (Ferguson, Little, & McClelland, 2000; Lingard & Barkataki, 2011). We suggest that activities that employ experiential learning practices such as role-playing that uses teamwork skills identified by geoscience employers. We recommend the suggestion by Viskupic et al. (2020) that geoscience courses should include service-learning techniques that employs community-based projects involving teamwork among students. Again, we suggest that students engage in community or service-learning activities that encourage structured teamwork. For example, having students analyze and plan towards a learning task before applying skills that directly impact task completion. Dunne and Rawlings (2000) found that doing this improve student learning outcomes toward the learning goal.

We also argue that geoscience faculty should communicate the importance of teamwork skills to students. If students do not know how highly employers value these skills, they cannot work to develop them. Finally, ethics was highly emphasized by geoscience employers as important to both internal workforce activities and external relations, especially with clients. Hence, geoscience educators and departments should include workforce preparation strategies that teach geo-ethics to students (Mogk & Bruckner, 2020; Mosher & Keane, 2021). Finally, the result of this study also suggests an implication for professional geoscience organizations. Although we do not know the extent to which employers are already doing this, employers might consider sponsoring regular professional development for students, perhaps at major regional or national conferences, that give students the opportunity to practice workforce teamwork skills.
2.11 Conclusions

Training students to be competent in essential non-technical workforce skills continues to be a concern for both educators and employers in the geosciences. To be successful in the geoscience workforce, employers require competence in teamwork skills. In this study, we set out to describe the range of teamwork skills that a subset of employers in hydrogeology and environmental geoscience desire. We used focus group interviews to elicit ideas from these employers about what teamwork competencies are essential for working in environmental-focused geoscience firms. We further asked participants to explain what teamwork skills they would require of new hires before employing them. We then synthesized our findings with those of Mosher and Keane (2021) to produce a robust description of the skills that employers seek.

Having competence in task evaluation and planning (transition skills) such as the ability to set specific goals, share and delegate work, prepare a budget, identify resources needed to do the work and setting boundaries in and around the team are among the desirable teamwork skills identified. Employers also describe that geoscience workforce teamwork require competency in skills such as independent problem solving, self-drive and motivation, mentoring, coaching and teaching, analytical skills and coordination that directly impact team task accomplishment and goal attainment (action skills).

Our results also suggest that interpersonal skills that promote management of human resources during teamwork are very important to hydrogeology and environmental geology teams. Skills related to identifying team dynamics using emotional intelligence, proactive verbal and written communication and management of team technical activities such as note taking and
data collection, and time management were identified among the most desirable teamwork skills in geoscience industries.

Finally, our results further suggest that teamwork skills which promote ethical norms within geoscience teams are essential to the workforce. Geoscience employers desire competence with ethical skills such as trust and integrity that ensures truthfulness, probity and accountability, and respect for diversity, equity, and inclusion. Humility, defined in focus groups as allegiance to team success over individual success, was perceived as especially valuable for new hires or students wanting to enter the geoscience workforce.

As described in our theoretical framework and conceptual definition of teamwork, we provide compelling evidence that teamwork skills desired by environmental geoscience employers cuts across skills that help team members plan and evaluate the task, and skills that directly impacts task execution. Interpersonal and ethical skills that ensures collective efficacy, cohesiveness and moral standards within teams promote both team task planning, evaluation and execution. These results indicate a strong need for a focused teamwork development approach that teach students these skills.
References


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CHAPTER 3

DEVELOPMENT AND VALIDATION OF THE GEOSCIENCE TEAMWORK OBSERVATION PROTOCOL

3.1 Abstract

Teamwork experiences continue to be an important aspect of Science, Technology, Engineering and Mathematics (STEM) education. However, assessment of teamwork skills in the physical sciences such as Earth sciences, environmental sciences and ecology continues to be a challenge for researchers and educators. Researchers have bemoaned the lack of valid and reliable instruments that assesses teamwork skills in real-time. This study developed and validated the Geoscience Teamwork Observation (GTO) Protocol to assess teamwork skill dimensions related to transition, action and interpersonal team skills. The instrument was developed through four stages: review and selection of items to create the preliminary GTO, expert reviews to modify the instrument, pilot testing and modification of instrument, and creation and evaluation of the final GTO. The effectiveness of the final GTO was evaluated for validity and reliability by collecting data from two students’ team participating in a field course. Both teams were observed on three occasions lasting two hours each. The information collected in the GTO was triangulated with focus group discussions to establish validity and reliability. Evaluation results indicate that the GTO can measure the frequency of nine observable teamwork behaviors as they are demonstrated and provides a checklist of demonstrated skills in real-time.
Also, reflective focus group discussions validated the information collected by the GTO. The GTO provides a unique framework for identifying teamwork skills as they occur and allows a single observer to simultaneously assess multiple teamwork skills and behaviors.

3.2 Introduction

Current geoscience employers emphasize both field training and teamwork (Mosher & Keane, 2021). Also, these skills have been identified as important learning outcomes in academic geosciences and other historical sciences such as ecology (Alwin et al. 2020). In the geosciences, fieldwork normally occurs in teams (Streule & Craig, 2016), and most educators and researchers would agree that both fieldwork and teamwork skills are very important for students’ success and interests. For example, during fieldwork, students feel a sense of belonging and are exposed to how geoscientists relate (the geoscience culture) in the real world (Levine et al., 2007; Stokes et al., 2015; Streule & Craig, 2016). Stokes and Boyle (2009) found that allowing students to work in small teams during fieldwork promotes greater interaction and active learning. Marshal (2018) also found that geoscience students feel a sense of inclusion and a strong social connection in field activities when they work with peers in teams. Also, teamwork that takes place within a social context in the field provides learners with appropriate tools and assistance to participate in social construction of knowledge (Streule & Craig, 2016).

In order to help students gain the benefit of teamwork, several higher education institutions have developed methodologies for introducing teamwork in their laboratory and field courses including student peer teams, student-instructor teams and teams that involve students, instructors and professionals (Alwin et al. 2021; Viskupic et al. 2020). Educators are also aware that teamwork helps improve employee performance in the corporate environment (Beyerlein & Han, 2017). Hence, teamwork is a key learning outcome for several teachers (Viskupic et al.,
Giving the enormous educational and research efforts devoted to teamwork in the geosciences and ecology, there is an urgent need to advance strategies that measure how well teamwork interventions work.

However, assessing student teamwork is a complex task as there are many elements and constructs involved in the process. Researchers have pointed out a lack of valid and reliable instruments that capture the skills involved in teamwork processes during educational interventions (Britton et al. 2017). Also, Hobson et al. (2014) have suggested that development and usage of rubrics that effectively assess teamwork skills in research continues to be a problem. Without effective assessment strategies that assess the efficacy of teamwork interventions, it would be difficult to know whether students are developing and using teamwork skills.

This study establishes a valid and reliable observation protocol for assessing teamwork during geoscience fieldwork, which can be used to enhance teamwork and fieldwork experiences for students. As described by Stokes and Boyle (2009), direct observation of fieldwork can be daunting, but the strategy is very effective in providing valuable insights for the assessment of behaviors as they occur in real-time.

3.3 Literature Review

3.3.1 Issues of assessment

Assessment of teamwork continues to be a problem for researchers due to the lack of clearly defined dimensions and the difficulty in quantifying this multidimensional construct (Britton et al. 2017; Rousseau et al. 2006). For example, while some researchers describe teamwork dimensions to consist of self-regulation and affective behaviors, others consider it to consist of interpersonal behaviors. Again, many teamwork researchers do not build on existing
frameworks and extant literature. Rousseau et al. (2006) emphasize that this continues to create an unclear and complex conceptual framework in which to study teamwork. Also, the transition (team planning and evaluation) and action (direct processes that affect task completion) phases that characterize teamwork are often overlooked by researchers. This often masks the essential skills required for each phase of teamwork.

Although empirical evidence suggests that teamwork is important in students’ learning, assessing teamwork skill development and competency continues to be a problem for researchers. A major concern for educators and researchers is a lack of clear and concise assessment instruments (Hobson et al. 2015). Britton et al. (2017) and Wright et al. (2009) also attribute the lack of validated teamwork tools to the difficulty in identifying what constitutes effective teamwork performance. Also, most of the instruments measure individual teamwork behaviors or functions and ignore whole team interactions which is the main feature of teamwork (Weller et al. 2011). However, to effectively assess teamwork skills, Baker and Salas (1992) and Wiggins (1998) suggest that protocols that involve systematic observation and assessment of the construct as it happens in real time should be encouraged.

3.3.2 Teamwork assessment in higher education

Globally, current efforts to measure students’ teamwork have revolved around the use of observation protocols. Observations have focused on two main techniques: the use of quantitative assessments such as observation rating protocols, and qualitative assessments using field notes and interviews. In this literature review, we synthesize and compare these two approaches.
3.3.2.1 Quantitative assessments.

Several research studies on students’ teamwork assessment in higher education have utilized self and peer rating observation instruments. This strategy allows observers to rate specific teamwork skills defined in advance by the researchers (Seelandt et al. 2014). Observers usually rate each behavior using a scale and provide a total score for each participant. As emphasized by Ruiz and Adams (2004), and Varela and Mead (2018), the use of self and peer rating instruments provide quality information about specific teamwork dimensions as raters usually focus on desired and pre-defined dimensions. Again, raters scores are normally discussed, and interrater agreement helps provide reliable and valid score data (Weller et al. 2011). Thus Seelandt et al. (2014) suggest that this method of measuring teamwork provides the possibility to assess the process on the ground and to provide immediate feedback after the observation. For example, self and peer observation rating instruments such as the Team Effectiveness Questionnaire (TEQ) by Ruiz and Adams (2004), Team Up Rubric and the Team Q (Britton et al. 2017) have been used to assess teamwork interactions, interest, member contributions, team climate and conflict management among engineering students in the United States and college students in Canada.

However, this method of measuring teamwork using self and peer ratings can pose validity and reliability problems for researchers. For example, in assessing how teamwork functions among Spanish university students, Planas-Lladó et al. (2021) identified that students who rate themselves higher also rate their peers higher even if their teamwork functioning were low. As suggested by Seelandt et al. (2014), the complex and extensive processes of continuous assessment and mental integration of observations into quality judgement poses risks for individual biases. Again, the use of rating instruments does not capture other teamwork
dimensions that happen during the teamwork process. This has the potential of masking other important teamwork skills utilized by team members or unusual events that may be relevant to the study.

Furthermore, Hughes and Jones (2011) argue that teamwork assessment strategies that uses self and peer ratings are more likely to assess teamwork knowledge and ignore teamwork skills. Finally, most of these self and peer rating instruments measure individual team member characteristics and ignore whole team interactions. Teamwork is multidimensional and involves collaborative practices, hence any instrument that ignores whole team interactions is likely to mask and ignore the real processes that characterize teamwork (Marks et al., 2001; Thistlethwaite et al., 2016).

### 3.3.2.2 Qualitative assessments.

In the past few years, there has been a renewed interest in exploring events as they happen in real-time as researchers have become more aware of the importance of this strategy to capture knowledge and skills development. As emphasized by Nava et al., (2019) and Palmer et al., (2016), the most effective way to know what goes on during learning is by observing the behavior of students as lessons proceed. Participant observation is a research technique characterized by the effort of an investigator to gain entrance into a group to attain a comprehensive understanding of the internal structure of the group (Kawulich, 2005; DeWalt & DeWalt, 2002). As described by Evans (2012), this strategy allows the observer to focus in on what happens in any situation. For example, classroom participant observation and interviews with six focal students (main observation participants) revealed students actively construct knowledge and develop skills by appropriating various social tools such as teamwork (Park, 2011).
A major feature of participant observation is the collecting of data through field notes - a journal that contain participant observer’s written observations obtained through both formal and informal conversations. Field notes allow a diverse angle on the construct to be observed (Seelandt et al. 2014). Field notes are written in a structured format in the form of reflection essays as the observation proceeds to facilitate development of narratives that explain teamwork as it happens. The use of field notes is suitable when little is known about the construct and therefore, it is difficult to define categories in advance. However, Seelandt et al. (2014) caution that field note techniques should be used when there is ample understanding of what is to be observed so that important events are not overlooked or misinterpreted.

The use of participant observation and field notes have their own limitations. Critics of the method have emphasized the lack of clear description of data collection process as a result of how unstructured and complex the method is, and logistical issues including cost as limitations of participant observation (Nava et al. 2019). Also, the challenge of trying to capture behaviors as they happen in a social environment and making sense of the significance and meaning these behaviors makes participant observation and the use of field notes a complex venture (Evans, 2012). Furthermore, replicability of participant observer studies is challenging when the individual is part of the interpretation of events (Yin, 2018).

3.4 Theoretical Framework

Basically, teamwork involves two or more people (input) performing cognitive, behavioral, and interactive activities (process) in order to produce outcomes or products (output). In order to assess the teamwork skills that participants use during fieldwork; we adopt the input-process-output (IPO) taxonomy of teamwork theory by Marks et al. (2001) – see figure 2. They suggest that teamwork process consists of repetitive transition and action processes that happen
throughout a team’s task completion cycle. The theory explains that the teamwork process occurs in phases consisting of a transition phase where teams plan and evaluate their activities to complete a task. This phase of teamwork includes skills related to team task analysis, specifying goals and strategy formulation.

Similarly, the action phase involves teams directly converting their plans and strategies into active processes to complete a task. Marks et al. (2001) posit those skills needed at this phase of teamwork processes include systems and team monitoring, providing back up responses and coordinating whole team efforts. The third teamwork phase relates to interpersonal processes that promote team cohesiveness, affect management and team maintenance. The interpersonal skills needed to navigate this teamwork process phase include skills related to communication, empathy and conflict resolution. Although team transition phases and action phases may occur at different episodes, Marks et al. (2001) suggest that the interpersonal phase of teamwork can
occur within both transition and action phases. This means that interpersonal skills can be used to support both transition and action skills to achieve effective teamwork.

Fieldwork usually occurs as a series of multitasking modules. For example, during a day’s fieldwork task in a module, students would be required to complete several tasks such as collect water samples, perform chemical analysis, and write a report. This means that team members need to be working on a set of multitasks where transition and action processes occur in a series of episodes. During these episodes, output from transition processes serve as the input for team action processes, and the cycle repeats. Therefore, in understanding and developing instrument to effectively assess teamwork, we need to delineate the processes of teamwork as they occur under multitasking conditions (Marks et al. 2001).

Several studies have utilized the model by Marks et al. (2001) in developing instruments for assessing teamwork. Using the IPO model, Britton et al. (2017) developed the Team Up Rubric that assesses independent teamwork skills such as member contributions to teamwork, planning and management, team climate, and conflict management. Similarly, Varela and Mead (2018) and Weller et al. (2011) have used the model to develop instruments that assess teamwork behaviors, performance and functions.

3.5 Purpose of Study

From the literature, it is evident that both quantitative and qualitative teamwork assessments have proven to be useful in assessing teamwork in higher education. However, they both come with their respective limitations. Again, we were not able to find any examples of teamwork observation protocols designed for the geosciences.
Baker and Silas (1992) argue that understanding the dimensions and the behaviors that represent teamwork dimensions is critical in the development of teamwork measures as such information will dictate what is measured and evaluated. Therefore, based on Marks et al. (2001) taxonomy of teamwork skills – transition, action and interpersonal skills, and the essential teamwork skills required in geoscience (Nyarko & Petcovic, in review), we propose a structured observation protocol (Geoscience Teamwork Observation) that combines both quantitative (ratings) and qualitative (field notes) techniques to measure teamwork in STEM during fieldwork. The protocol assesses whole team behaviors in real-time activities that involve teamwork, and allows the evaluator to directly observe, rate and annotate the specific nature of teamwork skills utilized.

3.6 Methods

3.6.1 Development of geoscience teamwork observation (GTO) protocol

Development and validation of the GTO proceeded in four stages (figure 3). The first three stages describe the development stages of the protocol, and the final stage (4) describes the evaluation of the protocol for validity and reliability.
Figure 3 Development framework for Geoscience Teamwork Observation (GTO) protocol.

**Stage 1**

Teamwork skills described by employers as essential to the geosciences (Nyarko & Petcovic, in review) and the Marks et al. (2001) taxonomy of teamwork served as the basis for designing the observation protocol. In stage 1 of the instrument development process, we combined 23 items - thirteen essential teamwork skills described as essential by geoscience employers (Nyarko & Petcovic, in review) and ten teamwork skill dimensions described by Marks et al. (2001). Due to the similarity in the 23 skill dimensions, we consolidated and reduced the items to 11 skill dimensions to develop the preliminary GTO.

**Stage 2**

Stage 2 involved expert review of the preliminary GTO. The instrument was sent to qualitative and teamwork research experts, and field camp coordinators for content validation to ensure that our conceptualization and operationalization of the teamwork skill dimensions are
accurate. We also wanted to validate the teamwork constructs by finding from these experts their perspectives on the selected teamwork skills and whether these skills could be adequately measured. Overall, we received expert evaluation and review comments from a science educator and evaluator, a teamwork and leadership researcher, two fieldwork coordinators and one qualitative research expert.

Stage 3

Stage 3 involved three steps: modification of the preliminary GTO using expert reviews, pilot testing and further modification to GTO using pilot test analysis. The first step involved making modification to the GTO using the expert suggestions obtained in stage two. For example, expert reviewers contended that capturing emotional intelligence, honesty and metacognition through observation is a daunting task, hence, those were eliminated from the list of observable skills. The items on the preliminary GTO were thus reduced to nine teamwork skill categories. Table 4 describes the representative teamwork skills and their definitions.

Table 4 Representative teamwork skills and definitions.

<table>
<thead>
<tr>
<th>Teamwork Skills Category</th>
<th>Example</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition Skills: Skills that promote team task evaluation and planning.</td>
<td>Interpretation of team mission</td>
<td>Skills that ensure clear description of team task for members’ understanding and identify material resources that will be needed to complete the task.</td>
</tr>
<tr>
<td>Identification and prioritization of goals</td>
<td>Ability to identify specific goals required of the team and decide which goals to embark on a particular time. This is to ensure that all members are on the same page.</td>
<td></td>
</tr>
<tr>
<td>Planning</td>
<td>Skills that promote the establishment of tactical procedures and contingency measures to set team up for task completion activities. This includes budgeting, sharing of work and design.</td>
<td></td>
</tr>
<tr>
<td>Action Skills: Skills and Mentoring/Teaching</td>
<td>Skills that highlight mentoring, teaching and coaching such as providing feedback to a colleague, helping a colleague complete a task, and providing back-up response.</td>
<td></td>
</tr>
</tbody>
</table>
behaviors that
directly impact
task accomplishment

<table>
<thead>
<tr>
<th>Information synthesis</th>
<th>Ability to analyze, interpret information, and share information within the team. This includes skills related to data analysis, collection of accurate data and making sense of data.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordination</td>
<td>Skills that bring whole team ideas together such as taking ownership of team, accept and acknowledge the ideas of others, coordinating technical skills and inscriptions such as note and image taking.</td>
</tr>
<tr>
<td>Interpersonal Skills:</td>
<td>Communication Skills related to receiving and relaying information proactively including both oral and written forms.</td>
</tr>
<tr>
<td>Skills that promote</td>
<td>Organizational management Personal organization skills and the ability to influence team organization and time management</td>
</tr>
<tr>
<td>management of human</td>
<td>Leadership Individual or whole team characteristics that influences the daily functioning of the team to achieve a common goal.</td>
</tr>
<tr>
<td>resource interactions</td>
<td></td>
</tr>
<tr>
<td>that occur within</td>
<td></td>
</tr>
<tr>
<td>teams</td>
<td></td>
</tr>
</tbody>
</table>

In the second step in stage 3, the first author pilot tested the preliminary GTO in the first week of a hydrogeology field course located at a mid-sized university in the Midwest United States, attended by undergraduate students, graduate students, and working professionals. The aim of the pilot test was to investigate if the protocol would effectively capture the set of predefined skills and other teamwork skills not included in the protocol. Again, the pilot test offered the researcher an opportunity to assess their own experiences with the observation protocol. During the pilot test, two teams were observed by the researcher on two different days for about five hours each as they worked in the field. Each of the two teams participated in different teamwork activities related to geophysical investigations and analysis that involved using the Geonics EM 31 electromagnetic to map average variations of electrical conductivity on 50 feet by 50 feet area. During the observation, observed teamwork skills were marked as ‘yes’ and the particular activity related to the skill was annotated (Figure 4).
Analysis of pilot test data suggested that the GTO is valid for assessing students’ teamwork during fieldwork. All nine teamwork skill categories were exhibited by both teams at some point during field activities as confirmed by annotations from the protocol and researcher’s field notes. For example, “members discuss how to measure their site area” and “members discuss how to use the EM 31 equipment” were considered as skills relating to team mission analysis. Also, evaluation was identified as a major common theme that was not included as a teamwork category during pilot testing. Students will usually evaluate their approaches to completing a task such as switching team members to work on tasks, re-evaluating their report and making contingency plans.

In step 3, the findings from the pilot test and the researcher’s experiences collected in field notes were discussed with research associates, and changes were made to create the final GTO (Figure 5). Some changes included the removal of the “yes” and “no” rows and replacing...
them with a Likert scale. Because teamwork skills are used repeatedly and continuously, a Likert scale was included to rate the frequency at which each skill category is utilized or exhibited by the teams. The Likert scale ranged from 0 (teamwork skill never occurred), 1 (rarely – teamwork skill behavior occurs just once), 2 (occasionally – occur more than once but less than four times), 3 (frequently – occur about four times but less than ten times), and 4 (always – occur more than ten times). Also, the section for annotation of exhibited teamwork skills was changed into field note section for documenting the teamwork skills that reflect the categories. However, the evaluation skill category was not included as part of the final GTO but included in the description of planning skills. Thus, the final GTO (Figure 5) is made up of three transition skill items, three action skill items and three interpersonal skill items.

### THE GEOSCIENCE TEAMWORK OBSERVATION PROTOCOL

<table>
<thead>
<tr>
<th>Interpretation of team mission or task, and resources</th>
<th>Identification and Prioritization of goals</th>
<th>Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 2. 3. 4.</td>
<td>1. 2. 3. 4.</td>
<td>1. 2. 3. 4.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mentor, Train and Coach</th>
<th>Information synthesis</th>
<th>Coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 2. 3. 4.</td>
<td>1. 2. 3. 4.</td>
<td>1. 2. 3. 4.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication</th>
<th>Organizational and Time management</th>
<th>Leadership</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 2. 3. 4.</td>
<td>1. 2. 3. 4.</td>
<td>1. 2. 3. 4.</td>
</tr>
</tbody>
</table>

Figure 5 The final Geoscience Teamwork Observation (GTO) protocol.
Stage 4

The final stage involved evaluation of the GTO for validation and reliability using a convenience sample of two student teams taking part in the hydrogeology field course. These teams were different to those we used in stage three. The field course used in the study is a series of six one-week modules taught six days per week. The modules observed for the study included geophysical investigations and Hazardous Waste Operations and Emergency Response (HAZWOPER) training. Students were provided minimal lecture every morning of the weekly module to support field exercises or demonstrations. The main instructional and learning strategies were problem-based and collaborative learning where students solve hydrogeology problems in teams. Although students worked in teams during fieldwork, they received no overt instruction on teamwork. About 50 percent of students’ grade was based on whole team field performance.

3.6.2 Participants

The participants for the study evaluation in stage four were a convenience sample of 10 geoscience students, from different geoscience programs and professional backgrounds across the United States. After receiving consent from each student, the students were placed in two teams of five members each by the field camp coordinator. Participants included members from the stage three pilot study, but they worked in teams different from those in the pilot study. Table 5 provides the characteristics of participants.

Table 5 Demographic characteristics of participants.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Team P1</th>
<th>Team P2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female: 2; Male: 3</td>
<td>Female: 2; Male: 3</td>
</tr>
<tr>
<td>Age (Range; Mean) Years</td>
<td>21 – 26; 22</td>
<td>23 – 27; 24</td>
</tr>
<tr>
<td></td>
<td>Asian: 1</td>
<td>White Caucasian: 5</td>
</tr>
<tr>
<td>Race/Ethnicity</td>
<td>White Caucasian: 4</td>
<td>Undergraduate Student: 1</td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Level of Education</td>
<td>Undergraduate student: 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Completed Undergraduate: 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Graduate student: 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Working Professional: 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Completed Undergraduate: 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Graduate student: 1</td>
<td></td>
</tr>
</tbody>
</table>

### 3.6.3 Data collection

I collected data using the GTO through structured participant observation (Emerson, 2011). Students had already been informed of my role during course orientation and they were familiar with me during data collection. To reduce the impact that participant observer role will have on student behaviors, the field course coordinator assured them that I will only be a visiting member of the teams to observe how they work as a group. Again, they were made aware that my participation in their activities will not affect their grades or performance in the course.

Each team was observed for a week during periods when they engaged in teamwork. Overall, six field activities (n = 3 observations per team) that involved independent teamwork were observed. Each team observation was normalized to two hours. At the beginning of observation, I the participant observer reiterated my role to the team members and joined them as a visiting member. During participant observation, information about the observation and team such as date and time of observation, team number/name and number of team members present were first collected and recorded. After this information had been collected, the I then began monitoring student teamwork skill behaviors as they worked on a task. Each teamwork skill observed was annotated in the portion for fieldnotes under the teamwork category. Field notes were very structured and when a particular description occurred more than once, it was assigned a number instead of writing it again in the field note section. For example, when members demonstrated skills related to verbal communication three times in the same observation session,
it was annotated as “members communicate verbally 1 2 3”. After each observation, the number of times each skill category was demonstrated was counted and rated using the Likert scale. An example of the GTO with collected data is shown in figure 6.
Figure 6 GTO showing recorded field information and ratings of demonstrated teamwork skills.
3.6.4 Data analysis

For the purposes of stage 4 (assessing the validity and reliability), the frequency data were simply compiled and tallied using SPSS 24. Also, all field note annotations representing exhibited teamwork skill description were coded using *a priori* codes and compiled in QSR Nvivo 12. For example, demonstration of skill such as “members listen attentively as colleagues make inputs” were coded under communication.

3.6.5 Results

The GTO was useful in recording teamwork skills utilized by participants that cut across all the nine categories of skills. Table 6 provides examples of some of the behaviors observed and annotated in the GTO protocol as observer’s field notes.

Table 6 Teamwork skill categories and example of demonstrated behaviors recorded in GTO.

<table>
<thead>
<tr>
<th>Interpretation of team mission or task, and resources</th>
<th>Identification and Prioritization of goals</th>
<th>Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Members discuss what is expected of them on the task</td>
<td>Members identify the goals of the task and select which ones to complete at what time.</td>
<td>Members identify their strength and decide on the goals they can contribute most to the task and delegate task.</td>
</tr>
<tr>
<td>Members discuss the task and make a list of resources they will need to complete the task.</td>
<td>Members discuss fieldwork manual and make decisions on what to submit to instructor.</td>
<td>Members discuss how they will collect data, conduct and complete their analysis. Members discuss and monitor the progress of the team.</td>
</tr>
<tr>
<td>Members regroup to discuss and review their responses to the task.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Mentor, Train and Coach**

<table>
<thead>
<tr>
<th>Information synthesis</th>
<th>Coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Members ask questions and get feedback from colleagues.</td>
<td>Members continuously discuss their data (log data, well data, etc.) as they go on with their work.</td>
</tr>
<tr>
<td>Members teach colleagues about how to use equipment.</td>
<td>Members interpret provided information together and make connections.</td>
</tr>
<tr>
<td>Members demonstrate to colleagues how to perform field activities such as sampling and logging.</td>
<td></td>
</tr>
</tbody>
</table>
Again, the GTO protocol measured the frequency with which teams demonstrated teamwork skills. We counted the rate of skill demonstration per observation task. Observation task describes the number of hours spent on a day’s task. Each observation task lasted for approximately two hours. To identify the counts, each annotated field note that describe demonstrated teamwork skills were counted in relation to the observation task and rated as rarely, occasionally, frequently or always (table 7). For example, we were able to identify that both teams demonstrated communication, coordination and leadership more than goal specification and organizational management.

Table 7 Ratings of demonstrated teamwork skills for teams per two hours of observation.

<table>
<thead>
<tr>
<th>Teamwork Skills Category</th>
<th>Team P1 (N=5 members)</th>
<th>Team P2 (N=5 members)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observation 1</td>
<td>Observation 2</td>
</tr>
<tr>
<td>Interpretation of team mission</td>
<td>O</td>
<td>F</td>
</tr>
<tr>
<td>Goal specification</td>
<td>O</td>
<td>R</td>
</tr>
<tr>
<td>Planning</td>
<td>O</td>
<td>F</td>
</tr>
<tr>
<td>Mentoring/Teaching</td>
<td>F</td>
<td>O</td>
</tr>
</tbody>
</table>
3.7 Establishing Validity and Reliability of GTO

We treated validity and reliability as the credibility and confirmability of our data respectively (Merriam & Tisdell, 2016; Creswell, 2003). We ensured credibility through persistent observation and member checking. The participant observer spent prolonged time in the field with the students and engaged and participated in students’ teamwork activities. This enabled us to obtain an in-depth understanding of teamwork and provides credibility to the account provided in the GTO during participant observation. As described by Creswell, (2003) and Fetterman (1989) spending long periods of time with participants just as we did provide validity to our data consistent with ethnographic participant observation.

Again, at the end of each observation week, team members participated in reflective focus group interviews – discussions based on what has been observed. This reflective focus group was done as part of the process to validate the GTO through member verification and corroboration. Before the start of each focus group, I wrote a list of all teamwork skill categories observed and their ratings on a white marker board and provided participants the opportunity to elaborate and corroborate. Each focus group discussion had different set of questions. For example, during Team P1 focus group discussion, I asked: “communication was very frequent in this group, do you agree or disagree with me on that? How was this skill useful or not useful to you as a team?”. Similarly, Team P2 members were asked: “identifying and specifying task goals

Table 7 – continued

<table>
<thead>
<tr>
<th>Information synthesis</th>
<th>O</th>
<th>R</th>
<th>R</th>
<th>O</th>
<th>O</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordination</td>
<td>A</td>
<td>F</td>
<td>A</td>
<td>F</td>
<td>A</td>
<td>O</td>
</tr>
<tr>
<td>Communication</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>F</td>
</tr>
<tr>
<td>Organization management</td>
<td>F</td>
<td>R</td>
<td>F</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Leadership</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>O</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

* R – rarely; O – occasionally; F – frequently; A – always.
is something that was rare in this team. Do you agree or disagree? How was this skill useful or not useful to you?"

All focus group discussions were audio recorded and automatically transcribed via WebEx. We then compiled codes that represent each category to explain the observed teamwork skills in the GTO. Results of reflective focus group interviews validated our GTO data. For example, both teams agreed that they had demonstrated high rates of communication and low rates of skills related to goal identification and specification.

Yes, goal identification was low in our team. Well, it was writing a report on drilling equipment, drilling fluids and how do you develop a well, so we already know the goal from the activity. So, our goal is to identify the work and what we are going to use for that work. So, we already know that this is the goal that is why we did not talk about it – Team P2

There is a lot of openness for that communication. We have a meeting where we can text and send message to every member. And if we have a question, and if we are not physically together the first is to send it out and whoever receives it gives feedback or the answer just keep coming – Team P1

To measure reliability, we engaged in inter-coder agreement between authors and an external associate familiar with qualitative coding. The first author created a priori codes using our theoretical framework (Marks et al. 2001) and then the authors and a research associate applied the codes to the two focus group transcripts. Inter-coder agreement (a measure of the percentage of identical coded text passages between the three coders) was 81% and 87% on two different transcripts between the authors, and 84% between the first author and the external
research associate. All inter-coder values are higher than Miles and Huberman (1994) accepted range of 80%. Again, the authors and research associate discussed and resolved all disagreements.

Data from the field-testing provide initial evidence of the validity and reliability of the GTO in assessing specific teamwork skills development during fieldwork, and the frequency with which these skills are demonstrated. The instrument was able to capture teamwork skills as they are used in real time during multitasking by teams.

**3.8 Limitations and Future Research**

A major limitation of this study is the lack of inter-rater assessment by the authors. Although both authors agreed on the value of Likert ratings, only one author participated in data collection. We suggest a further assessment of reliability and validity through inter-rater assessment to establish the reliability and validity of the GTO. Also, the GTO assesses only nine teamwork skills as compared to the several teamwork skill dimensions identified in the literature. This has the potential to mask other teamwork skills which are not in the GTO. We suggest that future research includes other spaces on the GTO to observe extra teamwork skills that might be demonstrated by participants.

Furthermore, we developed and tested the GTO in one context of geoscience field work - a hydrogeology field camp in a Midwestern university. Although our participants came from different educational backgrounds and schools, we believe that students from other institutions in a different field camp may behave differently. Hence, we suggest that the GTO is used in other educational settings and field camps such as field mapping and exploration. It will also be interesting to know how the GTO will perform in short fieldwork activities such as short field trips, and in classroom and laboratory activities that involve teamwork.
A final limitation is that the GTO measures the frequency with which teams demonstrate usage of specific skills. It does not, however, evaluate the competence with which teams use these skills. It is possible that a team could frequently use a particular skill but use it poorly or well. Future expansion of the GTO could include a mechanism to evaluate the quality of teamwork skills observed; at present, that evaluation is up to the observer to judge.

3.9 Uses and Applications

The GTO is a qualitatively reliable assessment instrument that has been validated by experts and through reflective focus group discussions and members checks. Consistent with other instruments, the GTO can assess teamwork skills demonstrated by students in the classroom, laboratory and the field. Hence, the instrument can be used as a research instrument for investigating teamwork in the field, classroom and laboratory settings. In addition, an instructor can use the instrument as a peer-assessment tool for assessing teamwork learning outcomes. An instructor can have student teams annotate and rate the frequency of demonstrated teamwork skills identified as learning outcomes. This will work well during authentic activities where students are allowed to work on a task independently as a team.

3.10 Conclusion

The study describes the development of the Geoscience Teamwork Observation Protocol (GTO) to measure real-time demonstration of teamwork skills during fieldwork. The instrument consists of nine teamwork skill dimensions taken from Nyarko and Petcovic’s (in review) geoscience essential teamwork skills and Marks et al. (2001) taxonomy of teamwork skills model. A major goal in the development of the GTO is to make available to geoscience educators and researchers an observation instrument that measures the frequency in which the whole team engages in a particular skill, and then qualitatively allows the researcher to record
what was going on. The instrument was field-tested during a hydrogeology field camp attended by students and professionals.

Our findings suggest that the GTO provides a practical and comprehensive assessment protocol for observing teamwork during fieldwork. The GTO can capture teamwork skills and demonstrated behaviors related to all three teamwork processes – transition, action and interpersonal skills. Ratings for the frequency of demonstrated skills provides an avenue to evaluate both the nature of teamwork skills exhibited by teams and how frequent they use these skills during team task completion.

In summary, the development of the GTO tries to bridge the gaps in the literature in three main ways. First, researchers bemoan a lack of clear and concise assessment frameworks that measures teamwork skill development (Hobson et al. 2015; Rousseau et al. 2006). The GTO provides a unique framework for identifying essential teamwork skills development and quantifying the rate at which these skills are been utilized or demonstrated. The literature also points to a lack of validated teamwork tools to identify what constitutes effective teamwork behaviors (Britton et al. 2017; Wright et al. 2009). The GTO can be systematically used to observe and assess teamwork behaviors as they happen in real time. Finally, most of the instruments identified in the literature measure individual teamwork behaviors and ignore whole team behaviors (Weller et al. 2011). However, the GTO allows a single observer to simultaneously assess multiple teamwork skills and behaviors. Finally, the instrument is useful in assessing teamwork in multitasking environments such as when students are working on a series of tasks.
References


Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis: An expanded source


CHAPTER 4

DO STUDENTS DEVELOP TEAMWORK SKILLS DURING GEOSCIENCE FIELDWORK?
A CASE STUDY OF A HYDROGEOLOGY FIELD CAMP

4.1 Abstract

Teamwork has been identified as an essential employability skill and learning outcome in the geosciences, especially during fieldwork. However, information relating to how students develop teamwork skills during their educational preparation is scant in the Science, Technology, Engineering and Mathematic (STEM) literature, including the geosciences. In this paper, we use a descriptive, qualitative embedded, single-case study to explore how geoscience students develop teamwork skills during a hydrogeology field camp through the lenses of input-process-output taxonomy of teamwork skills. We collected data using the Geoscience Teamwork Observation (GTO) protocol and triangulated against focus group discussions held after each week of team observations. Key emerging teamwork skills demonstrated by students included communication, leadership, peer-mentoring and teaching, and coordination. Skills related to goal identification, information synthesis and organizational management were utilized least often by student teams. Participants described the positive role of these skills in hydrogeology fieldwork. This paper provides first-time information on students’ teamwork skills development in the geosciences. We also provide a shared approach for evaluating teamwork skills to enhance workforce preparation and draw attention to key issue relating to creating effective teamwork outcomes during fieldwork.
4.2 Introduction

Fieldwork continues to be a major cornerstone for the geosciences and other historical sciences such as ecology (Alwin et al. 2020; Mosher & Keane, 2021). Employer and education expectations place great store on the importance of fieldwork experiences (Butler, 2008; Mosher & Keane, 2021). For employers, having employees with technical expertise combined with field experiences enhance internal communication and understanding (Butler, 2008; Katzenbach & Smith, 1993). Also, research attests to the positive impact of field education on students’ learning and interest in geoscience. Fieldwork provides students the opportunity to authentically synthesize previously obtained theoretical knowledge to develop a deeper understanding of geological processes (Boyle et al., 2007; Butler, 2008). Fieldwork, apart from its cognitive benefits, also provides students the opportunity to develop essential professional skills, learn the habits of geoscience practices, and helps them transform abstract concepts into reality through purposeful immersion (Fleischner et al., 2017; Mogk & Goodwin, 2012; Petcovic et al., 2014; Petcovic et al. 2020; Wall & Speake, 2012). Boyle et al. (2007) further suggest that fieldwork is an effective social educational strategy to break student-teacher barriers and motivate student metacognition.

In the geosciences, fieldwork has been identified as “a great way to enhance social learning and teamwork skills” (Butler, 2008, p.10). Due to the perceived benefits of fieldwork in skills development, several geoscience and ecology field education pedagogies and competency outcomes involve teamwork (Alwin et al. 2020; Viskupic et al., 2020). Similarly, students anticipate that fieldwork will provide them an authentic setting to learn key teamwork skills such as communication, time management and problem solving (Alwin et al. 2020; Boyle et al., 2007). Again, students’ team led fieldwork designs have been found to positively influence their
development of transferable skills (Peasland et al. 2019). This means that fieldwork that incorporates teamwork can be used to promote students’ personal development and efficiency.

Also, recent educational teamwork research has emphasized the productive role of teamwork in college and university students’ learning, and the skills required to create effective teams (Vance et al., 2015; Volkov and Volkov, 2015; Wilson et al., 2018). Volkov and Volkov (2015) found that use of team-based assessments allow students to engage in critical thinking and provide avenues to develop collaborative skills, appreciate the benefits of team unity and cultural diversity to learning. Teamwork has also been identified to promote students’ self-learning with less demands on teacher time (Riebe et al. 2016). Similarly, students perceive teamwork skills as essential to their future professional careers, and that developing teamwork skills will add value to their workforce opportunities (Vance et al., 2015; Wilson et al., 2018).

However, Myers and Goodboy (2005) have argued that simply allowing students to work as a team does not guarantee students’ teamwork skills development. Alwin et al. (2020) assert that relatively few field education courses and camps teach teamwork skills during fieldwork. Similarly, Dunne & Rawlins (2000), and Matusovich et al. (2012) found that most teachers do not integrate teamwork skills in their instruction and courses. Again, educational research on teamwork overly focusses on the benefits of the construct to learning, but do not investigate how students develop teamwork skills while going through their education. In this study, we consider these issues in the context of geoscience fieldwork. Through participant observation using the Geoscience Teamwork Observation (GTO) protocol (Nyarko & Petcovic, in preparation A) and focus group interviews, we document the teamwork skills used by geoscience students participating in a hydrogeology field course.
4.3 Literature Review

4.3.1 Teamwork

Teamwork involves orchestration of members’ interdependent activities directed toward organizing and completing taskwork to achieve collaborative success (Marks et al. 2001). Team effectiveness and success are highly dependent on both individual and whole team characteristics at play during teamwork. As argued by Adair (2009), both individual and group work need individual traits such as passion and/or whole team processes such as collective motivation and team goals in order to perform. This means that individual and/or whole team skills are important drivers for team performance. Having effective teamwork skills is important as teams bring together pool of experiences and knowledge base, which cannot be embodied in an individual.

Teamwork skills are the cognitive, verbal, and interactional behaviors that team members use to orchestrate their task environment to convert input to outcomes (Marks et al. 2001). In the geosciences stakeholders have emphasized the importance of effective teamwork skills to both industrial and academic needs (Mosher & Keane, 2021; Nyarko & Petcovic, in review; Viskupic et al. 2020). Skills such as mission analysis, identification of resources, goal specification, planning and budgeting have been identified for effective team planning and evaluation processes in environmental geology and hydrogeology (Nyarko & Petcovic, in review). Similarly, skills such as metacognition, peer mentoring/teaching, information synthesis, coordination and versatility are important for task completion (Mosher & Keane, 2021; Nyarko & Petcovic, in review). Geoscience employers have also reiterated that skills related to communication, management, emotional intelligence, leadership and ethics are important for effective teams.
4.3.2 Fieldwork and skills development

Fieldwork is a component of education that involves taking students out of the classroom to the natural environment for them to learn through first-hand experiences (Boyle et al. 2007). During fieldwork, learning takes place in a situated context and learning activities promote collaboration and interaction between students, instructors and professionals (Petcovic et al., 2020). Gold et al. (1991) and Petcovic et al. (2020) provide two ways through which fieldwork can contribute to learning outcomes. First, fieldwork can take the form of field trips where students are shown geologic phenomena or settings to gain both visual and embodied perspectives of that phenomena or setting. Second, field courses allow students to take part in fieldwork activities over multiple days with the goal of learning and practicing specific field skills or techniques. Field courses can take the form of problem-based fieldwork where students are tasked to solve problems by collecting and analyzing data, or residential and non-residential field camps which integrate both field knowledge and skills.

However, regardless of the form of fieldwork utilized, the common aim is to promote experiential learning and the development of skills related to the particular field. This means that fieldwork offers students the opportunity to learn through purposeful immersion, and the development of transferable and generic skills such as teamwork, metacognition, and the habits of the profession (Mogk & Goodwin, 2012; Petcovic et al., 2014; Petcovic et al., 2020; Streule and Craig, 2016; Wall and Speake, 2012). Despite the benefits of fieldwork in skills development, limitations related to equity and inclusion such as cost, lack of resources for disabled students, and inadequate orientation for students resulting in anxiety continue to exist (Boyle et al. 2007; Stokes et al. 2019).
Fieldwork provides several potential avenues for skill development in student preparation. Peasland et al. (2019) broadly categorize the skills developed through fieldwork into technical, personal development skills and transferable skills. Technical skills refer to subject specific content knowledge and skills such as learning to map or how to use geologic tools such as compass. Personal development skills refer to interpersonal and affective skills such as self-management and confidence building. Transferable skills are skills that can be employed in different disciplines, and includes teamwork, leadership, project management, problem solving and applying theoretical knowledge.

4.4 Purpose of Study

Despite the propensity of evidence supporting students’ development of technical skills and personal development through fieldwork (Boyle et al. 2007; Petcovic & Stokes, 2014; Petcovic et al. 2020; Rowland, 2000; Reynolds et al. 2006), research related to transferable and soft skills development such as teamwork remain scant in the geosciences. Also, teamwork skills gained through fieldwork have become particularly important considering the future of undergraduate geoscience education report (Mosher & Keane, 2021). The report emphasizes fieldwork and teamwork as important for both student learning and workforce employability.

One way that geoscience education has prepared students in teamwork skills is through fieldwork that incorporates peer-to-peer work. Yet, researchers have not investigated if students develop teamwork skills during fieldwork. Hence, it has become important that we identify the teamwork skills that students develop as they engage in fieldwork activities in order to bring to the fore the opportunities provided by fieldwork for students’ skill development. We employ a qualitative, embedded single-case study to answer the research question: How do teamwork skills develop among students during geoscience fieldwork?
4.5 Theoretical Framework

The theoretical foundation for this study is embedded in the input-process-output (IPO) taxonomy of teamwork skills model by Marks et al. (2001). The model suggests that teamwork involves an input (two or more people) – performing process (performing cognitive, behavioral, and interactive activities) – to create output (produce outcomes). In this study, we are interested in the team process skills that team members use to accomplish a task (figure 7).

Figure 7 Conceptualization of teamwork in the Input-Process-Output (IPO) model (Nyarko & Petcovic, in review).

The model presented by Marks et al. present an important framework for assessing teamwork that involves functional teams (problem-solving teams). They share that within functional teams, teamwork involves repetitive phases of team transition (planning and evaluation) and action (directly working on task completion) processes. During these phases, outputs from transition processes can become inputs for action processes. Similarly, outputs from action processes can become inputs for transition processes. Also, both transition and action
processes are supplemented by interpersonal processes (management of team conflicts and affective processes) to ensure team cohesion.

The case study seeks to draw attention to the teamwork skills developed by a team of geoscience students during fieldwork. In our case study, all the teams involved in the fieldwork are functional teams - defined as three or more individuals who combine their expertise and work interdependently to solve a common problem of which they are mutually accountable (Marks et al. 2001). For example, in a single day’s activity, teams can be asked to complete several problems involving drilling a well, collect well log data and samples at the same time. Hence, to effectively study teamwork processes under functional team conditions, the Marks et al. (2001) taxonomy of teamwork theory provides for an appropriate framework.

4.6 Methodology

4.6.1 Research design

This study uses a descriptive, qualitative embedded, single case study design (Yin, 2018) – single case unit with embedded sub-units to explore the teamwork skills that students develop and the real-life context in which these teamwork skills are utilized. According to Yin (2018), case study is a constructivist methodology for exploring social construction of reality, hence, to explore students’ teamwork development, a case study is appropriate. We followed Yin’s (2018) three recommendations in selecting case study as our design: study focus, control over participants, and contextual conditions and boundaries.

First, the focus of our study is to explore how teamwork develops among geoscience student teams during fieldwork. To explore “how” a skill is developed or demonstrated, Yin (2018) recommend the use of case study as it allows such skills to be probed within a particular context. Next, Yin (2018) suggests that a case study approach is appropriate to investigate events
as they happen when the researcher does not have any control over participants. In this study, there is no manipulation of participants. Finally, the contextual conditions under which teamwork is happening were factored because they are relevant to the phenomenon under study (i.e., students work in teams during the fieldwork, but they receive no explicit instruction on teamwork).

4.6.2 Case definition and boundaries

The case is defined as teamwork skills used by student teams during the third week of a six-week summer hydrogeology field program. In addition to this case, we also collected data about two other sub-cases – Team Ruby and Team Mica student teams during the fourth and fifth weeks of the summer program, respectively. Following Yin (2018), the case is bound by the independent teamwork activities of the three targeted student teams that includes activities during fieldwork, and group meetings. Group meeting is integral part of teamwork hence, its inclusion. In this study, we use single case examination, but we also undertook a combination of sub-case comparisons in our analysis to explore teamwork skill development.

4.6.3 Context

Hydrogeology Field Camp (HFC)

The HFC is a non-residential camp based out of a university in the upper Midwestern United States. It consists of six independent, one-week hydrogeology modules taught six days per week (Monday through Saturday from 8 a.m. each day and often run into the evening). The course involves state-of-the-art techniques for sampling, monitoring and evaluating groundwater systems with particular attention to contaminated systems, aquifer testing and selected geophysical techniques. Students are provided with hands-on field experience using modern field technologies and minimal lecture to support field exercises or demonstrations.
All six modules in the course begin with traditional lectures taught by faculty or an invited speaker in the classroom, followed by students’ interdependent work in teams in the field. The main instructional and learning strategies are problem-based and collaborative learning where students solve hydrogeology problems in teams. The majority of the fieldwork tasks involve scientific inquiry under real world conditions. For example, all six-week modules use real world problems such as geophysical investigations at a city park, well drilling, conducting physical and chemical analysis of well and surface water, pumping test analysis, and designing safety protocols. Students are graded based on whole team field performance, written reports, teamwork abilities and individual written final exams.

Student teams consist of five members each and students are assigned to teams by the field course coordinator. Most of the field activities provide student teams the autonomy to conduct their own inquiry with little to no instruction from teachers. Also, other complementary activities such as driving to field site, and selection and carrying of field equipment are responsibilities left to team members. After completing their inquiry, teams put together a weekly report submitted for a grade. The teams had no overt instruction in teamwork but were required to work collaboratively by drawing on the strengths of each member, and identify, analyze and resolve ethical issues.

**Team Opal – Main Case**

Team Opal consisted of five students (3 males and 2 females) who have worked together for one week in a different module before the observation. The team was observed during week three, a course module on principles and practices of well drilling and installation. The team was assigned tasks that involved conducting and supervising drilling operations and well
installations, solving problems encountered during fieldwork, providing a report on sampling, and generating logs through observations and analysis.

We observed Team Opal six times during field activities and group meetings totaling about 23 hours. However, two of the field observations involved team seminars with experts in the field so they were eliminated from data analysis as we wanted to analyze data that involved independent student work. The four observed teamwork contexts involved core logging at a geology observatory, hand-auger well drilling, well sampling and final group meeting for report writing and discussions. Each observation lasted for approximately four hours. Teamwork accounted for 50% of students’ final grades during this week’s module.

Team Ruby – Embedded Case

Team Ruby had five members that included three male and two female students. Team members had worked together for a week prior to observation. No member of this team had been previously observed as part of the earlier team. We observed Team Ruby four times during fieldwork and group meetings for about 19 hours. One of the observations included a combination of students’ teamwork and instructor demonstrations so we excluded this observation from analysis. Hence, the contexts for this sub-case included well location and gauging, surveying, bailing and purging; well sample collection and chemical analysis of collected samples; and a group meeting for report writing and discussions. Each observation lasted approximately four hours. Students’ teamwork accounted for 40% of the overall course grade.

Team Mica – Embedded Case

Like all the teams, Team Mica consisted of five members with two females and three male students and have worked together on a previous module for a week. Again, no member of this
team had been previously observed as part of the earlier teams. Team observation took place during the fifth week of the HFC. Their assigned tasks involved conducting and analyzing multi-well pumping tests that include slug, pneumatic and step-drawdown tests, data analysis using AQTESOLV (a software for analyzing aquifer data) and report writing and discussions meeting. We observed this team four times for approximately four hours each per session except for observation three (babysitting wells to collect pump test data) which lasted for about seven hours. However, this was normalized to four hours for analysis purposes.

4.6.4 Participants

The participants for the study consisted of undergraduate students, graduate students, and working professionals participating in the summer hydrogeology field course. About 26% of the students came from the host university offering the field course and the rest mainly from other institutions in the US. In accordance with the study’s human subjects and institutional review board (HSIRB) protocol, all participants of the field course were invited to participate in the study during an orientation process for the program. In all, 18 students consented to participate in the study. However, the course uses teams of five members, so 15 were placed into three groups of five students per group. Table 8 provides the demographic information of the 15 participants that were selected for the case study. Each of the teams had worked together for at least a week before being observed, and there was no rotation of participants between teams.

Table 8 Demographics of participants.

<table>
<thead>
<tr>
<th>Team Demographics</th>
<th>Team Opal (n=5)</th>
<th>Team Ruby (n=5)</th>
<th>Team Mica (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Female: 2; Male: 3</td>
<td>Female: 2; Male: 3</td>
<td>Female: 1; Male: 3; Non-Binary/Third gender: 1</td>
</tr>
<tr>
<td>Age (Range; Mean) Years</td>
<td>21 – 27; 24</td>
<td>21 – 38; 27</td>
<td>21 – 24; 22</td>
</tr>
</tbody>
</table>
4.6.5 Instrumentation

The research uses two main sources of data: The Geoscience Teamwork Observation protocol and focus group interviews.

**The Geoscience Teamwork Observation (GTO) Protocol**

We collected information on teamwork skills that students utilize to complete their tasks and the frequency of demonstrated teamwork skill using the Geoscience Teamwork Observation (GTO) protocol developed by Nyarko and Petcovic (in preparation A). The protocol allows for the collection of both field annotations of demonstrated teamwork skill and the frequency at which the skills occur during teamwork. The protocol uses nine teamwork skill dimensions from Marks et al. (2001) and Nyarko and Petcovic (in review). These include team transition skills such as interpretation of team mission - skills that ensure clear description of team task for members’ understanding and identify material resources that will be needed to complete the task; goal specification - ability to identify specific goals required of the team and decide on which goals to embark on a particular time to ensure that all members are on the same page; and planning - skills that promote the establishment of tactical procedures and contingency measures to set team up for task completion activities. This includes budgeting, sharing of work and task design.
The GTO also consist of three action skills: mentoring - skills that highlight mentoring, teaching and coaching such as providing feedback to a colleague, helping a colleague complete a task, and providing back-up response; information synthesis, which involves the ability to analyze, interpret, and share information within the team - including data analysis, collection of accurate data and making sense of data; and coordination - skills that bring whole team ideas together such as taking ownership of team, accept and acknowledge the ideas of others, and coordinating technical skills and inscriptions such as note and image taking.

Interpersonal skills included in the GTO are communication - skills related to receiving and relaying information proactively including both oral and written forms; organization and time management – personal organization skills and ability to influence team organization and time management; and leadership - individual or whole team characteristics that influences the daily functioning of the team to achieve a common goal.

To use the GTO, the observer records each teamwork skill that is demonstrated by a team under the teamwork skill category in the field note section, as teams work through their tasks. After observation, the number of times that category of skill is demonstrated or used is counted and rated using a Likert scale. The Likert scale ranged from 1 (rarely – teamwork skill behavior occurs just once or not at all), 2 (occasionally – occur more than once but less than four times), 3 (frequently – occur about four times but less than ten times), and 4 (always – occur more than ten times).

Focus Group Interview

The reflective anchored focus group discussions were based on observation data for each of the teams we studied. Hence, questions differed from team to team, but the central themes were related to teamwork skills. The questions were mostly aimed at identifying the perspectives
of the participants on the identified teamwork skills - clarifying data through member checks. For example, during focus group discussions, members were asked to corroborate the observation data and explain why the demonstrated teamwork skills were or were not important to them in completing their task.

4.6.6 Data collection

We employed structured participant observation with the observer (first author) as a participant (Emerson, 2011; Yin, 2018). However, the role of data collection was the main priority. Participant observation is a data collection technique used in settings where a skill of interest naturally occurs (Merriam and Tisdell, 2016). This allows the observer to collect first-hand information regarding skills that have become routine to the participants and helps to understand the context of these skills and how they develop. As emphasized by Emerson (2011), an important aspect of conducting participant observation involves gaining entering to the community, participating in activities as are allowable by teams.

The first author entered the HFC community through permission from the course coordinators. He was introduced to the cohort of the summer I HFC during course orientation. He explained the nature of this research to the participants and described the role of participant observer to them. To reduce the influence of participant observer on student teamwork behaviors, the nature of the research was vaguely described to the participants (i.e., to follow their teams and learn how they work together). Also, throughout the field course the observer participated in student academic activities such as classroom lectures, talks, fieldtrips and social activities like lunch breaks, parties, games, and informal conversations to become familiar with participants. During data collection, the first author rode in the same van with the teams, helped
them carry equipment and performed other peripheral duties, but did not engage in activities that
directly impacted their task.

Each of the three teams were observed on at least three occasions. The hours observed for
each team varied as there were different modules and tasks for each team every week. However,
al observations were normalized to four hours for analysis purposes. During fieldwork activities,
the first author recorded participants’ behaviors that demonstrate teamwork skills and annotated
the field notes portion of the GTO. Field notes were written to facilitate the development of
narratives that explain teamwork as it happened. After each observation, the frequency of
teamwork skill demonstration is rated by counting the number of times the skill was
demonstrated by the team and recorded on the Likert scale in the GTO. For example, a team that
demonstrate three planning skills are scored 2 (occasionally) on the Likert scale.

Focus group discussions (n=3) based on what has been observed were held at the end of
each observation week. There was one focus group session per team, and participants for each
focus group are members from the team observed for that week. Before the start of each focus
group, the first author, who also served as the moderator, wrote a list of all teamwork skill
categories observed on a white marker board, and provide participants the opportunity to
elaborate, corroborate and describe the benefits/demerits of that skill. All focus group
discussions were in person, and audio recorded using the online meeting tool, WebEx’s
recording feature. It is prudent to state here that we did not have to change any GTO data as a
result of focus group discussions.

4.6.7 Data analysis

The unit of analysis is our case - the teamwork skills demonstrated by student teams as
they participated in hydrogeology field work. Teams’ rating scores were compiled into Excel
sheet and analyzed using SPSS 24. Using simple time-series analysis (Yin, 2018), we conducted a non-parametric count per observation hours to determine the frequency of each demonstrated teamwork skill for each team.

Analysis of field notes (annotations of observed skills) and focus group discussions followed an interpretive analysis that identified essential features of teamwork skills that students develop during fieldwork, and the interrelationships among them. This allowed us to describe meanings into how geoscience students develop teamwork skills (Merriam and Tisdell, 2016). The first author read through all the GTO data sheets and compiled teamwork skills demonstrated by each team. We used the list of teamwork categories on the GTO to create *a priori* codes. Each demonstrated skill was coded into the appropriate category of teamwork skills using Nvivo 12. For example, an observable skill like ‘student A taught student B to use an equipment’ was coded as peer mentoring/teaching. The *a priori* coding scheme allowed for double coding of certain skills. For example, the code “breaking it (tasks) down and sharing among each other” was coded under both goal specification and planning.

Interview data were auto transcribed through WebEx, then manually cleaned and de-identified. The first author then subjected one of the transcripts to thematic analysis by underlining statements relating to teamwork skills to generate independent codes. After thematic analysis, we realized that the generated coding scheme is similar to the *a priori codes* used in the field notes analysis. Hence the two coding schemes were combined into a single coding scheme. The authors and a graduate research associate with no connection to this research then used the coding scheme to code the same transcript. We compared our codes to create a final coding scheme (Table 9). The first author then applied the finalized coding scheme to each of the focus group data, and compiled codes that represented each case using QSR NVivo 12. We generated
interpretations that explain teamwork skills demonstrated by each team. In this paper, we use focus group quotes and field notes from teams that represent our findings.
### Table 9: Description of teamwork skill categories and examples of coded texts.

<table>
<thead>
<tr>
<th>Category of Teamwork Skills</th>
<th>Description of code</th>
<th>Example of code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transition Skills</strong>: skills that promote team task evaluation and planning.</td>
<td>Interpretation of team mission Ability to clearly describe to the team, what the team task is and its scope, and to identify material resources.</td>
<td><em>We want to make sure everyone understands what the task is, so we have a lot of discussion on that immediately we are giving the task</em> – Team Ruby</td>
</tr>
<tr>
<td>Identification and prioritization of goals</td>
<td>Ability to identify specific goals required of the team and decide on which goals to embark on a particular time. This is to ensure that all members are on the same page.</td>
<td><em>We talked a lot about what the goals were going to be for the day, especially translating that into report and what those objectives were. How we are going to take that, so those conversations mostly happened</em> – Team Mica</td>
</tr>
<tr>
<td>Planning</td>
<td>Skills that promote activities required for task/goal accomplishment such as budget issues and task design, work delegation, evaluation and development of alternative pathways for team goal attainment.</td>
<td><em>I like planning and when I am sitting there in class, I usually think of how to do these different steps and there is always the expectation on me to be a good supporter of the team. Also feel like I am good at delegating tasks and like kind of breaking things out</em> – Team Opal</td>
</tr>
<tr>
<td><strong>Action Skills</strong>: Skills and behaviors that directly impact task accomplishment</td>
<td>Information synthesis Skills related to ability to analyze and interpret information</td>
<td><em>We are just trying to identify them visually by looking at them. If somebody says that it is fine-grained sand and I am saying that is medium sand, they are really close to each other, so we are re just going to discuss and pick one of them</em> – Team Mica</td>
</tr>
<tr>
<td>Mentoring</td>
<td>Serving as a mentor in the team that members can learn from, training and coaching members.</td>
<td><em>Being a teacher to your colleagues and then being a student to your peer was like very useful. I think they have a lot of ideas and to listen to somebody you are on the same set of information is great</em> – Team Ruby</td>
</tr>
<tr>
<td>Coordination</td>
<td>Skills that bring whole team ideas together such as taking ownership of team, accept and acknowledge the ideas of others, coordinating technical skills and inscriptions</td>
<td><em>Its more useful to more independently put together and kind of work together through that separately and then come together at once instead of having one person dictate to the team. You know, work together, take initiative and do what we see needs</em></td>
</tr>
<tr>
<td>Interpersonal Skills: Skills that promote the management of human resource interactions that occur within teams</td>
<td>Communication</td>
<td>Ability to receive and relay information proactively including both oral and written forms, and persuade people</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Organizational and time management skills</td>
<td>Personal organization skills and the ability to influence team organization and time management</td>
<td>The team worked great and like I said, like everyone had this and everyone did their stuff quickly and efficiently – Team Opal</td>
</tr>
<tr>
<td>Leadership</td>
<td>Individual or whole team characteristics that influence team members positively including identification and sharing of resources, team monitoring, and providing services such as driving</td>
<td>I am relatively fair, and I try to be open with other people and trying to give everyone else an opportunity to do it if they want to, but most of the time I just kind of do it because eventually becomes expected after the first – Team Mica</td>
</tr>
</tbody>
</table>
4.6.8 Validity and reliability

To ensure validity – defined as process of establishing the generalizability of our findings (Yin, 2018), we engaged in data triangulation. We collected data through observation, field notes and interviews. After each observation, team members participated in a reflective focus group discussion that focuses on the GTO observation. We triangulated these data sets in our analysis and utilized member checks to ensure that we have an accurate information. Also, common with participant observation, we established good rapport and trust with all the team members. The first author participated in both formal and informal team activities such as group meetings, game nights and riding in the van. This was instrumental in obtaining honest and complete information on teams.

Again, following Creswell, (2003) and Fetterman (1989), we ensured credibility of our results by spending longer time periods with the teams in the field, classroom, field trips and group meetings. This gave us an in-depth understanding of the students’ behaviors and actions relating to how they develop teamwork skills.

We approached reliability as the repetition of our results when the study is replicated (Yin, 2018). We engaged in inter-coder agreement process between authors and an external associate familiar with qualitative coding. Inter-coder agreement (a measure of the percentage of identical coded text passages between the three coders) was 81% and 87% on two different transcripts between the authors, and 84% between the first author and the external research associate. All inter-coder values are higher than Miles and Huberman (1994) accepted range of 80%. Again, the authors and research associate discussed and resolved all disagreements.
4.6.9 Researcher positionality

As emphasized by Feig (2011), the role, background and biases of the researcher has the potential of influencing data generation, analysis and interpretations. I am a geoscience educator and researcher with experiences in fieldwork, and teamwork. Hence, I am inclined to think positively about fieldwork and teamwork. However, discussing the findings and interpretations with research associates and experts reduced this degree of subjectivity. Again, only I had a role in subject recruitment and selection, and data collection. Each process taken and information collected was shared and discussed with research associates. This ensured multiple perspective to the analysis and interpretations.

4.7 Interpretation and Discussion of Results

As described earlier, we provide findings from a single case of student teamwork and cross-case comparisons to describe how teamwork develop among student during fieldwork.

4.7.1 A single case: Development of teamwork skills in team opal

Analysis of teamwork skill demonstration by members of team Opal centered around all nine skill categories (see table 10). Figure 8 provides the distribution of counts per four hours of observation for each teamwork skill category demonstrated by the team.
<table>
<thead>
<tr>
<th>Teamwork Skill Category</th>
<th>Example of Teamwork Behavior Demonstrated</th>
<th>Example of quote from field note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team mission analysis</td>
<td>Members discuss what they are supposed to do for the well drilling activity, identify and make a list of resources they will need for the activity.</td>
<td>We are supposed to drill a well and collect the well log and turn in the data and our plots so we must clean the data and put into excel and then we can plot the graphs using excel.</td>
</tr>
<tr>
<td>Goal identification and specification</td>
<td>Members discuss the goal of the water analysis activity they are tasked with and identify which task to complete first.</td>
<td>Let us get the complicated ones done first as the TAs are here to help us and then we can work on the other ones in the lab.</td>
</tr>
<tr>
<td>Planning</td>
<td>Members discuss how many boxes of rock cores they will get logged, what is next for the team, delegate and share work to make decision on who will have to write notes, make measurements, and serve as the project manager.</td>
<td>We will have to collect all the data today and consolidate it. King will be collecting from the North well, Faya for the South, Cissy and I will take care of the West and East and then Jimmy will be our project manager for today. He will sound the horn when it is time to collect the data.</td>
</tr>
<tr>
<td>Peer Mentoring/Teaching</td>
<td>Jimmy teaches the group members on how to set up the well pump; Casey allows team members to observe her log some few inches of drill core to teach them; Cicci teaches members how to make sure air is not allowed into their water sample and discuss the importance of using acid like hydrochloric acid.</td>
<td>Alright, I am going to demonstrate to you how to set up the pumping equipment in the well and then each one of you can take turn to set them up on your own.</td>
</tr>
<tr>
<td>Information synthesis</td>
<td>Members discuss how they will measure the hardness of sand; team members provide ideas on how to get through the gravel rock they hit during drilling; members continuously discuss the meaning of their pumping test and well data as they collect them; discuss scale of values for their results and come up with accepted values</td>
<td>Looking at the texture from the last sample, it should be silt</td>
</tr>
<tr>
<td>Table 10 – continued</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coordination</strong></td>
<td>Members come together to build a camp tent; members collect data independently and then compare, verify and discuss; members help each other carry their log boxes; teams set up online strategies such as snapchat and Line to check on members; members come together to fix the well pump when it developed a fault.</td>
<td>Can each of us share our data to the and then Jade can join us later through snapchat for us to discuss and write the report. He is going about 40 minutes away.</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td>Members listen attentively to Faya talking about how they will complete the chemical analysis of their samples; members are constantly close together and chatting; members circle together for some few minutes in between their work; members send online messages to their group chat for feedback.</td>
<td>I will send a google docs into your emails and the group chat for everyone to type in their data and what they think.</td>
</tr>
<tr>
<td><strong>Organizational management</strong></td>
<td>Members set a fix time to meet and complete their report at 4 pm; members make notes; Casey give members time to complete their task; members keep time to make sure they are on track.</td>
<td>Someone should be writing notes while we work on the drilling.</td>
</tr>
<tr>
<td><strong>Leadership</strong></td>
<td>Casey makes sure members have resources such as log sheet and samples to work with; members collect and share information; members take the initiative to drive the team van; Casey describes members’ role to them.</td>
<td>We can continue with the drilling. I will look for the equipment and bring them to you or I can borrow from the other group.</td>
</tr>
</tbody>
</table>
Communication was the most frequently demonstrated teamwork skill in this team. In all four observations, communication was rated as “always” developing among the student team members. Students used skills related to verbal, written, and visual communication and listening. During focus group discussions, Team Opal members alluded to the frequency of communication among members and shared that this skill is critical in the success of task completion when working together as a team.

*It is [communication] critical. How are we supposed to get anything done without communicating? It was verbal and very direct and of course there is a lot of nonverbal communication that takes place but being concise and direct was important in how we make those plans and get through a lot of those problems.*

This team also mentioned the importance of listening as a communication skill in ensuring effective team performance.

*Somebody knows something better than me; I am just listening. I will be listening because it is not important who knows what. The important thing is if you know something, we just need to be sharing your information so we will be learning all together and make it.*
Leadership skills closely followed communication as the most demonstrated skill by this team. Members exhibited both whole team and individual leadership. Members appreciated the importance of whole team leadership exhibited by the team and emphasized that

So, if for example she has better idea or would be faster than everyone, she would be the best to lead. It is [having everyone lead] so effective and it's great to be a leader, but it's not really affecting us like in a bad way. It affects us the new way because since we have all planned to lead, it will be easier to move.

Members also mentioned that leadership that involved the use of individual strengths to help the functioning of the team was important in holding the team together:

You said earlier that we are a diverse group, but at least in terms of demographic and in background knowledge. And so, everybody has something to offer, and I think we come back to it, almost every task. We all make use of our strengths and work for the group.
However, it is prudent to state here that, majority of the individual leadership roles were mostly performed in this team by women. For example, Casey and Cicci took the initiative of distributing resources most of the times, and Cissy served as the driver for the team throughout the week.

The least demonstrated teamwork skills by this team related to information synthesis (rarely happened throughout). Members attested to this observation during focus group discussion. However, they contested that this observation was due to the tasks they were working on in the week.

So, the data that we are processing right now is very straightforward. You are just reporting what you see. We are identifying whether something is a fine or medium grain, sand, or whether it has clay or silt, and those are all direct measurable values, so there's not much interpretation.

Members also shared that the skill is important to teamwork and that they used it more when the task was complicated.

Now we used these techniques [information synthesis] more often today. We used it a lot more when we have complicated large ideas, and you must take multiple of them and put them together to try to extrapolate.

Team maturity in opal

Throughout the observations, we found that as team members continued to work together, their teamwork skills were demonstrated more frequently or stayed the same as compared to previous observations. From the counts of demonstration per observation, we identified that teamwork skill demonstration was low among these members in the early part of teamwork.
However, by the final observation, team climate had improved and that there was more demonstration of teamwork skills among team members (see figure 2). The exception to this trend relates to planning and coordination skills which were low during the fourth observation. Organization and time management had the highest increase in count from “rarely” from the first three observations to “frequently” during the fourth observation. This maturity of team Opal was confirmed during focus group discussion: “It has been really interesting to see how our communication has evolved, especially from transitioning from the first week to the second week improvement”. They also shared that

*I wonder, like a progression from the first day. We had noticed that there has been a bit of a problem in the early days and now a little bit better.*

### 4.7.2 Cross-case comparison of teamwork skills development

Chi-square results (p-value > α, 0.05) in all cases, indicated that there was no statistical significance between any of the teamwork skills and demographic variables such as age, gender, and race/ethnicity. All the three teams demonstrated various teamwork skill behaviors. However, some teams demonstrated more frequent use of some skills than others.

Overall, the most frequent used teamwork skills for the three teams related to communication. However, in comparing the teams, it is evident that Team Opal demonstrated skills related to communication more than any of the teams (average of 4 ‘always’ counts for 16 hours of observation). Team Mica followed with 3 ‘always’ counts for 16 hours of observation and Team Ruby had 2 ‘always’ counts for 12 hours of observation. During focus group discussions, team communication emerged as a critical teamwork skill which promotes other dimensions of teamwork such as planning, coordination and organization.
When someone speaks up and breaks the news, it is also helpful because if they are wrong, someone will correct it and then you can go kind of figure out. For example, she corrected them, and now we know the answer to the question out of this, because we are all part of that conversation. So, it kind of helps with our organization when we are all kind of doing that [communicating] simultaneously.

Similarly, skills related to coordination were demonstrated more consistently by Team Opal (2 counts each of occasionally and frequently) and Team Mica (1 count of always and 2 counts of frequently). However, Team Ruby rarely demonstrated any form of coordination throughout the observations. This lack of coordination in Team Ruby was found to be due to the task delegation system used by team members – each member had their own work to complete within the team:

- You have an assigned task that needs to be done, there is no point having a rigid redefined structure. I am not doing it, because it is not my job.

Alternatively, members in Team Mica saw the benefits of coordination in their activity,

- We are not thinking about the people who has the most jobs or who has the less jobs. We do not think about that. We are just trying to share it and to finish it together, and this is the important part of our teamwork.

Similarly, Team Ruby shared that

- People kind of figure out what their strengths are and automatically, I will look at a member and say, hey, we just do not understand how to do that really well. Can you do this or can you take the lead.
Finally, consistent with all teams, skills related to organizational management and information synthesis were rarely demonstrated. Team Mica shared their frustration on the rare management skills they demonstrated.

*I had a group of people that were working on something together instead of just being like, hey, you and somebody else is going to run through the field and you are going to mark down all these striking dips. I was not able to learn anything in those cases. I was just trying to force it with everyone in terms of team management.*

However, team members described these skills as important to effective teamwork during focus group discussions. Team Ruby shared the benefits of synthesizing information

*So, we are all almost in the same level, so when we are looking at stuff, we will be identifying stuff in the same way because we are on the same level almost, so no one is like no, I do not think this is wrong because we know.*

4.8 Summary and Synthesis of Results

It is clear from our results that students demonstrate using teamwork skills, and these skills change with different teams and under different contexts during fieldwork. Although students are not giving any overt instruction in teamwork during the field course in our case study, our results suggest that students develop and demonstrate rich skills of teamwork needed for task planning and completion. This result is inconsistent with the suggestion of Myers and Goodboy (2005) that putting students into teams to work on a task does not automatically stimulate teamwork skill development. The participants were not given any overt instruction on teamwork as part of the HFC curriculum, but like the participants in Petcovic et al. (2020), this ill-structured way of learning during fieldwork was important to developing teamwork skills.
However, one must be cautious as teamwork skills development might also depend on the type of activity given to students. The activities provided to students in our case study were all activities that stimulate teamwork. For example, during pumping test activity, students must spend the whole night monitoring several pumping wells greater than the number of members in each team. This potentially sets up students to use their teamwork skills such as planning, coordination, communication and teaching others.

Again, our results demonstrate that communication is an important dimension to teamwork in our case during fieldwork. Working as a team in the field creates a social learning environment where communication becomes vital in ensuring team effectiveness. We believe the frequent rate of communication among students was due to the autonomy in which students worked on field tasks with less or no supervision. Members needed to always find their own ways to understand the task giving to them, plan and identify resources – all which elicit a lot of communication. Other skills such as coordination, and leadership were also frequently demonstrated in our cases. Our result is consistent with Vance et al. (2015) – engineering, Van Schaik et al. (2014) – medicine, Weller et al. (2011) – management, Wilson et al. (2018) – different STEM fields who found that student teams value communication, leadership and coordination as critical to effective teamwork. These are also like the teamwork skills identified by environmental and hydrogeology employers as essential workforce skills (Nyarko & Petcovic, in review).

However, students’ teamwork skills development was not uniform, and some skills were more often used than others. The teams in our case study demonstrated low levels of teamwork skill development related to team management, information synthesis and goal specification.
Although we do not know if this was due to the nature of fieldwork tasks, it is prudent to state here that this was visible in all the teams irrespective of the task that they worked on.

Another major point of discussion has to do with the number of women who took up individual leadership roles within their teams. There is little evidence from our data of any general correlation between leadership and gender, but the few explicit behaviors observed suggests that these women have stronger urge for management, resource distribution and motivation to succeed in teams than their male colleagues. For example, throughout the six weeks of the field course, about 90% of student drivers who drove the vans that carried field course participants were women. Again, although there were more men than women in each of the teams (usually 3:2), the majority of students who took up positions of team leadership during group meetings and report compilation were women. This result is consistent with Hendel et al. (2006) and Zhao et al. (2011) who found that female students in nursing and humanities exhibit quality leadership skills and rate the construct as more important to organizational success than their male counterparts. According to Zhao et al. (2011), this positive perception predisposes women to take up leadership roles with the aim of effecting transformational changes in organizations.

4.9 Limitations and Future Work

A limitation for this study is its focus on just one geoscience course. Although participants consist of diverse geoscience students that includes undergraduate students, graduate students, and working professionals, and the fieldwork is similar to other geoscience courses, it limits the possibilities of generalization. We suggest further studies with a wider population of other Earth science students and courses. It would be interesting to see in-depth studies of larger field teams to better understand how teamwork develops among them. Again, although some of
our findings are consistent with existing literature, we suggest future studies should concentrate on novel cases to confirm and extend our findings. Further studies are also needed to probe on why some skills were least demonstrated than others by all the teams, and the role of gender in student leadership in functional student teams.

Furthermore, the use of participant observation can influence participants’ teamwork behaviors such as making them more aware of teamwork. To reduce the influence of the participant observer on student teamwork behaviors, participants were not specifically told that the research is about their teamwork characteristics. They were vaguely informed that the study is interested in documenting how they work together. It was only during focus group discussions that participants are told about the main goal of the project. At this time all observations have already been made.

Also, the study took place at a time when COVID-19 protocols were enforced in the United States. This had an impact on the selection of field sites, activities, and other parts of the course. The researchers as well as participants were required to observe all COVID-19 protocols related to face-to-face instruction and learning, such as wearing facial coverings in the classroom (though not required outdoors in the field) and maintaining 6 ft distancing. Hence, all data collection strategies were conducted under these protocols reducing some level of interactions that might have taken place without the protocol in place. However, this did not have any major effect on the research.

Finally, the GTO instrument measures the frequency and type of teamwork skill use. However, it is not able to assess how competent students are with the teamwork skill. Future research should concentrate on assessing the competencies with which students use demonstrated skills.
4.10 Implication for Education

The findings of this study point to several implications for field education and teamwork skills development. Field courses should set clear teamwork outcomes for field activities since the construct is very important to students learning and task completion. Although the course used in our case study did not teach teamwork skills to students, clearly stating teamwork as a learning outcome in the syllabus and on assignments was helpful in triggering students’ teamwork and skills development.

As emphasized by Alwin et al. (2020), strategies for teaching teamwork should reflect the needs of future geoscience employee and industry – it should occur under authentic settings and be able to trigger students’ interest. We encourage educators to include authentic teamwork activities as instructional strategy to improve students’ teamwork practice. Again, observations can be useful strategy for teaching and assessing teamwork whether in the field, laboratory or classroom setting. Observing students work in teams while assessing them can be instrumental in giving them feedback on their performance and skills development. We suggest that educators provide activities that give some level of autonomy to student teams to work on their own while the teacher observe, assess and provide coaching to students.

4.11 Conclusion

A major learning outcome for most field education courses include learning and using skills related to teamwork (Alwin et al. 2020). In this research, the goal was to describe the teamwork skills that students develop during a field-based course using the IPO taxonomy of teamwork by Marks et al. (2001). We observed and collected student behaviors related to teamwork using the Geoscience Teamwork Observation protocol through participant observation, and reflective focus group interviews.
Our results suggest that student teams demonstrated high rates of communication skills such as talking, listening, visual demonstrations and online communication throughout the fieldwork. Similarly, skills related to whole team leadership and individual leadership was highly demonstrated by the student teams. Leadership skills included managing team members, resource distribution and information monitoring and sharing. Also, student teams demonstrated some level of teamwork skills development related to peer mentoring or teaching, team mission analysis and coordination.

Our results further suggest that students’ teamwork skills development is not uniform which may be due to context. Teamwork skills such as goal identification and specification, information synthesis and organizational management were less demonstrated and utilized by student teams. As stated earlier, we are not able to make inferences at this time if this is due to the nature of tasks given to the teams. However, with the high cognitive functioning and management skills needed to negotiate these three skill processes, we argue that a lack of explicit instruction on these teamwork skills might be the cause of this low demonstration and counts per observation tasks for these skills.

This results also suggest inconsistencies between students’ teamwork skill development and the essential teamwork skills required in geoscience workforce. Whereas employers emphasize on the need for strong students’ preparation in goal identification and specification, information synthesis and organizational management (Nyarko & Petcovic, in review), students’ demonstration of these skills were low in our case. It is also prudent to state here that students might be very good at these skills, but they just did have an opportunity to use them in these tasks.
Furthermore, our results indicate that fieldwork can be an important avenue for students’ skill development. Students demonstrated and utilized skills related to teamwork throughout the hydrogeology field camp. However, we propose that field camps designed to intentionally invoke teamwork among students such as placing high emphasis of teamwork as part of learning outcomes and assessments has the potential for providing avenue for students’ teamwork skills development. We further propose that independent field investigations and report writing by student teams has the potential of invoking teamwork skills development. Finally, as designated in our theoretical framework, the structure of the field course provided opportunities for students to engage in building proactive communication, leadership, coordination, peer-teaching and mentoring, and planning skills. Our participants specifically elaborated that the structure of the fieldwork presented an opportunity for teamwork skills development.
References


CHAPTER 5

CONCLUSION

Teamwork continues to be an important skill in industrial and academic geosciences. Employers have increasingly called for student competency in teamwork skills as it is critical in geoscience workforce activities. Similarly, educators seek to inculcate in students a stronger focus on the development of teamwork skills as they are useful for knowledge sharing and problem solving. This interconnected value of teamwork in both the workforce and academia means students' preparation should include learning teamwork in the geosciences. This dissertation is made up of three studies, presented as three papers, that investigate teamwork in the geosciences from the perspective of both geoscience employers and students.

The research was conducted as a series of studies that: identified and explored what geoscience employers consider as essential teamwork competencies, created and validated an instrument for assessing teamwork, and described how students develop teamwork skills in a case study of field-based learning. All research was conducted within the lens of the input-process-output (IPO) taxonomy of teamwork theory (Marks et al. 2001). The model proposes that teamwork consists of three repetitive episodes/phases, namely: transition processes (planning and evaluation of task), action processes (activities that directly impact task completion by teams), and interpersonal processes (team maintenance and management activities to ensure effective transition and action processes). The model offered a framework to critically investigate teamwork within functional contexts (problem solving teams).
5.1 Summary of Article I

This article explored the range of teamwork skill competencies desired by environmental geology and hydrogeology employers. Focus group interviews were used to elicit ideas from these employers about what teamwork competencies are essential for working in environmental and hydro-focused geoscience firms. Employers shared that having competence in transition skills such as the ability to set specific goals, share and delegate work, prepare a budget, identify resources needed to do the work and setting boundaries in and around the team are among the desirable teamwork skills in environmental and hydro geoscience firms.

Employers also shared that geoscience workforce teamwork require competency in action skills such as independent problem solving, self-drive and motivation, mentoring, coaching and teaching, analytical skills and coordination. Interpersonal skills that promote management of human resources during teamwork such as emotional intelligence, proactive verbal and written communication and management of team technical activities were also described as very important to hydrogeology and environmental geology teams. Finally, our results further suggest that teamwork skills which promote ethical norms such as trust and integrity that ensures truthfulness, probity and accountability, and respect for diversity, equity, and inclusion within geoscience teams are essential to the workforce.

Overall, the findings of this study were consistent with Mosher & Keane (2021) and Marks et al. (2001). This provide compelling evidence that teamwork skills desired by environmental and hydro geoscience employers cut across skills that help team members plan and evaluate the task, skills that directly impacts task execution, and interpersonal and ethical skills that ensures collective efficacy, cohesiveness and moral standards. These findings indicate a strong need for a focused teamwork development approach that teach students these skills.
5.2 Summary of Article II

A major goal of article II was to make available to geoscience educators and researchers an observation instrument that measures the frequency with which the whole team engages in a particular skill, and qualitatively allows the researcher to record what was going on. The Geoscience Teamwork Observation (GTO) instrument consists of nine teamwork skill dimensions – transition skills that include mission analysis, goal specification and planning; action skills related to mentoring/teaching, information synthesis and coordination; and interpersonal skills related to communication, organization management and leadership taken from results of study one (Chapter 2) geoscience essential teamwork skills and Marks et al. (2001) taxonomy of teamwork skills model.

Evaluation of the instrument for validity and reliability through empirical field-testing during observation of two student teams participating in a hydrogeology field course suggest that the GTO provides a practical and comprehensive assessment protocol for observing teamwork during fieldwork. The GTO can capture teamwork skills and demonstrated behaviors related to all three teamwork processes – transition, action and interpersonal skills. Again, the ratings for the frequency of demonstrated skills provides an avenue to evaluate both the nature of teamwork skills exhibited by teams and how frequent they use these skills during team task completion.

The development of the GTO provides three potential implications to geoscience researchers and educators. First, GTO provides a unique framework for identifying essential teamwork skills development and quantifying the rate at which these skills are been utilized or demonstrated. Second, the GTO can be systematically used to observe and assess teamwork behaviors as it happens in real time. Finally, the GTO allows a single observer to simultaneously
assess multiple teamwork skills and behaviors. In summary, we provide a valid, reliable, practical and comprehensive assessment protocol for measuring teamwork.

5.3 Summary of Article III

This article reports on a case study approach that describe the teamwork skills that students develop during geoscience experiential learning. The case is defined as the teamwork skills used by three student teams in a hydrogeology field course context. Data for this study were collected through observation of teams each week of the field course during independent teamwork activities by the students. Behaviors related to teamwork from each team were collected using the Geoscience Teamwork Observation (GTO) protocol through participant observation. The observation data were then triangulated with reflective focus group interviews to describe the range of teamwork skills demonstrated by each student team.

Findings from this article indicate that student teams demonstrated high rates of communication skills, whole team leadership and individual leadership, and moderate rates of peer mentoring or teaching, team mission analysis and coordination. Teamwork skills such as goal identification and specification, information synthesis and organizational management were less demonstrated and utilized by student teams. The findings of this research is consistent with Vance et al. (2015), Van Schaik (2014), Weller et al. (2011) and Wilson et al. (2018) indicating that skills related to team transition, action and interpersonal processes are important to effective student teamwork.

Also, findings indicate that fieldwork can be an important avenue for students’ skill development as students in our case demonstrated and utilized skills related to teamwork throughout the hydrogeology field course. Our participants specifically elaborated that the structure of the fieldwork presented an opportunity for teamwork skills development. Hence, we
propose that field camps are designed to intentionally invoke teamwork among students such as placing high emphasis of teamwork as part of learning outcomes and assessments to provide an avenue for students’ teamwork skills development.

Also, findings indicate that the structure of the fieldwork provided students the opportunity to engage in functional teamwork practices for building proactive communication, leadership, coordination, peer-teaching and mentoring, and planning skills. We further propose that independent field investigations and report writing by student teams has the potential of invoking teamwork skills development.

Furthermore, the findings of this research indicates inconsistencies between students’ teamwork skill development and the essential teamwork skills required in geoscience workforce. Whereas employers emphasize on the need for strong students’ preparation in goal identification and specification, information synthesis and organizational management (Nyarko & Petcovic, in review), students’ demonstration of these skills were low in our case.

5.4 Overall Conclusion

The first goal of this dissertation research was to identify from the perspective of environmental geoscience employers what specific teamwork competencies are desired in the workforce. This is important as it allows future employees to know what is expected of them in their future employment. The research also provide educators with information on how to develop focused teamwork approach to prepare students. This research suggests implications for how to prepare students for this workforce.

The second goal was to develop a valid and reliable observation instrument that assesses students’ teamwork skills. A valid and reliable instrument is important as it allows researchers
and educators to collect accurate data to make valid interpretations. The Geoscience Teamwork Observation (GTO) instrument is able to capture teamwork skills as they develop and allows a single observer to simultaneously assess multiple teamwork skills and behaviors. Also, the GTO provides avenue for quantifying the usage and demonstration of teamwork skills. For teamwork researchers interested in investigating teamwork in real-time, and educators who use teamwork as an instructional strategy, a unique assessment framework for identifying teamwork skills as they develop has been provided.

The final goal of this dissertation was to identify from the student angle how they develop teamwork skills during geoscience fieldwork. This is important as teamwork is a major feature of most geoscience fieldwork and most field courses identify teamwork as a learning outcome. The data indicate that students teamwork skill development is not uniform and that some skills are more developed and demonstrated than others. Student teams mostly demonstrated and utilized skills related to communication, leadership and coordination while skills such as information synthesis, organization management and goal specification were less utilized by the student teams. The data further indicate that fieldwork can be an important avenue for students’ skill development.

Together, these three articles provide information on specific teamwork skills essential to the domain of geosciences, provide a novel approach for observing teamwork skills, and describe the development of key skills in the context of a hydrogeology field course. This work draws attention to key issues relating to creating effective teamwork learning outcomes during student preparation activities such as fieldwork and other experiential learning processes.
5.5 Recommendations

The findings from this research point to several recommendations for geoscience and science education in general. First, I recommend that educators need to be intentional about teaching teamwork as a learnable skill. The literature emphasizes the importance of teamwork skill competencies, hence, skills such as team mission analysis, goal specification, planning, communication, coordination, mentoring and information synthesis and sharing should be included as learning objectives for team activities. Again, I suggest that students engage in community or service-learning activities that encourage structured teamwork; for example, having students analyze and plan towards a learning task before applying skills that directly impact task completion. I further recommend that geoscience faculty should communicate the importance of teamwork skills to students for them to know how highly employers value these skills.

Second, I recommend that educators employ authentic teamwork activities (experiential learning) such as fieldwork to promote the learning of these skills (Ferguson et al. 2000; Lingard & Barkataki, 2011). These authentic activities should set clear teamwork outcomes for field activities since the construct is very important to student learning and task completion. Students benefit from authentic activities that gave them autonomy to complete tasks in teams.

Also, observations can be useful strategy for teaching and assessing teamwork whether in the field, laboratory or classroom setting. Observing students work in teams while assessing them can be instrumental in giving them feedback on their performance and skills development. I recommend the GTO as a valid and reliable instrument for assessing teamwork skills developed or demonstrated by students during field, classroom and laboratory activities. The instrument can
be used as a research instrument for qualitative data collection or as an instructor/peer-assessment tool for assessing teamwork learning outcomes.

**5.6 Future Research**

First, given that students are supposed to be competent in the range of teamwork skills described by geoscience employers, future work should examine the perceptions of geoscience students regarding their familiarity with teamwork skills and how they master these skills during their education. For example, a study should compare students’ teamwork skills with desirable geoscience workforce skills.

Second, further research should replicate study three with a wider population of other Earth science students and courses to better understand how teamwork develops among them. Again, although some of our findings are consistent with existing literature, future studies should concentrate on novel cases to confirm our findings. Further studies are also needed to probe as to why certain teamwork skills are less often demonstrated than others, and the role of gender in student leadership in functional student teams.

Finally, the GTO instrument measures the frequency and type of teamwork skill used by team members. However, it is not able to assess how competently students use teamwork skills. Future research should concentrate on modifying the GTO to include evaluation of the quality of teamwork skill usage by students. Again, there is the need for further assessment on establishing the reliability and validity of the GTO through inter-rater assessment.
References


APPENDICES

A - Open-Ended Focus Group Interview Protocol

Introductory Script

Hello everyone, welcome to today’s focus group. We have in attendance [names and job titles of all participants] to discuss the teamwork and leadership skills needed in the geoscience workforce. I am very interested in finding out about teamwork skills and leadership skills important to the geoscience workforce. We will first talk about teamwork skills, take a five-minute break and then turn to leadership skills. I want to reiterate that your response is only for research purposes and that every information will be treated as strictly confidential. Thank you for your time once again.

Interview Questions

Icebreaker: Can you share with me what your team is like?

1. Please tell me about how people work in teams in your firm/company?
2. a. Can you describe some teamwork skills you think are essential for working in teams in your firm/company?
   b. Can you elaborate why these skills are considered essential?
3. What teamwork skills will you say are essential for fresh hires/students to have before joining the workforce?
4. Please tell me about how leadership looks like in your teams.
5. a. Can you describe some leadership skills you think are essential for working in teams in your firm/company?
   b. Can you elaborate why these skills are considered essential?
6. What leadership skills will you say are essential for fresh hires/students to have before employment?
7. What will you suggest geoscience departments/universities do to prepare students to develop these skills during training/education?
8. Is there anything you have to share with me about teamwork/leadership?
B - Qualtrics Demographic Survey

Q1 Have you previously/currently work as a member of a team?

☐ No
☐ Yes

*Skip To: End of Survey If Do you work as a member of a team in your company/firm? = No*

Q2 Are you currently a supervisor/manager/leader of a team in your company/firm?

☐ No
☐ Yes

*Skip To: End of Survey If Are you a supervisor/manager/leader of a team in your company/firm? = No*

Q3 How often do you bring on a new member/hire to your team?

☐ At least every 1 year
☐ Between 1 - 2 years
☐ Between 2 - 4 years
☐ Between 4 or more years

Q4 What is your job title?

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
Q5 How many years have you been doing this job?

Q6 Please give a brief description of your job

Q7 Please give a brief description of your team's work

Q8 Please give a brief description of your company/firm's work

Q9 Please select the date and time you will be available to participate in the one-hour focus group. You can select more than one date and time.
Monday, July 27 at 12:00 PM ET

Friday, July 31 at 12:00 PM ET

Tuesday, August 4 at 7:00 PM ET

Thursday, August 13 at 4:00 PM ET

Wednesday, Aug 19 at 4:00 PM ET

Saturday, August 29 at 7:00 PM ET

Monday, September 7 at 10:00 AM ET

Wednesday, September 17 at 10:00 AM ET

Thursday, September 24 at 10:00 AM

Saturday, October 3, at 12:00 PM

Friday, October 15 at 7 PM
C - The Geoscience Teamwork Observation (GTO protocol)
<table>
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<tr>
<th>Interpretation of team mission or task, and resources</th>
<th>Identification and Prioritization of goals</th>
<th>Planning</th>
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<td>Mentor, Train and Coach</td>
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<td>Communication</td>
<td>Organizational and Time management</td>
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D - HSIRB Approval Letter for Study 1

Date: August 19, 2020

To: Heather Petovic, Principal Investigator
    Samuel Nyarko, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: IRB Project Number 20-07-16

This letter will serve as confirmation that your project titled “Essential Teamwork and Leadership Skills: Perspectives of the Geoscience Workforce” has been reviewed by the Western Michigan University Institutional Review Board (IRB). Based on that review, the IRB has determined that approval is not required for you to conduct this project because marketing research for the purpose of refining or improving the quality of a service does not meet the Federal definition of human subject.

45 CFR 46.102 (f) Human Subject

(f) Human subject means a living individual about whom an investigator (whether professional or student) conducting research obtains:

(1) Data through intervention or interaction with the individual, or
(2) Identifiable private information.

Intervention includes both physical procedures by which data are gathered (for example, venipuncture) and manipulations of the subject or the subject's environment that are performed for research purposes. Interaction includes communication or interpersonal contact between investigator and subject. Private information includes information about behavior that occurs in a context in which an individual can reasonably expect that no observation or recording is taking place, and information which has been provided for specific purposes by an individual and which the individual can reasonably expect will not be made public (for example, a medical record). Private information must be individually identifiable (i.e., the identity of the subject is or may readily be ascertained by the investigator or associated with the information) in order for obtaining the information to constitute research involving human subjects.

“About whom” -- a human subject research project requires the data received from the living individual to be about the person.

Thank you for your concerns about protecting the rights and welfare of human subjects.

A copy of your protocol and a copy of this letter will be maintained in the IRB files.
E - HSIRB Approval Letter for Study 2 and 3

Date: May 11, 2021

To: Heather Petcovic, Principal Investigator
    Samuel Nyarko, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: IRB Project Number 21-05-06

This letter will serve as confirmation that your research project titled “Geoscience Students’ Teamwork Development During Fieldwork: A Case Study” has been approved under the expedited category of review by the Western Michigan University Institutional Review Board (IRB). The conditions and duration of this approval are specified in the policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may only be conducted exactly in the form it was approved. You must seek specific board approval for any changes to this project (e.g., add an investigator, increase number of subjects beyond the number stated in your application, etc.). Failure to obtain approval for changes will result in a protocol deviation.

In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the IRB for consultation.

The Board wishes you success in the pursuit of your research goals.

A status report is required on or prior to (no more than 30 days) May 10, 2021 and each year thereafter until closing of the study.

When this study closes, submit the required Final Report found at https://wmich.edu/research/forms.

Note: All research data must be kept in a secure location on the WMU campus for at least three (3) years after the study closes.