USING NETWORK ANALYSES TO UNDERSTAND THE INTERSECTION BETWEEN SMALL GROUP DYNAMICS AND SOCIOSCIENTIFIC ISSUE DISCUSSION

by

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ABSTRACT

Since socioscientific issues (SSI) are scientific issues situated in the larger society, it is important for many students to understand and effectively communicate information surrounding them. In-class small groups have been used by science instructors to provide students the opportunity to discuss and negotiate difficult SSI. However, learning about SSI in these small groups can be influenced by numerous factors beyond just the content. Therefore, it is important to gain a greater understanding of how these factors are impacting small group and individual responses to SSI. Because of the interactional nature of small groups, social network analysis (SNA) can be used to capture the structure of interactions between individuals, while also gaining an understanding of the flow of information between individuals.

In Chapter One, this dissertation sets out the case for using social network analysis to understand the intersection between SSI and small groups. This dissertation is in an alternative format structure in which Chapters Two through Four are presented as individual manuscripts for publication.

Chapter Two presents a systematic literature review that looks at how education research literature is using SNA to understand student discourse. The goal of this review was to better understand how social network methodologies have been applied in education research to highlight the usefulness of SNA in understanding discourse interactions particularly between students in small group settings. This review showed that SNA has only begun to be used to study discourse in education contexts, with the majority of those studies being conducted in online environments.

Chapter Three is a cross-sectional survey study that looked at the connection between undergraduates' acceptance of SSI and the sources they use to gain information on these SSI. From this survey, it was shown that undergraduates differed in their acceptance of various SSI and the sources from which they gathered information about these SSI. When comparing groups derived from cluster analysis, undergraduates indicated that they were using similar information sources, even though they differ on their acceptance of SSI. This may highlight that students are receiving siloed information from their information sources.

In Chapter Four, a longitudinal analysis of small-group discussion on SSI was conducted to gain an understanding of how small-group dynamics impact the learning outcomes of group work. This study found that interactions within groups varied across the semester, with groups becoming less collaborative toward the end of the semester. It also found that all groups used supportive statements to move group conversations forward. The contribution of new knowledge to the conversation varied by group and week of the semester.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE: PURPOSE OF STUDY

Introduction

Every day, individuals are presented scientific information through different media outlets (e.g., COVID-19, climate change). The information could potentially be about issues that are perceived as controversial due to differences in personal beliefs, cultures, and political views (Kolsto, 2001). In the science education research literature, these issues are called socioscientific issues (SSI). SSI are, usually, controversial social issues that require some component of scientific reasoning to fully explain or come to decisions about them (Sadler, 2004; Zeidler & Nichols, 2009). While scientific reasoning is required as a part of SSI decision-making, individuals also incorporate moral, ethical, and political views to arrive at a solution, due to the societal nature of SSI and the lack of consensus on one solution (Kolsto et al., 2006).

Due to their controversial nature, SSI have been used in the science classroom to provide students an opportunity to engage in current arguments about scientific research that have a societal dimension (Sadler, 2009; Zeidler et al., 2005). By allowing the students to discuss SSI in the classroom, they are then more prepared to navigate complex issues found outside of the classroom when they become decision-making citizens (Sadler, Barab, & Scott, 2011). Even though SSI instruction can help students to navigate these complex issues, it also exposes them to uncertainty always inherent within science (Acar, 2010; Aikenhead, 2006; Lee et al., 2020). This is especially true of current scientific issues for which there may not be sufficient evidence or scientific consensus. Walker et al. (2003) state the nature of uncertainty has two features: the limitation of an individual's knowledge (epistemic) and variability within models (variability). Exposing students formally to these features of uncertainty allow students to understand that science does not have a set method of gathering information and that ideas often come from informal ways of reasoning (Kolsto, 2006; Manz, 2015; Sadler, 2004).

Because SSI are always embedded in larger social issues, they are often presented from a perspective that aligns with the presenter's beliefs (e.g., political, religious; Carter & Wiles, 2014). This makes it challenging for individuals to sift through the information to understand the ideas that are being supported by scientific evidence, rather than ones being driven by personal beliefs. With the integration of personal beliefs into the classroom, SSI may create conflict between students' scientific and personal ideas about an issue. The uncertainty and complexity of factors used in decision making can put teachers in unfamiliar or uncomfortable positions, making it challenging for SSI instructional implementation (Bosser et al., 2015; Sadler, 2009).

To help students navigate these complex issues that incorporate uncertainty and personal beliefs, researchers have designed scaffolded interventions on SSI (Dawson & Carson, 2020; Dawson & Venville, 2013; Lee et al., 2013; Leung & Cheng, 2020; Yoon, 2011). These SSI interventions have primarily utilized small student groups to encourage discussion and allow students to collaboratively construct an answer for an SSI prompt (Ratcliffe, 1997; Eastwood et al., 2012; Leung, 2020), which has shown to help students improve students' communication skills (Chung et al., 2016). Even though SSI studies have shown improvement in students' communication skills, they have often ignored the impact of small-group dynamics on student outcomes related to the SSI.

That is not to say that science education research has not examined collaborative or cooperative small-groups dynamics and its impacts on student learning (Slavin, 1996).

These forms of structured small-group learning have demonstrated positive student outcomes on achievement, formal reasoning ability, and motivation (Johnson & Johnson, 2009; Slavin, 1996). These studies have also noted that the effectiveness of student interactions to generate positive learning outcomes relies on many complicated content-related and social factors (Chang & Brickman, 2018). This includes group composition, student values and behaviors, and the community factors (Chai et al., 2019). Previous studies on small group learning have had difficulty disentangling these factors and their role in student learning.

This dissertation explores student learning at the intersection of SSI instruction and small group learning for undergraduates. In science education, there has been a push to help undergraduates improve their scientific literacy (American Association for the Advancement of Science, 2011). For SSI interventions, a major goal is to help improve students' Vision II scientific literacy, which is concerned with helping students understand the integration of personal and societal perspectives in science (Roberts, 2007; Sadler & Zeidler, 2009). In classrooms that incorporate Vision II, Roberts & Bybee (2014) state, "students learn how the discourse of resolving issues and making decisions differs from and complements the explanatory discourse of science itself." Therefore, students' personal and social perspectives need to be integrated into discussions on SSI, but these perspectives have the potential to impact the discussion between students by utilizing information gained from sources outside of science (Solli et al., 2019; Zeidler & Nichols, 2009). Also, because Vision II literacy is focused on discourse, integrating instructional practices, such as small learning groups, that create opportunities for students to discuss complicated SSI are needed to support scientific literacy goals.

Since SSI are situated in the larger society, they are important for individuals, both within and outside of science, to understand and effectively communicate information surrounding them (Driver, Newton, & Osborne, 2000; Sadler, 2004; Yacoubian & Khishfe, 2018; Zeidler & Nichols, 2009). An educational practice often used in SSI interventions to improve student communication is small groups. Although small groups provide students the opportunity to discuss SSI, small groups are complex due the numerous factors influencing student learning (Chai et al., 2019). It is important to gain a greater understanding of how these factors are impacting the co-construction and negotiation of group responses to SSI. Therefore, the purpose of this dissertation is to gain an understanding of how small-group dynamics within SSI discussion contexts influence group negotiation and response to these issues.

To do this I will draw upon social network methodologies that are only just now being applied to small group interaction dynamics. Because of the interactional nature of small groups, social network analysis (SNA) can be used to capture the structure of interactions between individuals (Carolan, 2014). Since SNA is focused on understanding the structure of interactions, it shifts the level of analysis away from individual descriptions within a group to descriptions of the group as a whole (Borgatti & Ofem, 2010). This shift allows group-level understanding to be gained about how students are interacting and the flow of information within the group (Marin & Wellman, 2014).

Structure of Dissertation

For this dissertation, Chapter Two presents a systematic literature review that looks at how education research literature is utilizing social network analysis to understand discourse. The goal of this review was to better understand how social network methodologies have been applied to discourse studies in education to highlight the usefulness of SNA in understanding discourse.

Chapter Three looked at the connection between undergraduates' acceptance of SSI and the sources they use to gain information on SSI. To understand this connection, this study answered the following research questions: 1) how do demographics relate to individuals' acceptance of socioscientific issues, 2) how are information sources related to individuals' acceptance of socioscientific issues, and 3) how are information sources of SSI and SSI-Acceptance clusters associated with one another?

In Chapter Four, a longitudinal analysis of small-group discussion on SSI was conducted to gain an understanding of how small-group dynamics impact group work. This chapter was guided by the following research questions: 1) Does group structure impact the development of the group engagement, 1a) If so, what factors (i.e., political affiliation, religious affiliation, gender, race, sexual orientation, ethnicity, assigned role) of group structure impact group engagement, 2) how do students' interactions change over time?

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CHAPTER TWO: A SYSTEMATIC LITERATURE REVIEW ON THE USE OF SOCIAL NETWORK ANALYSIS IN DISCOURSE STUDIES WITHIN EDUCATIONAL CONTEXTS

(In Review for the journal Review of Education Research)

Abstract

Education policy has called for educational practices that increase student discourse within the classroom. For education researchers, discourse in the classroom can be difficult to capture and measure, therefore finding effective methods to understand discourse is important. Social network analysis (SNA) is an analytical method that seeks to understand the interactions between individuals and has the potential to provide researchers with a useful tool to explore discourse. This systematic literature review analyzed 41 articles within education that used SNA to understand discourse, in order to highlight the SNA measures and supplementary analyses used by researchers. From this review, we concluded that SNA provides researchers with a flexible analysis that can help gain a deeper understanding of student discourse interactions in formal classrooms.

Keywords: Social Network Analysis, Discourse, Education

Introduction

Current policy documents have called for K-12 and higher education to integrate instructional methods that align more with science, technology, engineering, and mathematics (STEM) practices used by professionals (e.g., American Association for the Advancement of Science, 2011; Honey et al., 2014). Of these STEM practices, promoting professional discourse between students has become a pervasive and useful way to promote student learning within STEM classrooms (Kelly, 2007). Despite its usefulness as an instructional method, its impact on student learning can often be difficult for education researchers to capture and measure. This is due to its complex and interactional nature, which may hinder the researcher's ability to fully capture the structure and process of effective student discourse (Greckhamer & Cilesiz, 2014). In addition, most studies have focused on the individual students as the unit of analyses by examining the text of student discourse, rather than the interaction between students (e.g., Candela, 1998; Lam et al., 2009; Russ et al., 2008). By emphasizing individual dialogue, these analyses may be missing an important interactional component of students' discourse tied to learning, such as the impact of students' culture on conversation development.

In a recent essay, Wagner and González-Howard (2018) discuss the usefulness of social network analysis (SNA) as a methodology for understanding the interaction between students in discourse studies within education. The authors state that SNA provides insight into the social nature of this work because it views students' discourse as an interconnected network made up of the interactions and the nature of those interactions. Within networks, interactions are defined as connections (called "ties") between entities (called "actors") (e.g., individual to individual, individual to machine) where information is being shared through text, talk, gestures, or some other form of communication (van Dijk, 2011; Gee, 2011). For SNA, Wagner and González-Howard (2018) highlight three network features that are important in understanding the nature of discourse interactions; (1) *density* which is a measure of how inter-connected the actors are in the network (2) *reciprocity* which is a measure of how often actors respond to each other when prompted and (3) *centrality* a measure of how central a person in the network interactions. The authors find these network features are particularly useful when looking at discourse networks because they provide an understanding of the amount of an individuals' participation in the dialogue, the direction of individuals' interactions with others, and the connectedness of individuals within a network.

While these three network features can provide useful new insights into discourse networks, Wagner and González-Howard (2018) also provide four analytic methods to better understand network structures (i.e., position analysis, cluster analysis, attribute analysis, and longitudinal analysis) of trends within discourse networks. For example, because student discourse can change over time, longitudinal analysis may provide added understanding to the temporal dynamic nature of networks. Additionally, they suggest that discourse networks can provide rich qualitative data that can then be integrated with the more traditionally quantitative SNA to provide a more encompassing view of student discourse interactions. Wagner and González-Howard (2018) also mention the lack of studies utilizing SNA to understand discourse. Researchers can extend beyond an individual-level view of discourse to a group or classroom view because SNA provides a network perspective on the patterns of discourse.

To build from the argument of Wagner and González-Howard (2018), this literature review focuses on collecting and synthesizing research studies interested in understanding student discourse in educational contexts that use SNA. The broader goal of this synthesis is to better understand how the SNA method has been leveraged in this context. Note, that the purpose of this literature review is to synthesize the methodological and analytical decisions related to social network analysis and discourse made within these studies, as opposed to synthesizing their findings. Since we captured a large sample of studies across broad disciplinary and educational contexts, synthesizing the findings themselves is not fruitful, nor the purpose of this project. We chose to focus on the use of SNA as a methodology in studies that explore student discourse to help show the flexibility of SNA to encourage its use among education researchers. To show this flexibility, we provide a historical view of how this method has been used in education and highlight potential future methodological advancements of SNA on discourse. Also, because this review is looking broadly across education contexts, the purpose for each study can be very different which make it difficult, if not impossible, to generalize the studies' findings at least as they relate to disciplinary learning objectives.

For this review, the first section will detail the theoretical and methodological connection between discourse and social network analysis, while also providing an introduction to the fundamental components, network parameters, and network approaches of SNA. The second section will detail the methodology used to conduct the systematic search for this review. The third section will present the results from the systematic search with an emphasis placed on the data, analyses, and SNA measures used in the article sample, in addition to the distribution and types of articles. Lastly, the final section will discuss the results of the review and provide potential methodological suggestions for future use of SNA in discourse studies in educational contexts.

Methodological Framework

Discourse within Education Contexts

Discourse can be defined as the use of language within social contexts (Gee, 2001). van Dijk (2011) goes into more detail and highlights ten critical properties of discourse. Three of these properties that are of particular importance to this manuscript are that discourse includes social interaction; it involves contextually situated communication; and discourse is a complex, layered construct. These three properties are tightly interwoven and difficult to separate, meaning it is important for studies to use methods that can maintain their interwoven nature (Gee, 2014). The following section will explore these properties in more detail.

As social interactions, discourse occurs among and between humans, as well as humans and machines (van Dijk, 2011). Within these social interactions, the communication between individuals is socially constructed and based on the context in which the individuals are situated. Communication is socially constructed because discourse is the integration of an individual saying, doing, and being something (Bourdieu & Passeron, 1990; Gee, 2015). Being something is related to an individual's identity, which Gee (2014) defines as, "different ways of being in the world at different times and places for different purposes" (p. 3). To help clarify this idea, we provide an example. An individual who identifies as a gay man may avoid gestures and vocal inflexions that are considered more effeminate when he is around men who identify as straight to avoid possible ridicule, but might not avoid these same gestures and vocal inflexions when he is around other gay-identifying men. This change within the gay-identifying man's speech highlights their identity changing to fit into a particular context. Discourse as a construct cannot be separate from the interaction between individuals because it is the interaction that is shaping discourse within a particular context.

The social construction of discourse can be seen within educational contexts when conceptualized using a situated learning framework. Lave and Wenger (1991) showed that everyday interactions help individuals build knowledge instrumental in shaping the individuals' thinking (i.e., legitimate peripheral participation). The knowledge that is gained from these interactions by individuals is constructed within a community, meaning the knowledge is situated within a particular context. Lave and Wenger (1991, p. 40) state that the concept of situated learning is an analytical viewpoint on learning.

Analyzing Discourse in Education Research

Within education contexts, researchers have shown the usefulness of creating classrooms using the situated learning framework in encouraging authentic student learning (e.g., Sadler, 2009; Herrington et al., 2014). By acknowledging discourse is socially constructed, the nature of discourse then shifts from an individual perspective to a group or community-based perspective, where context and interactions are foregrounded as the important unit of analysis over the individual (Wagner and González-Howard, 2018).

In conjunction with discourse being a contextually situated social interaction, van Dijk (2011, p.4) discusses the complex, layered, and multidimensional nature of discourse. van Dijk mentions three major dimensions of natural language (i.e., Form or Expression, Meaning, Action), which each contain local (e.g., sequences of sentences) and global (e.g., organizational schemata of conversation) structures. Although discourse has general structures that are shared across contexts, the way it is analyzed can vary depending upon the discipline of the research in which the interactions are embedded (Bazerman, 1990; Potter, 2004).

For example, Manz (2015) discusses that argumentation (a form of discourse) can be applied in many different disciplines but develops norms that are specific to the disciplines. In particular, Manz (2015) highlights that scientific argumentation can utilize argumentation frameworks that provide a structure that is not specific to one discipline for arguments (e.g., Toulmin, 1959), but the manifestation of these arguments is driven by the norms within the science community (e.g., utilization of empirical evidence, theoretical claims). Therefore, even though there are structural elements of scientific argumentation that expand beyond the discipline of science (e.g., creating a claim), the discourse relevant to scientific argumentation is situated within scientific norms.

Now that we have provided a brief overview of the properties of how discourse can be conceptualized and its disciplinary connection, the following section provides an overview of social network analysis and how it might be used as a methodology to examine discourse in education contexts.

Social Network Analysis

Fundamental Components

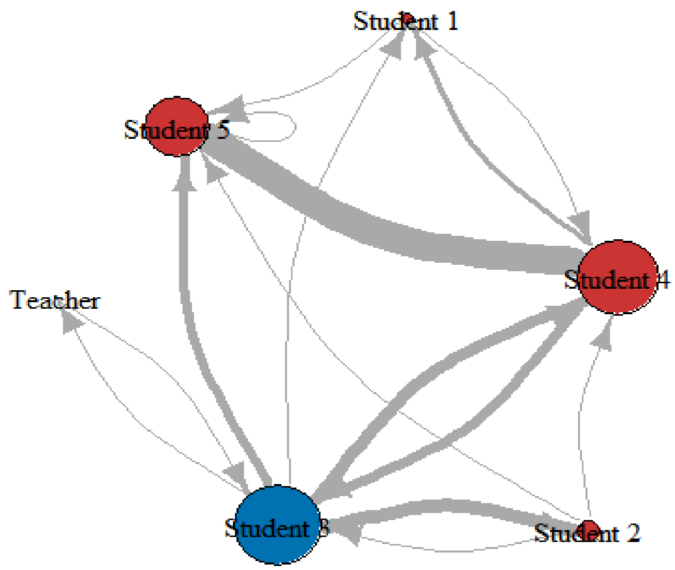
Social network analysis (SNA) is used to understand the structure and content of relationships between entities (e.g., students, companies, words, academic papers) within a network (Borgatti & Ofem, 2010). Social networks are made up of two main features: actors and ties. Actors, also referred to as nodes, often represent the individuals within a network and can be further associated and annotated with different attributes for the individuals (e.g., gender, race, socioeconomic status) during analysis. Network displays are called sociograms (Figure 2.1).

Ties refer to the connection between actors. These ties can represent several different types of connections (e.g., behavioral, physical, association; Carolan, 2014) and can have varying degrees of magnitude (i.e., strong: Nelson, 1989; weak: Granovetter, 1973 & 1983). These ties can be undirected (for example, Student A and Student B talk to each other) and are often represented as single lines or directed (for example, Student A talks to Student B) and represented as directional arrows. These ties can also be weighted (for example, Student A talks more to Student B than Student B talks to Student A) or unweighted. These components of ties can be brought together to better understand how information is passing through a network. For instance, Baker-Doyle and Yoon (2011) used SNA to understand how teachers developed their social networks and if these networks were maximizing the teachers' access to practitioner-based social capital.

As actors begin to make ties with each other, smaller sub-groups can form within a larger network that can be analytically useful. The smallest potential group formed within a network is referred to as a dyad (two actors interacting), from which larger groups can form, such as triads (three actors interacting) and cliques (multiple actors interacting) (Carolan, 2014). Once these components are put together to form a network, researchers are able to gain quantifiable information about the network by calculating standardized network parameters.

Figure 2.1

Example of a Sociogram



Note. Circles represent nodes. Lines represent ties. Arrows represent direction of tie. Width of line represents weight of tie. Color of circles represents some demographic characteristic.

Network Parameters

A feature of SNA is that it allows for the calculation of standardized network parameters, which then allows for comparisons across networks. Borgatti and Ofem (2010) discuss three levels of analysis for networks: dyad, node, and whole network. For the dyad level, measures are focused on understanding the properties between a pair of actors. As mentioned above, ties (i.e., connections between actors) can have varying degrees of strength (i.e., strength of ties) which is often calculated as the frequency of interaction between actors (e.g., daily). For instance, Granovetter (1973, 1983) discussed the idea of weak ties, which are ties where actors do not interact often. Granovetter notes that despite the infrequent interaction, these weak ties play an important role in the dissemination of information within a network because they allow actors to gain new information that they may not receive from strong ties. This is because actors that have strong ties interact with each other more often and, usually, are more similar to each other (e.g., friends). This means actors with strong ties have a higher potential to exchange similar information with each other.

In contrast, weak ties present the opportunity for actors who interact less frequently and are less similar to each other (e.g., acquaintance) to potentially share new information between them. To illustrate this idea, within Figure 2.1, Students 3 and 4 talk to each other often and, therefore, share similar information with each other. In contrast, Student 1 does not talk with Student 3 and rarely talks back to Student 4, which could mean that Student 1 is providing Student 4 with information they are not getting from Student 3. The potentially new information shared by Student 1 may then lead to Student 4 sharing the information they received from Student 1 with Student 3, so Student 3 receives the information from Student 1 even though Students 1 and 3 do not talk to each other.

In contrast to dyad-level measures, node-level measures are concerned with the connections to other nodes and placement of a particular node within a network. Commonly used node-level measures are centrality metrics, which focus on position of a node within the network (Freeman, 1978). As the name implies, centrality measures are used to show how central actors are located within the network, which is often measured by looking at the number of connections that go to and from a particular actor. This can provide an understanding on the influence of those particular actors on the larger network

(Hanneman & Riddle, 2014). For Figure 2.1, Student 4 may be playing a central role within the network because they are connected to a majority of the other students through interactions where they give and receive information (arrows going to and from the student), as well as talk often during discussion (thicker lines). By occupying a central role, Student 4 is able to gain all of the information that is being shared within the network, as well as control who they share the information with. To further highlight this concept, Student 2 is not central in the network because they only receive their information from Student 3 and rarely share information with other students. This means that Student 2 may be missing out on information shared within the group if Student 3 does not share it with them.

Group- or whole-network measures look to gain insight on the network as whole by comparing all nodes and connections to each other or other networks. A whole network-level measure that is often used is density because it allows for researchers to gain an understanding of how interconnected individuals are within a network. Pulling from the example above, Figure 2.1 shows that Student 2 has the potential to receive all the information that is flowing within the network because they are connected to Student 3, who is connected to everyone else. This connectedness within the network shows that Figure 1 has fairly high density because all of the individuals are connected, which then shows that these individuals have access to all the information that is flowing through the network.

When calculated for a network where connections are represented as present (1) or not present (0) (i.e., a binary network), density is the number of connections present in the network divided by the total number of possible connections (Carolan, 2014). A value network builds from a binary network by containing a range of values to indicate differing weights for connections. For a value network that considers the direction of connections, density is calculated by taking the sum of the weight of the ties present in the network and dividing them by the total possible ties (Hanneman & Riddle, 2014). The purpose for indicating differing weights of interactions could be to show which individuals talked more than others. Aside from differing between organizational levels within networks, analytic measures can differ based on the type of network approaches used by the researcher when conducting the network analysis. Network approaches are discussed further below.

Network Analysis Approaches

SNA can take two potential views on how networks should be envisioned and subsequently analyzed, whole and ego network (Borgatti and Ofem, 2010; Scott, 1988; Wassermann & Faust, 1994). The whole network approach focuses on understanding all interactions within the researcher's population of interest (Borgatti & Ofem, 2010). To obtain all of the interactions within a particular network, researchers will often use surveys that are sent out to each actor within the network. The ego network approach does not take a whole network view, but rather takes a more focused view by narrowing in on an individual node and creating networks that radiate out from this focal actor (called the ego) (Carolan, 2014; Hannemann & Riddle, 2014). Peripheral actors connected to the focal actor are called alters. Ego network analysis shifts the focus of SNA from multiple actors' interactions with each other across an entire network (whole network) to an individual's direct and indirect interactions within their immediate social context.

Each of these approaches has its limitations. For the whole network approach, a particular limitation is that the researcher must be aware of missing data. A whole network is only "whole" if all relevant actors are included, and not having data that allow particular nodes to be present in the network weakens internal validity of the research. The ego network approach does not have this limitation because it is only focusing on an ego (e.g., person) and its connections to alters, but is limited by not being able to provide a full understanding of the structural features for the entire network (see Borgatti & Ofem, 2010 for details). Despite these limitations, both of these approaches, and more broadly SNA, have been applied to networks across many different disciplines (Wasserman & Faust, 1994; Carolan, 2014; Carrington & Scott, 2014, Yang et al., 2017).

Because discourse is created between people (i.e., socially constructed), rather than solely by an individual, it creates a network of interactions. Therefore, social network analysis is able to provide an understanding of discourse that maintains the contextually situated nature of those interactions by focusing on the connections between individuals.

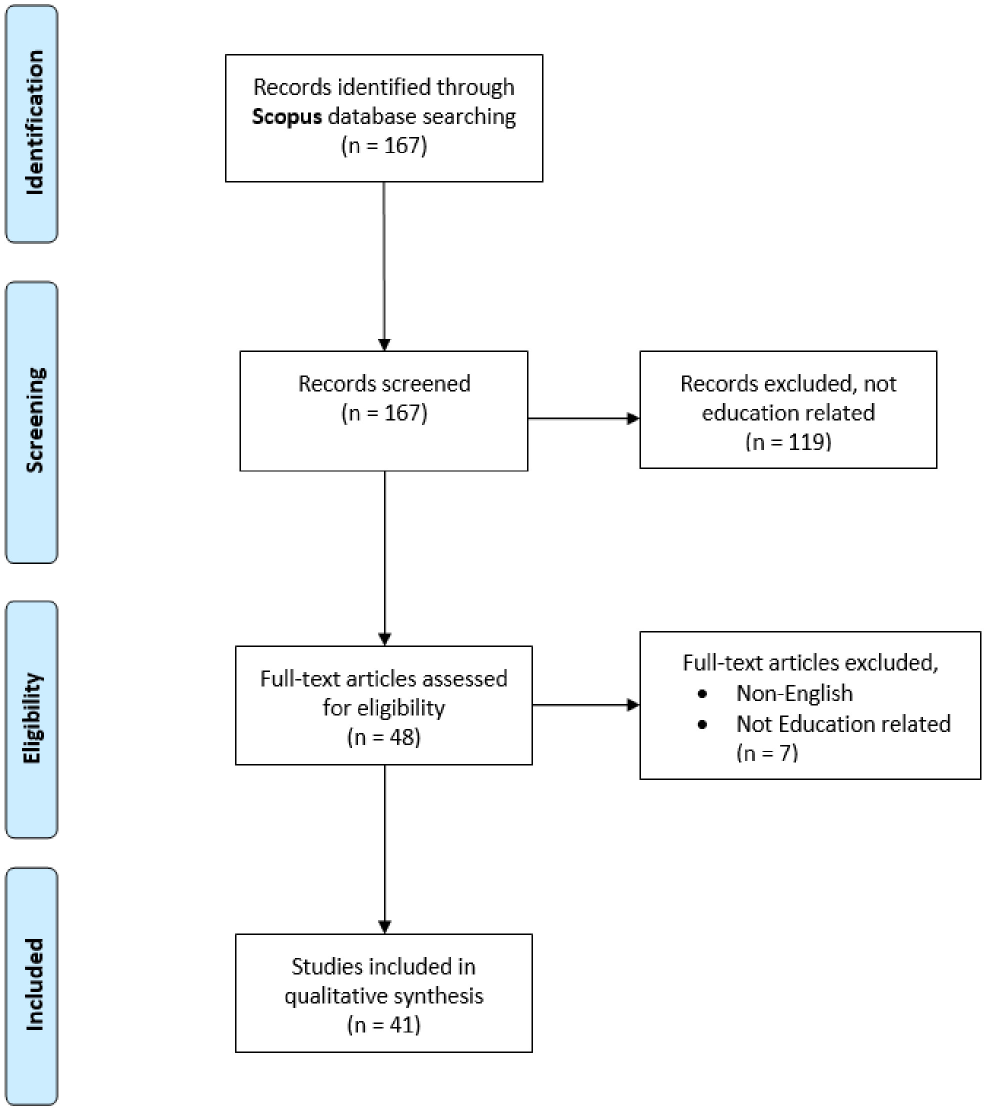
Methods

Article Selection Criteria

For this literature review, we followed the PRISMA Group methods of inclusion (Figure 2.2; Adapted from Moher et al., 2009). Because we are interested in understanding how social network analysis is being leveraged across educational disciplines, we used the broad search terms of social network analysis and discourse. The term social network analysis was used, rather than network analysis, because SNA is a specific type of network analysis that focuses on the structure of social interactions. We decided to limit my search results to only contain peer-reviewed articles and reviews. This was to help exclude published works that are focused on a more descriptive or conceptual understanding of SNA measures (e.g., book chapters), rather than using or developing social network analysis methods. The initial search was conducted on 3rd July 2020 in the Scopus database using the following query string TITLE-ABS-KEY ("social network analysis" AND "discourse") AND DOCTYPE (ar OR re). While we understand Scopus is not a complete database of published works, it does provide a comprehensive selection of articles that span across a diversity of disciplines (25,331 active journals that span 31 subjects; data downloaded from https://www.scopus.com/home.uri). With SNA only recently gaining traction as a beneficial methodology in education (Carolan, 2014, p. 24, Figure 1), we did not provide a timeframe for article publication to ensure we captured a truly comprehensive pool of articles.

Figure 2.2

Flow Chart of Inclusion Methods for Articles



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

Analysis

The initial search term yielded 167 articles from Scopus. For these 167 articles, all abstracts were read, and abstracts not contextualized in an education discipline were excluded. This exclusion step removed 119 articles and left 48 articles for the full-text assessment. After the full-text assessment, 3 non-English articles and 4 articles that did not frame their research perspective in education were removed. The analysis of the remaining 41 articles was guided by the following questions:

1) What is the frequency distribution of the number of studies across time, across journal, and across education research disciplinary sub-type? (RQ1)
2) What was the study type in terms of methodological approach? (RQ2)
3) What type of educational environment was the data collected in? (RQ3)
4) Did the authors utilize other analyses in addition to SNA and how did this analysis complement or supplement the social network analysis? (RQ4)
5) What SNA measures were used in this study to better understand discourse structure? (RQ5)

We will discuss each one of these questions, as well as the codes they generated, in the following section to highlight the usefulness of SNA for discourse.

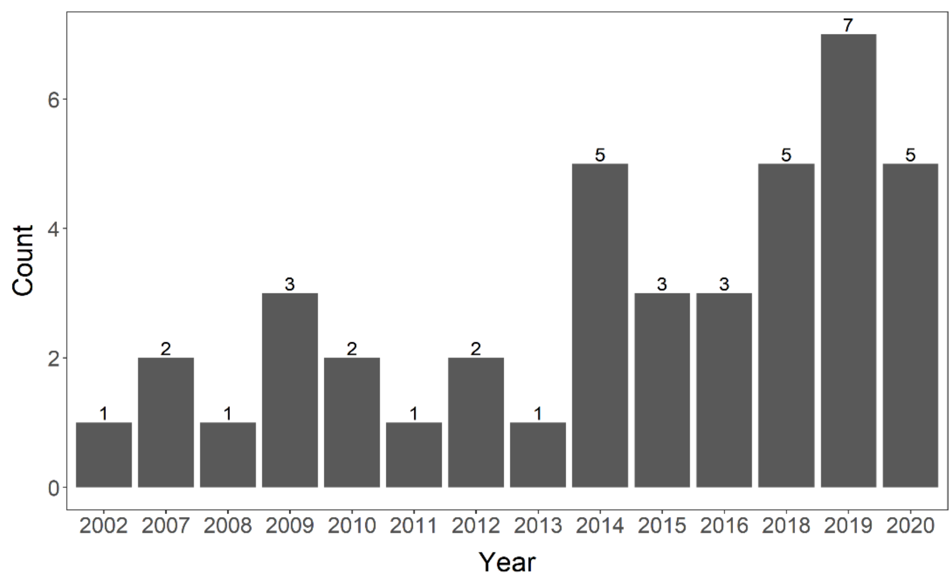
Results

RQ1: Distribution of Articles

The articles ranged in publication from 2002-2020, with 2019 ($n = 7$) containing the most publications and 2002 containing the least publications ($n = 1$; Figure 2.3). Even though 2002 had the fewest number of publications, it is important to note that between 2002 and 2007, the search did not uncover any published articles. Also, based on the trend and when this literature search was conducted, July 3rd, 2020, it is possible that 2020 may end up having more publications than 2019. This follows similar trends presented by other researchers on social network analysis (SNA) publications (Freeman, 2014, p.34; Carolan, 2014, p. 24), meaning SNA is continuing its growth as a useful analysis across research disciplines. For the articles in this literature review, there were many journals (*n* = 34) represented that span across several different research areas (Table 1 in Appendix 2A). Although there were several journals represented, all journals contained only one to three of the articles in the sample (Table 1). Even though the articles do not fit well into cohorts of generalizable research areas (Table 2 in Appendix 2B), the areas still provide an important view of the breadth of research within education that is utilizing SNA.

Figure 2.3

Counts for Publication Years of Articles



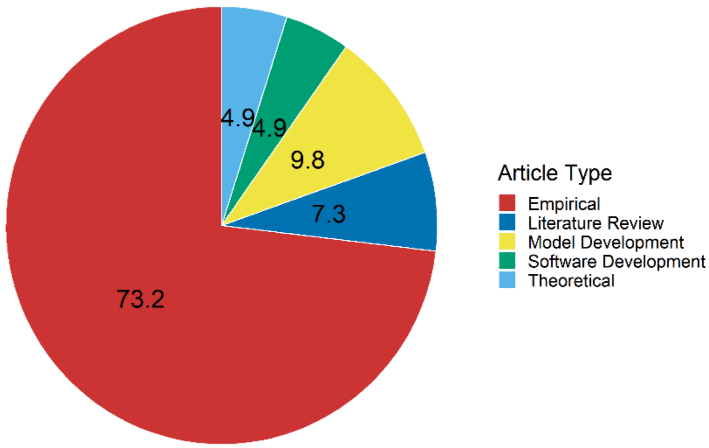
RQ2: Article Type

The articles fell within five different categories for type of study: empirical (73.2%), model development (9.8%), literature review (7.3%), software development (4.9%), and theoretical (4.9%; Figure 2.4). The empirical articles (Table 2: 1-7, 10-15, 17-22, 24, 27-30, 33-35, 38-40) conducted SNA on their data to gain an understanding of particular phenomena of interest, which spanned across several different research areas (e.g., teacher education, K-12 student learning, online learning). For literature reviews (Table 2: 16, 36, 41), these articles used SNA to create at connections between journal articles within a research area (i.e., global citizenship education, computer-supported collaborative-learning, distance learning) by looking at the articles sighted within particular papers. The model development articles (Table 2: 8, 9, 23, 26) combined social network analysis with other analyses to create new analytic models to understand discourse.

Although model development articles (Table 2: 8, 9, 23, 26) used an extension of SNA, rather than solely SNA, we felt it was important to include them in this literature review to help highlight new approaches that incorporate SNA and could potentially provide new insights on discourse analyses. The software development articles focused on providing a proof of concept for an analytic tool (i.e., Knowledge Building Discourse Explorer) for discourse studies (Table 2: 25) or to construct an integrated participation evaluation tool (i.e., Integrated Participation Evaluation Tool) for distance learning courses (Table 2: 32). Lastly, the theoretical articles (Table 2: 31, 37) discussed the potential use of SNA in analyzing certain phenomena (i.e., engagement and communities of practice).

Figure 2.4

Categories for the Type of Article Published



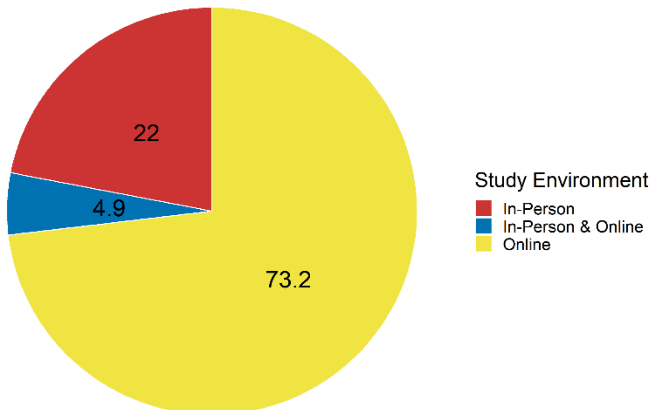
Note. Numbers represent percentages of the number of articles within each category

RQ3: Data Collection

The majority of articles collected had only online interaction data for their study (73.2%), followed by only in-person data (22%). Only a few articles collected data both online and in-person (4.9%; Figure 2.5). Within the 28 studies that collected online data, the type of data collected included discussion posts (Table 2:1, 7-9, 21, 23, 24, 27-30, 34, 35, 37-39), twitter posts (Table 2: 4, 15, 17), Facebook posts (Table 2: 2, 17), blog posts (Table 2: 18, 33), journal articles (16, 36, 41), emails (Table 2: 14), surveys (Table 2: 2, 32), syllabi (Table 2: 38), learning reports (Table 2: 38), announcements (Table 2: 38), messages (Table 2: 22), log files (Table 2: 5, 19), written productions in a computer supported intentional learning environment (Table 2: 19), and discussion notes (Table 2: 5).

Figure 2.5

Categories for the Type of Data within Articles



Note. Numbers represent percentages of the number of articles within each category

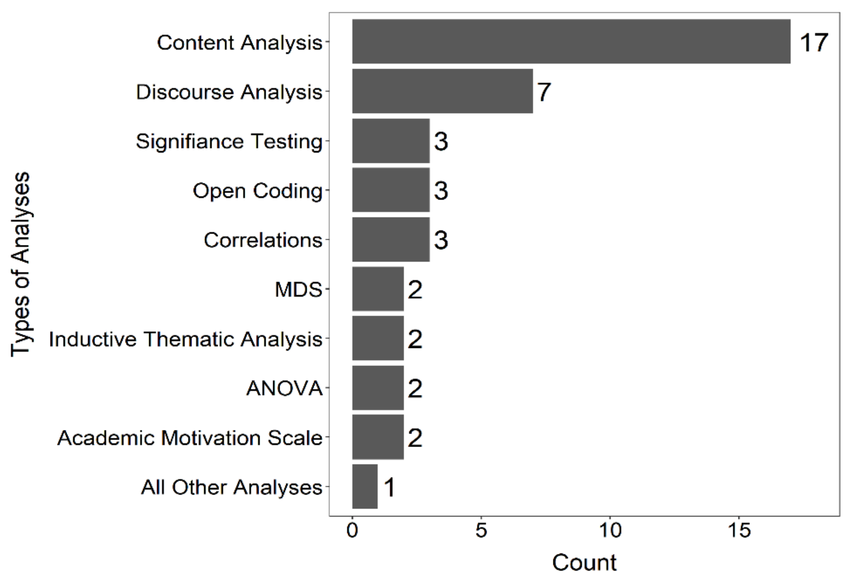
For articles that only collected in-person data (Figure 2.5), the method/instrument of data collection were fieldnotes (Table 2: 3, 20, 31), video recordings (Table 2: 3, 31, 10, 11, 20, 25, 26), informal conversations (Table 2: 3), interviews (Table 2: 3, 12), free-list exercises (Table 2: 13), open-ended questions (Table 2: 13), student assessments (Table 2: 31), pre-posttests (Table 2: 26), teacher evaluations (Table 2: 20), and transcripts (Table 2: 10, 11, 20, 25, 26). Articles that collected both in-person and online data (Figure 5) used a combination of classroom observations, interviews, and post threads (Table 2: 40) or interviews and a survey (Table 2: 6).

RQ4: Supplemental Analyses to SNA

For discourse studies, data often begins as qualitative data (e.g., words) that need to be transformed into quantitative data in order to be used in SNA. Because of this required data transformation, the rich qualitative description of the data may be lost. In order to negate the loss of qualitative thick-rich descriptions, studies can combine other methods with SNA (Wagner & González-Howard, 2018). When looking across the sample, all but one article (Table 2: 18) had at least one supplemental analysis to SNA in their study. There were 48 different supplemental analyses used in the articles. Content analysis (*n* = 17; Table 2: 1, 7, 9, 13, 19, 21, 22, 24, 27, 28, 29, 33, 34, 35, 38, 40) was the most used supplemental analytic method, which was followed by discourse analysis (*n* = 7; Figure 2.6; Table 2: 3, 4, 22, 23, 30, 31, 37).

Figure 2.6

Counts for Analyses Utilized in Addition to SNA in the Articles



Note. Numbers represent counts of each analysis. The bar labeled "all other analyses" represents 39 additional analyses that were utilized once across all articles. See Table 2 for detailed representation of additional analyses.

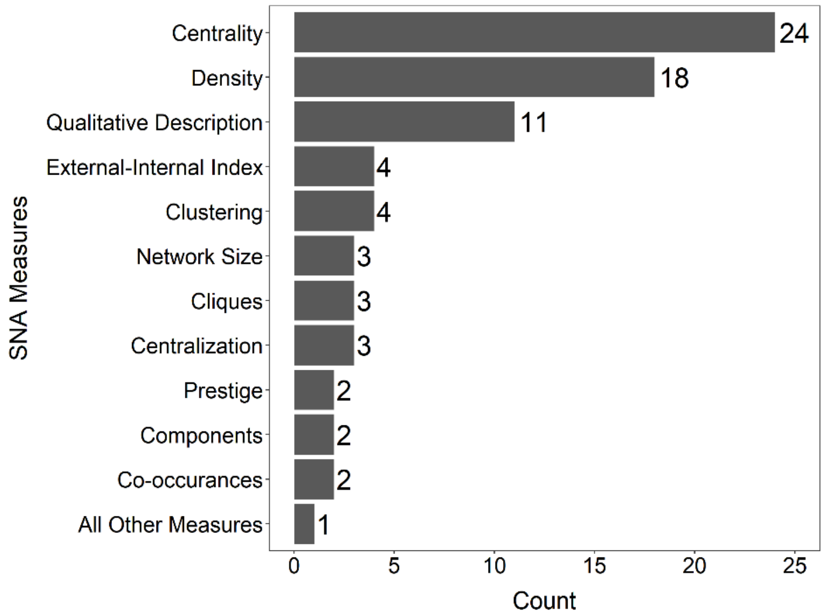
RQ5: Social Network Analysis Measures

For the articles, there were 38 out of the 41 articles that solely used SNA when analyzing connections (Table 2: 1-7, 10-25, & 27-41). Four of the articles used analyses that incorporated SNA but specifically stated that their models were expanding upon the initial analyses (Table 2: 8, 9, 23, & 26). For instance, Reference 8 (Dascalu et al., 2018) used cohesion network analysis to understand the structure of discourse based on cohesion indices. They describe cohesion as, "the incidence of explicit lexical, grammatical, or semantic text cues that help readers make connections among the presented ideas" (p. 606). For cohesion network analysis, they state it expands on SNA by using natural learning processing techniques, latent semantic analysis, and latent Dirichlet allocation (Blei et al., 2003) to create cohesion indices. These are then used to create a sociogram where they can calculate SNA measures.

For the purposes of this literature review, similar SNA measures were grouped together in a single code. For example, Reference 36 (Tang et al., 2014) calculated degree, betweenness, and closeness centrality in their study, but all three of these measures were grouped together as "centrality". While we recognize that centrality measures, as well as others, may provide different results based on the measure selected by the researcher, they are attempting to understand the same basic concept of the actor's position within the network. By grouping similar measures, we are attempting to draw parallels between the analyses of articles to help provide clarity on how SNA is being used within discourse studies to uncover the value of SNA for understanding discourse more clearly. When looking across the articles, researchers used 41 different measures. The most used measure to describe the networks within the articles was centrality (Figure 2.7; Table 2: 1, 8, 9, 12, 14, 15, 17, 18, 19, 20, 23, 24, 25, 26, 27, 28, 31, 33, 34, 35, 36, 38, 39, 41).

Figure 2.7

Counts of SNA Measures Utilized in Articles



Note. Numbers represent counts of each measure. The bar labeled "All Other Measures" represents 34 measures that were used once across all articles. See Table 2 for detailed representation of measures.

An interesting category of measures used in the articles was a qualitative description of their SNA results, which were sociograms (Figure 2.7; Table 2: 2-4, 10, 11, 22, 30, 32, 33, 37, 40). For example, Reference 11 (González-Howard, 2019) discusses the usefulness of SNA as a visualization for interactions during argumentation discussions. For the results, Reference 11 provides a detailed description for each of their sociograms, which were then used to show directionality of ties, counts of total utterances, and counts of utterances towards other individuals (i.e., out-degrees), by focusing on both whole- and ego-network level descriptions. Within the 11 articles, all of them stated that they created sociograms and all but one (Table 2: 2) reported their sociograms.

Discussion

SNA is used to capture and provide insight into the social nature of networks because it is focused on the connections between nodes (e.g., students, words) (Wasserman & Faust, 1994; Borgatti & Ofem, 2010; Carrington & Scott, 2014). Because discourse is constructed between individuals (Van Dijk, 2011), SNA has the potential to capture the social nature of the interaction and provide unique insights into researchers' understanding of discourse (Wagner & González-Howard, 2018). In this literature review, we have highlighted the areas and types of discourse studies in education that have used SNA, as well as the types of data collected, additional analyses used in combination with SNA, and SNA measures conducted within these studies. As a reminder, the goal of this study was not to synthesize the diverse findings from these studies, but to get a better handle on the methods related to SNA and how they have been used to explore discourse within educational settings. For each of these, we will discuss what these results might mean for discourse research studies in education contexts and potential future research directions leveraging SNA methods in studies focused on student discourse.

RQ1: The Distribution of SNA in Discourse Studies

For the distribution of studies, this review showed that the utilization of SNA for discourse has been fairly recent with the earliest article being published in 2002. Although it is increasing in use, SNA it is not commonly used to explore and analyze discourse. This is also highlighted by the sparse publication rate of SNA papers across a range of different journals. The sparse publication rate might indicate that: 1) the statement made by Wagner and González-Howard (2018) that researchers are not taking advantage of the usefulness of SNA in discourse research is true, or 2) journals are reluctant to publish discourse studies that involve SNA. From these two hypotheses, we believe it is more likely that researchers are not taking advantage of the usefulness of SNA. Researchers may not be taking advantage of SNA because they are unfamiliar with the capabilities of SNA, such as being able to analyze qualitative data (Marin & Barry, 2014, p. 22). Because data from discourse studies is often times qualitative (e.g., video, transcripts, discussion posts), SNA may not stand out a particularly useful analytic tool. While SNA does require data to be transformed into matrices in order to be analyzed or visualized, this review has shown that the rich description of qualitative data is not lost or that it is particularly challenging to transform the data when utilizing SNA.

RQ2: Article Type

To help combat these potential issues (i.e., reluctance to publish, unfamiliarity with SNA), future researchers can begin developing SNA methods that are more specific to discourse to help bridge the gap between SNA and discourse concepts, similarly to articles within this review (Table 2: 8, 9, 23, & 26). To highlight this idea, Reference 26 (Oshima et al., 2020) developed a new methodological approach called socio-semantic network analysis of vocabulary that was specific to gaining insight on the knowledge-creation metaphor. For this method, they modified SNA to understand the change in students' ideas through collaborative discourse by creating bipartite graphs, sociograms that use two sets of nodes (Borgatii & Everett, 1997), with a network of words and a network of exchanges. This bipartite graph allowed the researchers to visualize the connections between words and students. The resultant exchanges were a network of student interactions between each other, whereas the network of words represented students' ideas and discourse exchange units. For both the network of exchanges and the network of words, the authors created unipartite graphs, one set of nodes, which allowed them to separately analyze structural components of student interactions and word interactions. To evaluate the network of words, they calculated the total value of degree centrality because it allowed them to see which words were had more connections (i.e., degree), which was the only measure discussed in the article.

RQ3: Data Collection

When looking at the type of data collected in the articles, the majority of them had collected online data (See Figure 2.5). With online courses becoming used more often in education (Al-Rahmi et al., 2019; Anderson & Rivera-Vargas, 2020), especially in the wake of COVID-19, SNA may be able to provide a useful way to effectively capture the dynamics of student interactions (e.g., discussion posts, twitter posts, log files) that could help further the understanding of student discourse and improve teaching practices in online learning environments. Although SNA can provide a useful tool for understanding online learning environments, this review has also shown that research utilizing SNA to understand in-person learning environments is lacking.

The lack of SNA utilization for in-person learning environments could potentially be due to data collection of in-person discourse (e.g., group discussions, interviews, pre-posttests) often being laborious and time-consuming. SNA may provide an analytical tool to researchers that can help circumvent this issue by allowing them to track and view student interactions (e.g., talk-turns) through sociograms to find any interactions of interests, which can then be analyzed further from a whole discourse perspective (Yoon, 2011).

By creating sociograms across several time points, researchers could also gain an understanding of longitudinal changes within student discourse as an entire classroom (i.e., dynamic social network analysis: Moody et al., 2005; Bokhove, 2018), which then could provide useful information to help tailor teaching practices within the classroom. Another potentially useful application of longitudinal social network analysis that would be of particular interest to small group discourse in education contexts. Small groups are used to help encourage discussion within the classroom (Webb & Farivar, 1994), but, to my knowledge, have not been looked at with SNA. In a study by Chai et al. (2019), the authors mentioned that there are no sufficient quantitative tools to help gain an understanding on the dynamics of small groups. The authors were able to combat this issue by utilizing graph theory, of which SNA is based on, to track students' communication within small groups. They highlight that their methodology did not allow them to track the content of the discussion, but could if combined with discourse analysis, similar to studies in this review (Table 2: 3, 4, 22, 23, 30, 31, 37). From this Chai et al. (2019), it shows promise for utilization of SNA to provide a needed tool to help understand discourse within small groups.

RQ4 and RQ5: Additional Analyses and SNA Measures

All but one of the articles in this review used an additional analysis to SNA, with content analysis and discourses analysis being the top two used analyses. These two additional analyses highlight the flexibility of SNA to incorporate data regardless of its nature because content analysis is a quantitative analysis of message characteristics

(Neuendorf, 2017, p.17), whereas discourse analysis is a qualitative analysis of text, talk, and other forms of communication (van Djik, 2011, p. 6). We make this distinction between content analysis and discourse analysis because SNA is often discussed as utilizing only quantitative data, but it also has the ability to be used qualitative data, such as interviews and ethnographic data (Marin & Barry, 2014, p. 22). Because SNA is able to use both quantitative and qualitative data, it offers researchers flexibility in the data they can collect. This was also emphasized in this review with 11 of the articles opting to use qualitative descriptions for their SNA results. By utilizing SNA on qualitative data, researchers can maintain the rich description of qualitative data, while also gaining a broader view that is offered by quantitative data.

Conclusions

For discourse studies, the flexibility of SNA offers a unique analysis that has the potential to provide new insights on discourse by highlighting connection within researchers' data. This potential is beginning to be recognized within discourse studies, as indicated by an upward trend in publications, but is still not a prominent analysis. This potential has also been siloed to mainly studies on online environments. To help combat these issues, researchers can use SNA across more disciplines for in-person and online discourse to help further the understanding of discourse networks within the classroom, as well as establish a solid literature base and develop discourse-specific network analyses.

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APPENDCIES

Appendix 2A: Counts by journal of articles

Table 1

Number of Articles Published in Each Journal

Number of Journals	Journal Title	Number of Articles
1	British Journal of Educational Technology	3
2	Computers in Human Behavior	3
3	Internet and Higher Education	3
4	Online Learning Journal	2
5	American Educational Research Journal	1
6	American Journal of Distance Education	1
7	Behavior Research Methods	1
8	CIN - Computers Informatics Nursing	1
9	Computers and Education	1
10	Distance Education	1
11	Educational Psychologist	1
12	Educational Technology and Society	1
13	Educational Technology Research and Development	1
14	IEEE Internet Computing	1
15	Informatics in Education	1
16	Interactive Learning Environments	1
17	International Journal of Computer-Supported Collaborative Learning	1
18	International Journal of Distance Education Technologies	1
19	Journal of Computer Assisted Learning	1
20	Journal of Computing in Higher Education	1
21	Journal of Education and Work	1
22	Journal of Educational Administration	1
23	Journal of Educational Computing Research	1
24	Journal of Environmental Education	1
25	Journal of Professional Capital and Community	1
26	Journal of Research in Science Teaching	1
27	Language, Learning and Technology	1
28	Pedagogy, Culture and Society	1
29	Research in Learning Technology	1
30	Research Papers in Education	1
31	Science Education	1
32	Teachers College Record	1
33	TESOL Quarterly	1
34	Ubiquitous Learning	1

Appendix 2B: Description of each article

Table 2

Descriptive table of articles in literature review

Reference Number	Authors	Research Area	Type of Article	Study Environment	Analyses	SNA Measures
1	Alwafi, Downey, & Kinchin (2020)	Teacher Education (Professional Learning Community)	Empirical	Online	ANOVA; Faction Analysis; Iterative Coding	Cohesive Subgroups; Faction Density
2	Bell, Mackness, & Funes (2016)	Online Learning	Empirical	Online	Content Analysis; SNA	Degree Centrality; Density; Network Size; External-Internal Index
3	Bernstein (2018)	Linguistics (English Language Learners)	Empirical	In-Person	Content Analysis; SNA	Cohesiveness; Centrality
4	Bonnah (2019)	English (Online Learning)	Empirical	In-Person & Online	Content Analysis; SNA	Density; Degree Centrality; Network Size; Components; Fragmentation; Average Distance; Diameter; Breadth; Compactness
5	Chai & Tan (2009)	Professional Development	Empirical	In-Person & Online	Content Analysis; SNA	Density; External-Internal Index; Qualitative Description
6	Cho, Hamilton, & Tuthill (2019)	Administration	Empirical	In-Person & Online	Content Analysis; SNA; Academic Motivation Scale	External-Internal Index; Significance Testing
7	Chung & Paredes (2015)	Online Learning	Empirical	Online	Content Analysis; SNA; Academic Motivation Scale; Significance Testing; Correlations	Degree Centrality; Density
8	Dascalu, McNamara, Trausan-Matu, & Allen (2018)	Computer-Supported Collaborative-Learning	Model Development	Online	Content Analysis; SNA; Lag Sequential Analysis	Density; Degree Centrality; Instructor Centrality; Peripheral Members

9	Gašević, Joksimovic, Eagan, & Shaffer (2019)	Computer-Supported Collaborative-Learning	Model Development	Online	Content Analysis; SNA; Pearson Correlations	Density; Efficiency; Contribution Index; External-Internal Index; Content Richness Score; Average Tie Strength
10	González-Howard & McNeill (2019)	K-12 (Science)	Empirical	In-Person	Content Analysis; SNA; Significance Testing; Correlations	Degree Centrality; Density
11	González-Howard (2019)	K-12 (Science)	Empirical	In-Person	Discourse Analysis; SNA	Qualitative Description
12	Hora, Parrott, Her (2020)	Work (Skills Discourse)	Empirical	In-Person	Discourse Analysis; SNA; Correlations	Qualitative Description
13	Hora, Smolarek, Martin, & Scrivener (2019)	Work (Internship)	Empirical	In-Person	Ethnographic Approaches; Discourse Analysis; SNA; Corpus Analysis	Qualitative Description; Cliques
14	Hsu & Chou (2009)	Higher Education (Online Learning)	Empirical	Online	Genre Analysis; SNA	Density; Betweenness Centrality
15	Joksimović, Dowell, Poquet, Kovanović, Gašević, Dawson, & Graesser (2018)	Higher Education (Online Learning)	Empirical	Online	Inductive Coding; SNA	Qualitative Description
16	Kolleck & Yemini (2020)	Global Citizenship Education	Literature Review	Online	Inductive Thematic Analysis; SNA; Cultural Analysis	Co-occurrences; Degree Centrality
17	Koseoglu & Bozkurt (2018)	Online Learning	Empirical	Online	Interaction Analysis Model for Examining Social Construction of Knowledge; SNA	Density
18	Lin (2013)	Nursing (Online Learning Community)	Empirical	Online	Linguistic Analysis; PCA; SNA; Linear Mixed-Effects Models	Degree Centrality; Eigenvector Centrality; Betweenness Centrality; Closeness Centrality

19	Lipponen, Rahikainen, Hakkarainen, & Palonen (2002)	Computer-Supported Collaborative-Learning	Empirical	Online	Open Coding; Inductive Thematic Analysis; Content Analysis; SNA; Saliency	Density; Co-occurances
20	Mameli, Mazzoni, & Molinari (2015)	K-12 (Literacy and Mathematics)	Empirical	In-Person	SNA	Density; Centrality; Centralization
21	Markauskaite & Sutherland (2008)	Online Learning Community (Pre-Service Teachers)	Empirical	Online	SNA; ANOVA; MANOVA; Two-Step Cluster Analysis	Degree Centrality; Information Centrality; Centralization; Cliques
22	Mylläri, Åhlberg, & Dillon (2010)	Online Learning Community	Empirical	Online	SNA; Content Analysis	Degree Centrality; Density; Qualitative Description
23	Nistor, Baltes, Dascălu, Mihăilă, Smeaton, Trăuşan-Matu (2014)	Online Learning Community	Model Development	Online	SNA; Content Analysis	Degree Centrality; Betweenness Centrality; Closeness Centrality; Prestige
24	Oh, Huang, Hedayati Mehdiabadi, & Ju (2018)	Computer-Supported Collaborative-Learning	Empirical	Online	SNA; Content Analysis; Discourse Analysis; Emergent Coding of Interviews; Analysis of Message Generation; Structure of Message Threads	Qualitative Description
25	Oshima, Oshima, & Matsuzawa (2012)	Software	Software Development	In-Person	SNA; Content Analysis; Indexes of Engagement; Relative Collocation Matrix; Significance Testing	Network Size; Intensity; Interactivity
26	Oshima, Oshima, & Saruwatari (2020)	Knowledge Creation	Model Development	In-Person	SNA; Content Analysis; MDS	Density; Degree Centrality; Betweenness Centrality; Centralization; Components
27	Rienties, Giesbers, Tempelaar, Lygo-Baker, Segers, & Gijselaers (2012)	Computer-Supported Collaborative-Learning	Empirical	Online	SNA; Content Analysis; Spearman Rho correlations	Degree Centrality; Density

28	Rienties, Tempelaar, Giesbers, Segers, & Gijselaers (2014)	Computer-Supported Collaborative-Learning	Empirical	Online	SNA; Open Coding	Qualitative Description
29	Rienties, Tempelaar, Van den Bossche, Gijselaers, & Segers (2009)	Computer-Supported Collaborative-Learning	Empirical	Online	SNA; Open Coding	Qualitative Description
30	Ruane & Lee (2016)	Online Learning (Teacher Education)	Empirical	Online	SNA; Thematic Analysis	Betweenness Centrality; Local Measures; Global Measures; Clustering
31	Ryu & Lombardi (2015)	Theoretical Framework	Theoretical	In-Person	SNA; Citation Analysis; MDS	Density; Centrality; Prestige; Congruence; Send/Receiving Ratio; Self-Feeding Ratio
32	Saltz, Hiltz, Turoff, & Passerini (2007)	Software	Software Development	Online	SNA; Exploratory Factor Analysis	Degree Centrality; Betweenness Centrality; Closeness Centrality; Clustering; Density
33	Sharma & Tietjen (2016)	Computer-Supported Collaborative-Learning	Empirical	Online	SNA; Machine-Learning; Natural Language Processing	Density; Clustering; Co-occurrences
34	Shea, Hayes, Vickers, Gozza-Cohen, Uzuner, Mehta, Valchova, & Rangan (2010)	Online Learning	Empirical	Online	Cohesion Network Analysis	Degree Centrality
35	Shea, Hayes, Uzuner-Smith, Gozza-Cohen, Vickers, & Bidjerano (2014)	Online Learning	Empirical	Online	SNA; Cohesion Graph; Discourse Analysis; Acceptance Model	Betweenness Centrality
36	Tang, Tsai, & Lin (2014)	Computer-Supported Collaborative-Learning	Literature Review	Online	Social Epistemic Network Signature; Content Analysis; Cluster Analysis	Clustering; Weighted Centrality; Degree Centrality; Closeness Centrality; Betweenness Centrality; Directed Ties; Homophily; Reciprocity;

						Popularity; Expansiveness; Cyclical Ties; Triadic Closure; Simmelian Ties
37	Thorpe, McCormick, Kubiak, & Carmichael (2007)	Online Learning Community	Theoretical	Online	Structures, Behaviors, Functions (SBF) Framework; Socio-semantic Network Analysis; Epistemic Network Analysis	Degree Centrality
38	Wang & Liu (2020)	Computer-Supported Collaborative-Learning	Empirical	Online	SNA; Rule-based System; Technology Acceptance Model; Dezhi Wu and Starr Hiltz's work	Qualitative Description
39	Wu, Gao, & Zhang (2014)	Computer-Mediated Communication (Teacher Education)	Empirical	Online	SNA; Stepwise Analysis	Degree Centrality; Betweenness Centrality; Closeness Centrality
40	Yuan & Zhang (2019)	K-12	Empirical	In-Person	SNA; Discourse Analysis	Cliques; Centrality; Density
41	Zawacki-Richter & Anderson (2011)	Distance Education	Literature Review	Online	SNA; Discourse Analysis	Qualitative Description

CHAPTER THREE: STUDY ONE

(Manuscript will be submitted to CBE-Life Sciences Education Journal)

Introduction

Students in today's society have the ability to gain information on science topics from a vast number of sources, which may or may not be vetted by the science community (Bryne et al., 2022; Gabarron et al., 2021; Williams Kirkpatrick, 2021). Although students have access to more scientific information, these sources may purposefully present misinformation to further an ideology that is not aligned with the consensus of the science community. This has led to the term "post-truth" which is defined by emotion and personal belief having more impact on the opinion of the public rather than objective facts (Barzilai & Chinn, 2020; Lewandowsky et al., 2017; McIntyre, 2018; West & Bergstrom, 2021). In support of science education in a post-truth world, Iyengar and Massey (2019) state that the issue for science communication is no longer one of improving science content, but rather combating misinformation that is being presented by various media sources. Iyengar and Massey (2019) also highlight the use of the internet to create narratives that are aligned to political parties' beliefs and present it in a news format, which has become more polarized over time and a potential source of misinformation.

By presenting information in this news-style format, which is assumed to be valid and reliable, many individuals are left confused on basic facts on current scientifically related issues and events (Barthel et al., 2016). These targeted misinformation campaigns have often been directed toward science issues and lead to individuals in the general public questioning the science behind the issues (Hamilton & Safford, 2021). Southwell et al. (2022) discuss this questioning of scientific information and the threat it poses to the science community by attacking the integrity the scientific community and undermining the public's trust in science. Within educational settings, this can be particularly challenging for instructors to navigate because of the rapid change in where this misinformation is coming from and how it is being presented by information sources (Sinatra & Lombardi, 2020).

Despite the challenge, a potential effort that may combat this misinformation is the central goal of science education to improve scientific literacy within society to help individuals make more informed decisions on scientific issues (American Association for the Advancement of Science, 2011; Roberts & Bybee, 2014; Sharon & Baram-Tsabari, 2020). To achieve the goal of improving scientific literacy, science educators have utilized multifaceted scientific problems called socioscientific issues (SSI) (Ke et al., 2021). SSI are complex social issues that are rooted in science with a potentially controversial nature because they require scientific and informal reasoning to reach a clear solution (Sadler, 2004; Zeidler & Nichols, 2009). Because these SSI are situated in the larger society, it is important for individuals, both within and outside of science, to understand and effectively communicate information surrounding them (Kolstø, 2001; Yacoubian & Khishfe, 2018).

Within the classroom, SSI can provide students the opportunity to develop their skills in creating solutions for real-world situations, which help them navigate current issues that are new to science (e.g., COVID-19; Herman et al., 2022). Students are expected to become scientifically literate through examining SSI, as well as gain the ability to effectively communicate these ideas to argue their validity to others. Although important, learning effective communication and argumentation of SSI is not straightforward. Students often must incorporate nonscientific information in communicating SSI (Sadler & Zeidler, 2005; Dawson & Carson, 2017). This can be tricky as SSI arguments incorporate nonscientific information such as beliefs and values (Zeidler, Walker, Ackett, & Simmons, 2002, Carter & Wiles, 2014). By having beliefs influence their arguments, students' acceptance of SSI can vary by SSI topic.

In the science education literature, one SSI where student acceptance has been extensively looked at is the theory of evolution (Hermann, 2007). This research has shown that students' acceptance of the scientific components of evolution can be influenced by their non-scientific religious affiliation (Barnes et al., 2020; Nadelson & Hardy, 2015). This conflict between religion and evolution is often based on the idea that a higher power (e.g., God in Christianity) created humans and, therefore, humans could not have evolved from other primates, which is the current scientific consensus (Dobzhansky, 1973). Because some students hold this religious belief, they see conflict with ideas related to the science of evolution. As a result, some students are less likely to utilize science content knowledge when discussing evolution (Fowler & Zeidler, 2016). For evolution, information sources may be accessed less online and more through interactions with family and friends, as well as religious text. For example, Barnes et al. (2017b) found that parents' attitude towards evolution played a significant role in students' acceptance of evolution, which suggests that parents and friends are pivotal sources of information around decision making and evolution.

Another SSI where acceptance has been thoroughly investigated is climate change. Even though there is a consensus in the scientific literature that global climate change is occurring, agreement on the human induced nature of this change outside of the science community is limited (Gallop, 2010). For students, climate change acceptance can be impacted by individuals' political beliefs (Carter & Wiles, 2014; Dietz et al., 2007; Weber, 2010). Since the science of climate change is a topic in the political discourse, politicians continue to perpetuate dialogue in conflict with the scientific consensus to help secure their status with their party (Yale Program on Climate Change Communication, 2015). Therefore, the lack of consensus outside of the science community may exist because debates around climate change are often times politically driven, rather than scientifically driven.

Recently, a SSI that is receiving more attention is the efficacy of vaccinations in preventing infectious disease. Misinformation has been on the rise about vaccines, especially those for COVID-19 (Bin Naeem & Kamel Boulos, 2021; Dillon & Avraamidou, 2021; Lockyer et al., 2021). Because of social media platforms, misinformation related to vaccines may spread quickly through social networks and be presented within a dense network echo chamber (Baines et al, 2021; Jennings et al., 2021). This has real implications for decision making. Perri et al. (2022) showed that as more misinformation on COVID-19 that was shared in a particular geographic area, there was a subsequent increase in vaccine hesitancy. Also, acceptance of COVID-19 vaccinations has been shown to vary by demographic group (Hildreth & Alcendor, 2021; Latkin, 2021; Malik et al., 2020; Mondal et al., 2021). The combination of these could indicate that communities may be more prone to sharing misinformation amongst each other and highlighting the need to understand community differences in where they get their information.

While climate change, evolution, and vaccination have been highlighted as critical topics in the SSI literature, SSI can cover an expansive amount of science issues (e.g., ecotourism, deforestation, pollution), that can be utilized in the classroom to promote science literacy. With a diversity of beliefs influencing SSI acceptance and the expansive amount of SSI, instructors may benefit from understanding where students are gaining their information to help inform the development of SSI interventions. To help offer insight into students' acceptance across SSI and their information sources, I explored how different student groups accept various SSI and the connection between acceptance within these groups and the information sources from which their scientific knowledge was derived.

Research Questions

1) How do demographics relate to individuals' acceptance of socioscientific issues?
2) How are information sources related to individuals' acceptance of socioscientific issues?
3) How are information sources of SSI and SSI-Acceptance clusters affiliated with each other?

Methods

Research Design

The research design for this study is a cross-sectional survey. This allowed me to collect a large and diverse sample, to assess differences in SSI acceptance and information sources between respondents. A limitation to this design is that the information gathered is limited to the survey, which is only given during one timepoint. This means that I was unable to return to respondents to ask further questions on their SSI acceptance. Also, because this survey is only given during one timepoint, it is not capturing the potential change respondents have in SSI acceptance and information sources over time.

Sample

The population of interest in this study was undergraduates enrolled in any biology course. I distributed the survey across various science-related listservs (e.g., National Association for Research in Science Teaching, Society for the Advancement of Biology Education Research) to capture a diverse sample of undergraduates enrolled in a biology course across different universities.

According to the National Center for Education Statistics (De Bray et al., 2019), there were 118,663 undergraduates in 2017-2018 who received a biology or biomedical bachelor's degree. This can be multiplied by four to better reflect the total population of undergraduates majoring in biology (assuming a typical four years to degree completion), which gives a total estimate of 474,652 undergraduates currently majoring in biology in the United States. Even this number does not fully represent the actual population of undergraduates enrolled in a biology because it does not take into account attrition rate and non-biology majors enrolled in a biology course, which means the actual number is probably larger.

Also, this statistic does not provide an understanding for the demographics of undergraduates enrolled in a biology course. Since the actual population size and demographic composition of undergraduates enrolled in a biology course cannot be determined, it is impossible to obtain a representative sample to answer these particular research questions. Therefore, because I intend to conduct cluster analysis on my data, I will utilize the recommendations put forth by Qui and Joe (2009) and Dolnicar et al. (2014) to set the range for responses. Qui and Joe (2009) recommends cluster analysis have 30 data points for each variable in the study, whereas Dolnicar et al. (2014) recommends 70 data points for each variable. Because I will have eight SSI topics, the range for responses will be n = 240 to n = 560 undergraduates.

Survey Instrument Description

To capture undergraduates' acceptance of SSI, a four-point Likert-scale survey (i.e., agree, somewhat agree, somewhat disagree, disagree) that has statements about currently relevant biology SSI was created. The SSI topics covered in the survey are climate change, deforestation, ecotourism, evolution, invasive species, pesticides, pollution, and vaccinations (See Appendix for items). These particular SSI topics were chosen because they are highlighted in many biology textbooks (Morris, 2014, Freeman et al., 2019). The items used for evolution were taken from the Inventory of Student Evolution Acceptance (I-SEA; Nadelson & Southerland, 2012). For the I-SEA, there are 24 questions that span across three evolution subscales (i.e., Macroevolution, Microevolution, and Human Evolution). The survey only used the items from the Human Evolution construct because that is where individuals seem to have the most disagreement when discussing evolution (Sinatra et al., 2003) and to help reduce survey fatigue.

For the remaining SSI topics, the items were created to highlight statements about SSI that are often agreed upon in the scientific community (e.g., Global climate change is a natural occurrence that has been amplified by humans.), the inverse of agreed upon statements (e.g., Global climate change is not happening.), and components of statements (e.g., Global climate change is a natural occurrence.; Global climate change is caused by humans.). Because SSI are complex, components needed to be separated to highlight whether participants agree with the entire scientifically agreed upon statement or only a part of it. For instance, an individual may agree that climate change is a natural occurrence but does not agree that humans have any part in climate change. To create these items, literature was utilized within and outside of science education to gain an understand of the accepted views within the science community for each SSI (Climate Change: Carter & Wiles, 2014; Deforestation: Faust et al., 2018; Östlund et al., 2015; Ecotourism: Cini et al., 2015; Sutcliffe, 2018; Invasive species: Otieno et al., 2014; Marris, 2009; Pesticides: Ames et al., 1997; Mahmood et al., 2016; Pollution: Moss, 2008; Danielson & Tanner, 2015; Vaccines: Sarathchandra et al., 2018). See Table 3.1 for scientifically agreed upon statements used in the survey. For each SSI topic, the survey prompted participants to indicate the main information source (e.g., news, person, social media) they used to gain information about that particular SSI. The survey also collected demographics on the participant (e.g., political affiliation, religious affiliation, race, ethnicity, sexual orientation, number of science courses taken).

To establish reliability and validity evidence for this survey, a pilot study was conducted by distributing the survey to undergraduates enrolled in an introductory biology course. Although this sample was not collected across multiple courses, it allowed for an understanding of if the survey was able to discern the portion of undergraduates who, theoretically, have the least exposure to SSI in the classroom (e.g., non-biology majors in an introductory biology course). For the pilot study, a polytomous Rasch model called a rating scale model (RSM) was ran because the data were a Likert

Table 3.1

Statements from the survey that are agreed upon by science

SSI Topics	SSI Acceptance Statements
Climate Change	• Global climate change is a natural occurrence. • Global climate change is caused by humans.
Deforestation	• Removing native trees and other native plants from an area impacts human health. • Removing native trees and other native plants impacts the health of the environment.
Ecotourism	• Ecotourism in neither good nor bad because it provides some benefit and harm to the habitat and people.
Human Evolution	• There is reliable evidence to support the theory that describes how humans were derived from ancestral primates. • The many characteristics that humans share with other primates (i.e., chimpanzees, gorillas) can be best explained by our sharing a common ancestor. • I think that humans and apes share an ancient ancestor. • I think humans evolve. • Physical variations in humans (i.e., eye color, skin color) were derived from the same processes that produce variation in other groups of organisms.
Invasive Species	• Species introduced to new places by humans need to be removed by humans from that new place. • Humans need to use any lethal or non-lethal tactics necessary to remove species introduced to new species.
Pesticides	• Pesticides are harmful to the environment and can be used for specific tasks.
Pollution	• Pollution is a global problem. • Fossil fuels create pollution. • Agriculture creates pollution. • Natural processes create pollution. • Humans create pollution.
Vaccination	• Vaccines prevent disease. • Vaccines are beneficial to people. • I will get all vaccinations recommended by health professionals.

scale that maintains the same structure (i.e., 1 = Disagree to 4 = Agree) for all items in the survey (Ostini & Nering, 2006). A dichotomous Rasch model was also ran to determine if a four-point or two-point scale was best for the survey instrument. Following Donnelly and Boone (2007), infit and outfit measures were used to identify misfit items and create Wright maps for each of the SSI to establish concurrent and construct validity. For infit and outfit measures, a range of -2 to 2 is used to determine if an item is a misfit (Wright & Masters, 1982). Reliability was be established for each SSI through calculation of Rasch item reliabilities. To conduct the RSM, I needed to collect 40 responses, ten per rating scale category (Linacre, 2002).

Data Analysis

To understand the relationship between student demographics and SSI acceptance, latent profile analysis was conducted using the *TidyLPA* package (Rosenburg et al., 2018) in RStudio (R Core Team, 2020) to detect potential statistical clusters by acceptance of SSI based on their responses to the survey. A matrix was created to have each participant as a row and each column associated with a survey item. Based on individuals' responses to the survey, the cells of the matrix were populated by binary scores that were created from the survey responses (i.e., Disagree = 0 to Agree = 1). To understand clustering across SSI, each participant's binary scores were added up and then divided by the number of items for each SSI to create an average SSI topic acceptance score. The average was used, as opposed to total scores, because each SSI topic had a varying number of items associated with it. With this matrix, an exploratory latent profile analysis was run to find the best fitting model for the data to create groups of individuals who answered similarly on the survey items. For each group, the acceptance rate indicates alignment between the participants responses to science experts' thinking. I also described the demographics within each group. This acceptance rate of SSI was categorized into high acceptance and low acceptance. These cutoffs were based on prior research for climate change, evolution, pesticide, and pollution acceptance because the longevity of research on these topics. Acceptance of COVID-19 vaccines was not used, even though there is a current focus on it, because the survey asked generally about vaccines. For the remaining topics (deforestation, ecotourism, and invasive species), there was a lack of research on public acceptance. Acceptance of climate change ranged from 57% - 72% (Marlon et al., 2022) depending on the question being asked about by the survey. Evolution acceptance was shown to range from 32% - 88% (Funk, 2019) with another prior nationwide study indicating 65% of adults accept evolution (Pew Research Center, 2015). Pesticides ranged from 46% - 79% for adults that saw them as a health concern (Funk et al., 2018). Finally, pollution ranged from 63% - 75% of adults in the United States that saw it as environmental problems (Funk et al., 2020). Based on these ranges, the cutoffs were set as high acceptance is greater than or equal 0.8 and low acceptance is less than or equal to 0.6.

A one-way ANOVA was conducted to investigate the connection between information sources and participants' acceptance of SSI for each SSI topic followed by pairwise comparisons with a Bonferroni correction, if the ANOVA was significant.

In order to show the connection between students and their information sources, social network analysis was used to create a bipartite network for information sources and the groups created from the latent profile analysis. For the network, a matrix was created to indicate each group's connections with each information source. A count of the number of individuals within a group was assigned to indicate a weight for a particular information source with an SSI. For example, if 46 people in Group 1 indicated they received their information on climate change from social media, I recorded 46 in the cell of the matrix for social media and climate change. After the matrix was created the bipartite network was made.

Results

Survey Instrument Validation

To conduct the Rasch analysis, I collected a convenience sample of 66 survey responses from undergraduates within an introductory biology course at a university in the southeastern portion of the United States. The Rasch analysis determined that a dichotomous scale had a better fit than a four-point Likert scale. All items fell within the acceptable fit statistics range (See Appendix 3A), except Human Evolution items (Q8.1_1, Q8.1_4, Q8.1_5, Q8.1_7, Q8.1_8) and two pollution items (Q11.1_4, Q11.1_7). Because Human Evolution items were pulled from a previously validated instrument, I decided to keep them in the final survey version to allow for comparison in future studies. The two pollution items were kept because they are topics often discussed within classrooms on pollution (i.e., fossil fuels create pollution; humans create pollution) and, therefore, made conceptual sense to keep in the survey.

From the initial survey, I removed one item each from Climate Change (Q5.1_3), Invasive Species (Q9.1_5), and Pesticides (Q10.1_5, Q10.1_6). These items were combinations of other items in the construct (e.g., Q5.1_3 combined Q5.1_1 and Q5.1_2) and did not add any new understanding to survey responses since the initial Likert scale was reduced from four to two points. Therefore, I was able to reduce survey fatigue while maintaining the information captured by removing these items.

The final survey consisted of an agree/disagree scale for 44 items across eight SSI topics with individuals being prompted to select their main information source (i.e., academic journals, direct communication, news, other, or social media) and to type out the specific information source (e.g., Facebook, CNN) for each SSI topic. At the beginning of the survey, individuals were asked a series of demographic questions on age, major, parents' level of education, gender identity, race/ethnicity, international student status, religious identity, religiosity, political identity, household income, size of household, hometown setting (e.g., rural), and US state location (See Appendix 3B). The final survey was sent to biology instructors through listservs for the NARST Association and Society for the Advancement of Biology Education during the Fall semester of 2021. The biology instructors then shared the survey with undergraduates in their classes. Undergraduates were offered the opportunity to be entered into a drawing for one of eight $25 Amazon gift cards by providing their email in a separate form, so that surveys were anonymous.

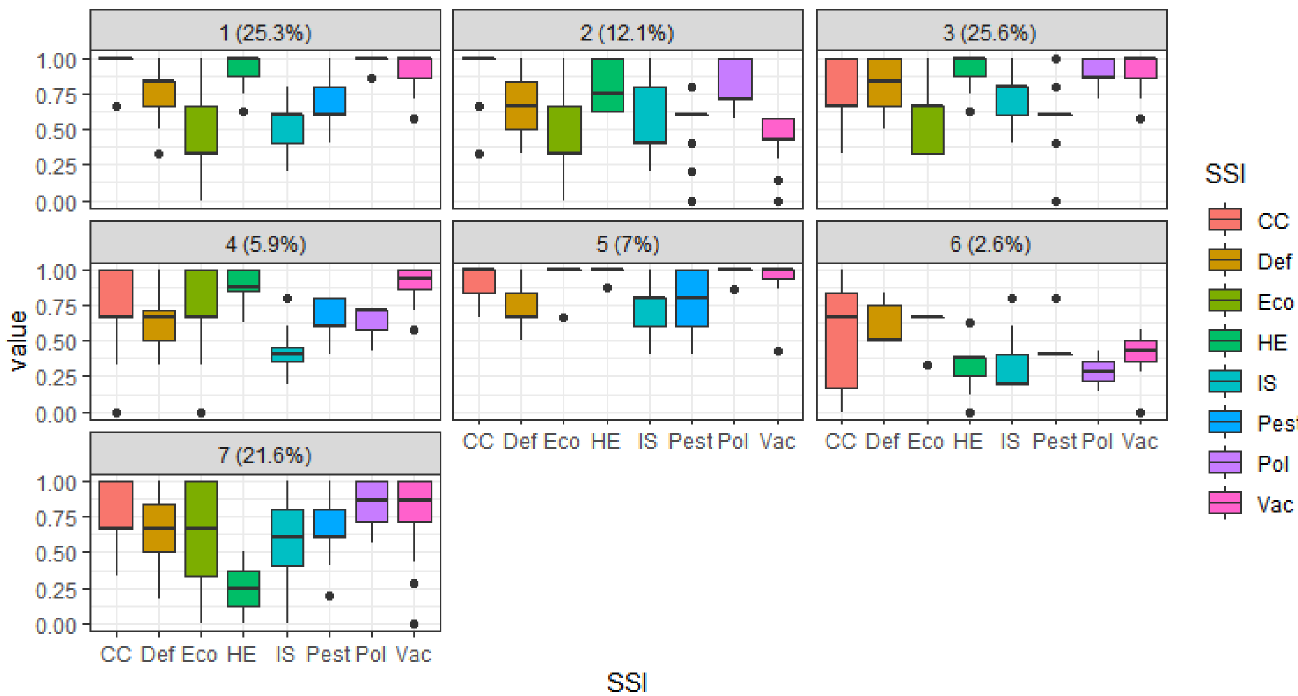
RQ1: Profile Analysis

With the final survey, I collected 385 survey responses. From these 385 responses, a total of 112 responses were removed because they did not complete the survey (100 responses), consent to data collection (11 responses), or were not an undergraduate (1 response). For the remaining 273 responses, the exploratory latent profile analysis showed that the best fitting model assumed equal variances and covariances fixed to zero (Model 1) for 7 groups (Figure 1). Overall, the demographics that had the highest percentages from respondents were woman (70.0%), white (58.6%), non-Evangelical Christian (44.0%), politically moderate (26.4%), household income of

$100,000-$199,999 (24.5%), household size of four (25.3%), hometown located in an urban area (76.9%), and at least one parent holds a bachelor's degree (28.9%), with a mean age of 20.5 years. A brief description of the groups derived from the latent profile analysis is below (Figure 1; See Appendix 3C for demographic table).

Figure 3.1

Boxplot representing undergraduate acceptance rates of SSI for each group



Note. Numbers represent the different groups were created from the latent profile analysis. Percentages represent the percent of the total sample within each group. Colors represent the different SSI (CC = Climate Change, Def = Deforestation, Eco = Ecotourism, HE = Human Evolution, IS = Invasive Species, Pest = Pesticides, Pol = Pollution, Vac = Vaccination). Horizontal black line within boxes represent median. Black dots represent outliers.

Group 1 contained 69 individuals (25.3% of respondents) that had high acceptance rates of climate change ($\bar{x}$ = 0.96), human evolution ($\bar{x}$ = 0.95), pollution ($\bar{x}$ = 0.98), and vaccination ($\bar{x}$ = 0.92) concepts and low acceptance rates of ecotourism ($\bar{x}$ = 0.50) and invasive species ($\bar{x}$ = 0.53) concepts. Since they had high acceptance for climate change, human evolution, pollution, and vaccination, Group 1 was named the Popular Topics group because these are topics that are typically seen discussed outside the science classroom. For this group, individuals ranged in age from 18-27 years old. The demographics with the highest percentages were white (71.0%), woman (63.8%), politically liberal (31.9%), non-Evangelical Christian (42.0%), a parent with a bachelor's degree (36.2%), household income between $100,000-$199,999 (31.9%), six or more individuals in the household (27.5%), and a hometown located in an urban area (71.0%). For Christian identifying individuals, most stated they were a part of the Church of Jesus Christ of Latter-Day Saints (21.7%).

Group 2 contained 33 individuals (12.3% of respondents) who had high acceptance rates of climate change ($\bar{x}$ = 0.91), human evolution ($\bar{x}$ = 0.80), and pollution ($\bar{x}$ = 0.82) and low acceptance rates of ecotourism ($\bar{x}$ = 0.53), invasive species ($\bar{x}$ = 0.54), pesticides ($\bar{x}$ = 0.58) and vaccination ($\bar{x}$ = 0.44) concepts. Although they had high acceptance of human evolution and pollution, Group 2 was named the Climate Focus group because the medians for human evolution (median = 0.75) and pollution (median = 0.71) were much lower than climate change (median = 1), indicating a stronger overall group acceptance of climate change. For this group, individuals ranged in age from 18-38 years old. The demographics with the highest percentages were white (51.0%), woman (69.7%), politically conservative or declined to state (27.3%), non-Evangelical Christian

(42.4%), a parent with a master's degree (36.2%), household income between $25,000-$49,999 (27.3%), four individuals in the household (27.5%), and a hometown located in an urban area (75.8%). For Christian identifying individuals, most stated they were Baptist (30.3%).

Group 3 contained 70 individuals (25.6% of respondents) who had high acceptance rates of human evolution ($\bar{x}$ = 0.93), deforestation ($\bar{x}$ = 0.85), pollution ($\bar{x}$ = 0.89), and vaccination ($\bar{x}$ = 0.91) concepts and low acceptance rates of ecotourism ($\bar{x}$ = 0.57) and pesticides ($\bar{x}$ = 0.59) concepts. Group 3 was named the Human Focus group because most of their high acceptance SSI (i.e., human evolution, pollution, vaccination) are often discussed as having direct impacts on humans, whereas their low acceptance SSI are discussed as having direct impacts on other organisms (e.g., pesticides killing fish). For this group, individuals ranged in age from 18-23 years old. The demographics with the highest percentages were white (47.1%), woman (71.4%), politically liberal or moderate (30.0%), non-Evangelical Christian (40.0%), a parent with a bachelor's degree (31.4%), household income between $25,000-$49,999 or $100,000-$199,999 (22.9%), four individuals in the household (27.1%), and a hometown located in an urban area (90.0%). For Christian identifying individuals, most stated they were a part of the Church of Jesus Christ of Latter-Day Saints (28.6%).

Group 4 contained 16 individuals (5.9% of respondents) who had high acceptance rates of vaccination ($\bar{x}$ = 0.89) concepts and low acceptance rates of invasive species ($\bar{x}$ = 0.41) concepts. Due to their only SSI with high acceptance being vaccination, Group 4 was named the Vaccination Focus group. For this group, individuals ranged in age from 18-36 years old. The demographics with the highest percentages were white (56.3%), woman (81.3%), politically moderate (50.0%), non-Evangelical Christian (68.8%), a parent with a bachelor's degree (25.0%), household income between $25,000-$49,999 (37.5%), six or more individuals in the household (37.5%), and a hometown located in an urban area (68.8%). For Christian identifying individuals, most stated they were a part of the Church of Jesus Christ of Latter-Day Saints (37.5%).

Group 5 contained 19 individuals (7% of respondents) that had high acceptance rates of climate change ($\bar{x}$ = 0.91), ecotourism ($\bar{x}$ = 0.96), human evolution ($\bar{x}$ = 0.99), pesticide ($\bar{x}$ = 0.80), pollution ($\bar{x}$ = 0.99), and vaccination ($\bar{x}$ = 0.94) and did not have a low acceptance for any of the SSI. Because Group 5 did not have any low acceptance of SSI and had high acceptance for most SSI, they were named the Overall Acceptance group. For this group, individuals ranged in age from 18-30 years old. The demographics with the highest percentages were white (78.9%), woman (57.9%), politically liberal (31.6%), non-Evangelical Christian (42.1%), a parent with a master's degree (36.8%), household income between $50,000-$99,999 (31.6%), three or at least six individuals in the household (21.1%), and a hometown located in an urban area (84.2%). For Christian identifying individuals, most stated they were a part of the Church of Jesus Christ of Latter-Day Saints (47.4%).

Group 6 contained 7 individuals (2.6% of respondents) that did not have high acceptance rates for any of the SSI and low acceptance rates for climate change ($\bar{x}$ = 0.52), human evolution ($\bar{x}$ = 0.32), invasive species ($\bar{x}$ = 0.34), pesticides ($\bar{x}$ = 0.46), pollution ($\bar{x}$ = 0.29), vaccination ($\bar{x}$ = 0.39). Most of the SSI had low acceptance within Group 6 and none of the SSI had high acceptance, which is why Group 6 was named the Overall Rejection group. For this group, individuals ranged in age from 18-22 years old.

The demographics with the highest percentages were white (85.7%), woman (85.7%), politically extremely conservative (57.1%), non-Evangelical Christian (57.1%), a parent with some college but no degree (57.1%), household income between $50,000-$99,999 or $100,000-$199,999 (28.6%), three, four, or at least six individuals in the household (28.6%), and a hometown located in a rural area (71.4%). For Christian identifying individuals, most stated they were Baptist (57.1%).

Group 7 contained 59 individuals (21.6% of respondents) that had high acceptance rates of climate change ($\bar{x}$ = 0.80), pollution ($\bar{x}$ = 0.85), and vaccination ($\bar{x}$ = 0.80) and low acceptance rates for human evolution ($\bar{x}$ = 0.26) and invasive species ($\bar{x}$ = 0.54). For Group 7, they had the lowest average acceptance of human evolution compared to the other groups and were therefore named the Human Evolution Rejection group. For this group, individuals ranged in age from 18-30 years old. The demographics with the highest percentages were white (52.5%), woman (74.6%), politically moderate (28.8%), non-Evangelical Christian (44.1%), a parent with a bachelor's degree (28.8%), household income between $50,000-$99,999 (35.6%), four individuals in the household (35.6%), and a hometown located in an urban area (74.6%). For Christian identifying individuals, most stated they were Baptist (28.8%).

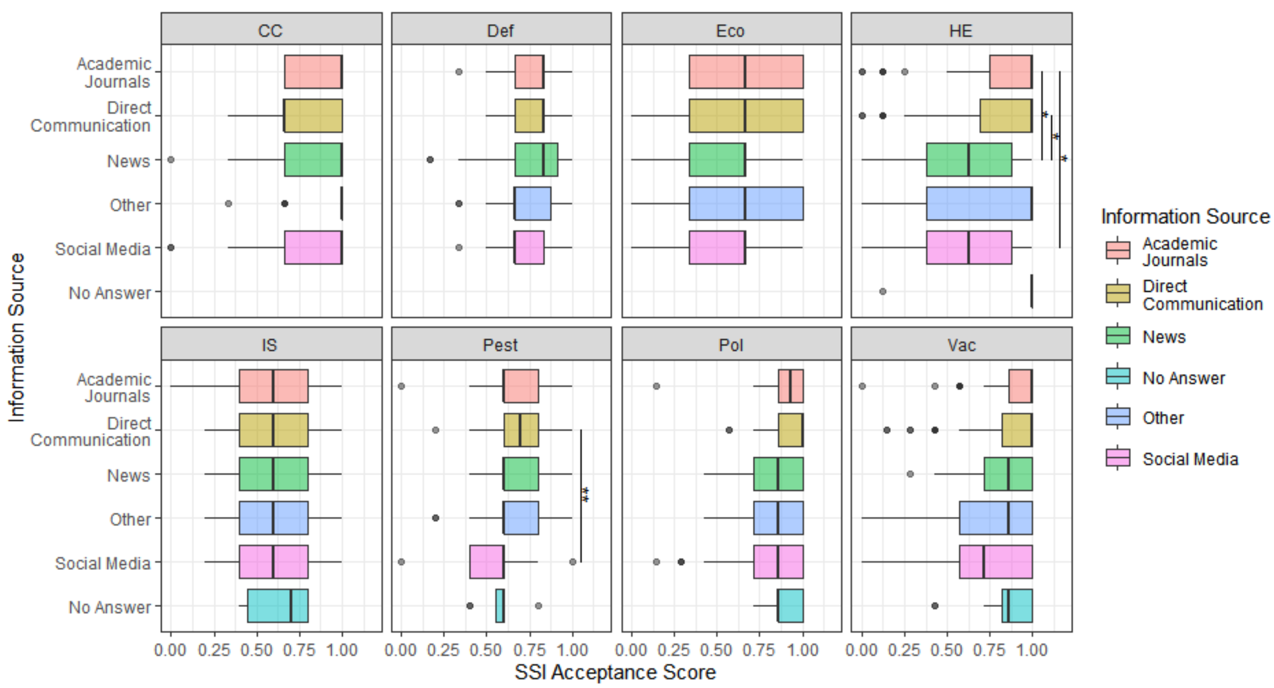
RQ2: Information Sources and Acceptance of SSI

For most of the SSI topics, there were no differences in SSI acceptance between information sources with the exceptions being human evolution, $F(4, 268) = 3.801$, $p = .002$, and pesticides, $F(4, 268) = 3.585$, $p = .004$. For human evolution, SSI acceptance was higher for individuals who indicated academic journals (M = 0.83, SD = 0.27) as their main information source compared to those who indicated the news (M = 0.60, SD =

0.32), p = .012, or social media (M = 0.62, SD = 0.29), p = .042. SSI acceptance was also higher for human evolution among individuals who indicated direct communication (M = 0.81, SD = 0.29) was their information source as compared to the news (M = 0.60, SD = 0.32), p = .042. For pesticides, individuals who indicated direct communication (M = 0.71, SD = 0.18) was their information source had higher SSI acceptance than individuals who indicated social media (M = 0.58, SD = 0.18) was their information source (Figure 2).

Figure 3.2

Boxplot representing undergraduate acceptance rates of SSI for each information source by SSI



Note. Vertical black line with * above boxes highlight significantly different comparisons (* < .05, ** < .01). Vertical black line within box represents median. Black dots represent outliers. Titles on panels represent the different SSI (CC = Climate Change, Def =

Deforestation, Eco = Ecotourism, HE = Human Evolution, IS = Invasive Species, Pest = Pesticides, Pol = Pollution, Vac = Vaccination).

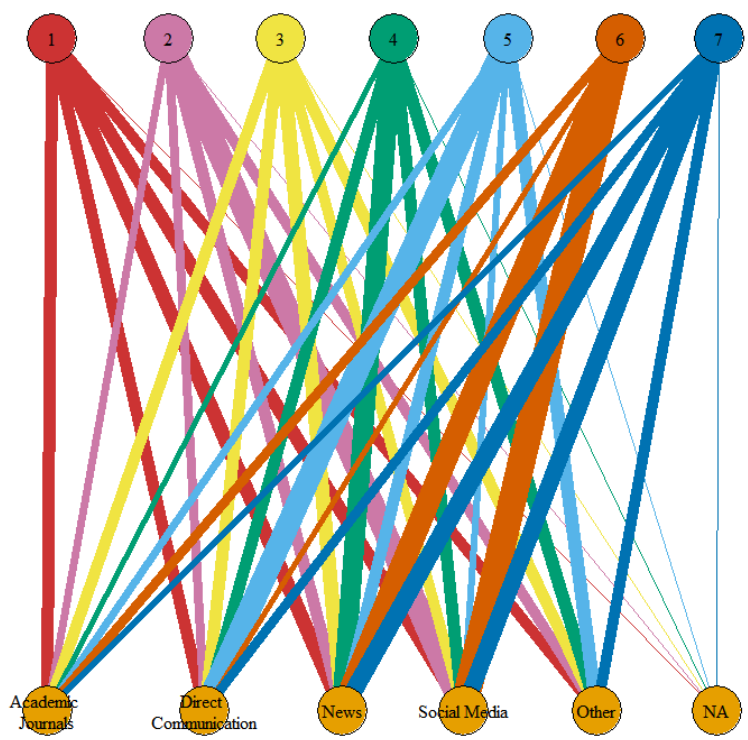
RQ3: Relationship Between Group Profiles and SSI Information Sources

All groups, except the Overall Rejection group, utilized all information sources across all SSI topics (Figure 3.3). For the Overall Rejection group, they did not indicate using another information source outside of those provided in the survey (i.e., they did not select the “Other” option in the survey). When looking at the overall usage of information sources, some groups (i.e., Popular Topics, Human Focus, Vaccination Focus, Human Evolution Rejection) have a more uniform usage across multiple information sources, whereas other groups have usage that is skewed toward social media (i.e., Climate Focus, Overall Rejection) or direct communication (i.e., Overall Acceptance) (Figure 3.3). When looking at the groups’ information source usage by SSI, usage of information sources varies by SSI (Figure 3.4; See Appendix 3D).

For climate change as an SSI, social media (34.8%) and the news (34.8%) made up the majority of total information sources accessed across all study participants. Within each group, social media and the news made up the majority of information sources, except for the Overall Acceptance group. In the Overall Acceptance group, other sources had the largest percentage of information sources (31.6%) with individuals indicating their professor, National Geographic, classes, peers, friends, Scientific American, Science Direct, Twitter, and Facebook as common sources. While some of these may fall into “other information source” categories, individuals made it a point to type out these sources and highlight that they used them simultaneously. This could mean that these individuals did not feel as though they had one main information, as the survey prompted, or they saw these sources as providing unique information.

Figure 3.3

Bipartite network for SSI groups and information sources



Note. Top row of circles with numbers represents SSI groups (1 = Popular Topics; 2 = Climate Focus; 3 = Human Focus; 4 = Vaccination Focus; 5 = Overall Acceptance; 6 = Overall Rejection; 7 = Human Evolution Rejection). Bottom row of circles represents the information sources used by undergraduates. Lines between circles represent a connection between a group and information source because undergraduates from that group selected the information source. Colors for the top row of circle and lines represent the different SSI groups. The width of the lines represents the percentage of undergraduates in a group that selected a particular information source.

For deforestation, social media (33.3%) and the news (30.4%) made up the majority of overall information sources used by the entire sample. In the Human Focus group, the news (30.0%) made up the largest percentage with direct communication (22.9%) and social media (22.9%) tied for the next largest when looking for information related to deforestation. The Overall Acceptance group had direct communication (31.6%) as the largest information source followed by academic journals (21.1%) and social media (21.1%).

Overall, the majority of individuals indicated social media (33.3%) and Other (22.3%) as their information sources when looking for information on ecotourism. Within other sources, most individuals stated that they did not get information on ecotourism, or they did not know about ecotourism. The Popular Topics (34.8%), Climate Focus (51.5%), Human Focus (32.9%), and Overall Rejection (42.9%) groups had social media making up the largest information source.

For the Vaccination Focus group, “other sources” was selected the most (37.5%) and individuals wrote they did not know about ecotourism, had not heard much about it, or their information source was school. The Overall Acceptance group indicated that they received most of their information on ecotourism through direct communication (47.4%). Lastly, 32.2% of the Human Evolution Rejection group had the news as their information source.

When looking for information on human evolution, the majority of individuals stated that direct communication (28.9%) and academic journals (27.1%) were their information sources. The Popular Topics, Human Focus, and Vaccination Focus groups also had direct communication (Popular Topics = 27.5%, Human Focus = 31.4%, Vaccination Focus = 31.3%) and academic journals (Popular Topics = 40.6%, Human Focus = 31.4%, Vaccination Focus = 25.0%) as the majority of information sources. For the Climate Focus group, academic journals (24.2%) and social media (24.2%) were the most selected information sources. Direct communication (52.6%) was the largest information source for the Overall Acceptance group. In the Overall Rejection group, the majority of individuals indicated the news (42.9%) and social media (28.6%) as their primary information source. Lastly, the Human Evolution Rejection group had direct communication (25.4%) and other sources (30.5%) as the majority of information sources. For other sources, the Human Evolution Rejection group wrote the bible, family, school, church, friends, teachings, a website, God, and textbooks as their sources of information on human evolution.

Individuals had other sources (24.9%) and news (23.1%) for the majority of their information sources on invasive species. Sources of information individuals indicated as other sources were class, common knowledge of ecosystems, ecological literature, textbook, professors, Google, various sources, Twitter, ethics, and documentaries. The Popular Topics, Vaccination Focus, and Human Evolution Rejection groups had other sources (Popular Topics = 26.1%, Vaccination Focus = 31.3%, Human Evolution Rejection = 27.1%) and news (Popular Topics = 24.6%, Vaccination Focus = 31.3%, Human Evolution Rejection = 27.1%) as their main information sources for invasive species. In the Popular Topics group, the other sources were life, class, articles, textbook, professors, ethics, and Twitter. The Vaccination Focus group highlighted biology teachers. Finally, the Human Evolution Rejection group listed no source, class, and "various sources" as their other information sources. For the Climate Focus group, social media (27.3%) and other sources (26.1%) were the majority of information source usage. Within the other sources, Climate Focus individuals stated common knowledge of ecosystems, class, documentaries, and no source as information sources. The Human Focus and Overall Acceptance groups had direct communication (22.9%) and other sources (21.4%) as their top two information sources for invasive species. The Human Focus group's other sources were class, scientific literature, Google, and no source. The Overall Acceptance group had class and no source as their other sources. Lastly, the Overall Rejection group had social media (42.9%), news (28.6%), and academic journals as their primary information sources.

The main information sources used by individuals for pesticides were the news (21.6%) and direct communication (21.2%), which was also the case for the Popular Topics (News = 20.3%, Direct Communication = 20.3%), Vaccination Focus (News = 25.0%, Direct Communication = 43.8%), and Overall Acceptance (News = 21.6%, Direct Communication = 21.2%) groups. The Climate Focus group selected social media (33.3%), other sources (18.2%), and academic journals (18.2%) for the majority of their information sources, with class and no sources stated as the other sources. The Human Focus group utilized other sources (24.3%) and academic journals (22.9%) as their main information sources. For their other sources, the Human Focus group said internet articles, commercials, personal experience, Facebook, Rachel Carson's books, Google

Scholar, JEWL Search, were their information sources. In the Overall Rejection group, social media (28.6%), the news (28.6%), and academic journals (28.6%) were the most selected information sources. The Human Evolution Rejection group had the news (25.4%) and social media (22.0%) as the main information sources.

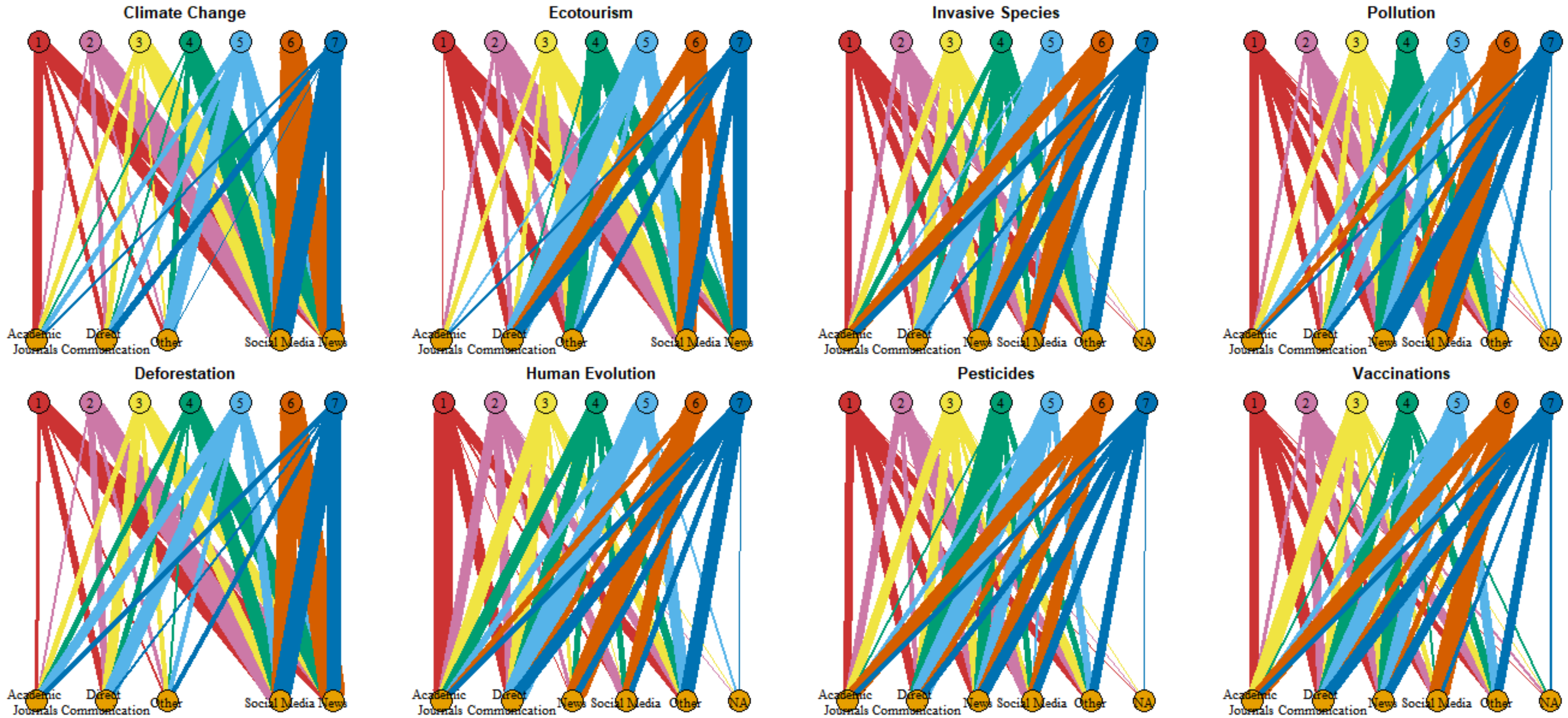
For pollution, individuals used the news (28.9%) and social media (21.2%) the most to find their information. The Climate Focus and Human Evolution Rejection groups also used the news (Climate Focus = 24.2%, Human Evolution Rejection = 37.3%) and social media (Climate Focus = 33.3%, Human Evolution Rejection = 25.4%) the most for their information sources. The Popular Topics group had the news (27.5%) as their top information source but differed by utilizing academic journals (21.7%) much more. In the Human Focus group, the news (24.3%) was the most selected information source, with social media (20.0%) and other sources (20.0%) being the next most selected information sources. For other sources, the Human Focus group highlighted various sources including, class, documentaries, observations, textbooks, scientific journals, Google. The Vaccination Focus group had the highest percentage of individuals (43.8%) choose the news as their main information, followed by other sources (25.0%) that were class and no source. Direct communication (26.3%) and the news (26.3%) were the majority of information sources selected by the Overall Acceptance group. For the Overall Rejection group, social media (71.4%) was dominant information source for individuals.

Lastly, direct communication (24.9%), the news (23.1%), and academic journals (19.4%) made up the majority of sources used by individuals for information on vaccination. The Popular Topics, Vaccination Focus, Overall Acceptance, and Human

Evolution Rejection groups selected direct communication (Popular Topics = 27.5%, Vaccination Focus = 31.3%, Overall Acceptance = 36.8%, Human Evolution Rejection = 27.1%) and the news (Popular Topics = 23.2%, Vaccination Focus = 31.3%, Overall Acceptance = 31.6%, Human Evolution Rejection = 23.7%) as the majority of information sources. The news (21.2%) and direct communication (21.2%) were also highly selected by the Climate Focus group, but other sources (24.2%) were the highest selected information source. The Climate Focus group stated their own judgement, class, news articles, their opinion, and no source as the other sources of information. The Human Focus group had academic journals (32.9%) and the news (20.0%) making up the majority of selected information sources. For the Overall Rejection group, social media (42.9%) and academic journals (28.6%) were the used the most to find information on vaccination.

Figure 3.4

Bipartite networks for SSI groups and information sources separated by each SSI



Note. Top row of circles with numbers represents SSI groups (1 = Popular Topics; 2 = Climate Focus; 3 = Human Focus; 4 = Vaccination Focus; 5 = Overall Acceptance; 6 = Overall Rejection; 7 = Human Evolution Rejection). Bottom row of circles represents the information sources used by undergraduates. Lines between circles represent a connection between a group and information source because undergraduates from that group selected the information source. Colors for the top row of circle and lines represent the different SSI groups. The width of the lines represents the percentage of undergraduates in a group that selected a particular information source. Each panel represents a different SSI.

Limitations

Although the sample size for the validation of the survey followed guidelines from the literature (Linacre, 2002), it might be worthwhile to collect a larger sample size to see if the usage of a dichotomous scale is still the best, rather than a polytomous scale. Also, the sample for the validation step was collected from one university, which may have had an impact on the results. From the survey results, it was evident that many of the respondents did not know anything about ecotourism and therefore the results may not truly reflect their acceptance of ecotourism. This was not anticipated from respondents because ecotourism is discussed within the classroom during topics on population and ecology, as well as outside of the classroom (e.g., safaris), so a description was not included in the survey. In future iterations of this survey, the use of the word ecotourism may need to be accompanied by a description to help respondents, although survey fatigue should be considered when creating the description.

Discussion

This study was conducted to understand the connection between undergraduates' acceptance of SSI and their information sources. From the analysis, I found that there were seven distinct groups (i.e., Popular Topics, Climate Focus, Human Focus, Vaccination Focus, Overall Acceptance, Overall Rejection, Human Evolution Rejection) within the sample that varied based on their acceptance of SSI. SSI acceptance did not differ between most information sources, except for those on human evolution and pesticides. Undergraduates had lower acceptance rates when they received their information on human evolution from social media or the news compared to academic journals or direct communication. When looking individually at each group, undergraduates utilized different sources to gain their information on SSI.

For climate change and pollution, only one group (Overall Rejection) had a low acceptance rate and gained their information from social media and the news, which were also used by the majority of other groups. This could highlight a potential silo effect on information gathered by the undergraduates that is based on their personal beliefs and preferences on climate change (Aruguete & Calvo, 2018). Therefore, it may be challenging to improve these undergraduates' acceptance of climate change and may require interventions that explicitly expose them to information that provides a counterargument to their current ideas.

Ecotourism had three groups (Popular Topics, Climate Focus, Human Focus) with low acceptance rates. For all three of these groups, they gained their information on ecotourism from social media. Despite these being the only groups with low acceptance rates, many undergraduates across groups stated that they did not know about ecotourism. This lack of knowledge about ecotourism and gaining information on social media may indicate that instructors might need to use materials make the connection between the term ecotourism and examples of ecotourism (e.g., safaris, hiking), which may be more familiar to undergraduates.

When looking at human evolution, there were two groups that had low acceptance rates (Overall Rejection and Human Evolution Rejection). For the Overall Rejection group, undergraduates had a lower acceptance rate of human evolution and indicated that their information sources were social media and the news, which follows the overall pattern of information sources used by other groups. In contrast, the Human Evolution

Rejection group had the lowest acceptance rate and indicated direct communication and other sources were their primary information sources. This difference highlights the breadth of sources undergraduates are utilizing to receive information, which may not be the typical sources we would consider. For instance, the Human Evolution Rejection group specifically indicated sources researchers and instructors may assume are utilized by undergraduates who do not accept human evolution (e.g., the bible, church, and family), whereas the Overall Rejection group indicated the news and social media. Also, within these two groups (Overall Rejection and Human Evolution Rejection), the highest selected religion was Baptist, which could be having a potential role in their low acceptance (Barnes et al., 2021; Miller et al., 2021). Although it should be noted that in this study, the Climate Focus group primarily identified as Baptist and had a high acceptance rate of human evolution with academic journals and social media being their primary information sources.

Invasive Species had five groups (Popular Topics, Climate Focus, Vaccination Focus, Overall Rejection, Human Evolution Rejection) that had low acceptance rates with other sources, social media and news being the main sources of information. Within other sources, these groups highlighted academically based resources (e.g., professors, textbooks). This is a potentially alarming result because it could mean that students are leaving the classroom with an alternative conception that they see as "approved" by experts in science. Also, there were no groups that had a high acceptance rate for invasive species, which may further indicate that concepts on invasive species are not being effectively communicated to undergraduates.

For pesticides, there were three groups (Climate Focus, Human Focus, Overall Rejection) that had low acceptance rates. These groups used social media, news, other sources, and academic journals as their information sources for pesticides. For this SSI, undergraduates are pulling from a diversity of information sources but that does not seem to have an impact on their acceptance rates. This is especially interesting considering all three of the groups indicated that academic journals were one of their main information sources because these would be seen as primary literature that aligns with scientific views on pesticides. Since these groups had low acceptance rates despite using academic journals as an information source, this result could point to certain information sources having a greater influence on undergraduate thinking. When investigating factors influencing the public's concern on climate change, Brulle et al. (2012) found that science articles had no impact on public concern, whereas media had a significant impact. Therefore, simply exposing undergraduates to science articles may not be enough.

Finally, the Climate Focus and Overall Rejection groups had low acceptance rates of vaccination. Within the Climate Focus group, direct communication and other sources were the main information sources. For other sources, the Climate Focus group mentioned their own judgement and opinion, highlighting a disregard for scientific information. In contrast, academic journals were one of the main sources for the Overall Rejection group, but they also stated social media was also a main information source.

Across all SSI, social media seems to be an important information source for undergraduates, which is not surprising given the growing presence of social media in society (O'Day & Heimberg, 2021). A result from this study that should be taken note of is that social media is often the main information source for both undergraduates with high and low acceptance rates. This result could highlight undergraduates maintaining social media networks with individuals that are ideologically similar to them, so they are only interacting with information that does not present different opinions (McPherson et al., 2001). Another reoccurring result across SSI was undergraduates indicating academic resources (e.g., academic journals, professors, textbooks) as their main information sources despite having low acceptance rates of SSI. Although research has shown that simply exposing individuals to science information does not help improve science literacy, this mentality still persists within science (Simis et al., 2016). Therefore, instructors need to consider how they approach discussing SSI.

Implications for Teaching

Because students utilize a breadth of information sources to develop their understanding across SSI, it may be important for instructors to engage with multiple information sources to help instructors navigate how to address potential misinformation being brought into the classroom. To encourage this engagement with multiple information sources, instructors could integrate materials pulled from these sources into the classroom (Greenhow & Lewin, 2016). These materials could potentially be integrated into an already developed SSI intervention (e.g., Sadler & Dawson, 2012; Sadler et al., 2017), so the instructor does not have to start from scratch when integrating these materials into their classroom. This could allow instructors to help students 1) improve their understanding of SSI and 2) develop skills to create complex arguments withing real-world situations.

Within the classroom, it has been shown that instructors can highlight scientists who accept evolution during instruction to help improve students’ acceptance of evolution (Barnes et al., 2017a; Truong et al., 2018). For this study, undergraduates from similar religious backgrounds had differing acceptance of human evolution, which could potentially be influenced by their sources of information. Therefore, in addition to prior interventions, there may be the potential to allow students to discuss their views on evolution and where they find information amongst each other. This discussion could further the bridge between the religious and scientific ideologies by allowing students to experience differing ideas from others of similar backgrounds. Having students of similar backgrounds discuss differences in their understanding and acceptance of evolution may allow for a more nuanced discussion on the potential conflict between religious and scientific ideologies that a non-religious instructor may not have. This would also take pressure off of the instructor to know multiple religious perspective and instead allow them to focus on helping manage productive classroom discussion.

Implications for Research

Prior studies have found that information sources have varying impacts on students' discussions of SSI (Bryne et al., 2022; Emery et al., 2017; Lin et al., 2020; Solli et al., 2018). In this study, undergraduates indicated that they used the same information sources, regardless of SSI acceptance, which could highlight students are receiving or seeking information that aligns with their beliefs. Therefore, researchers may benefit from gaining an understanding of where SSI information is coming from and the impact it is has on students SSI acceptance, in order to help improve students' SSI views.

This study highlighted the diversity of information sources used by undergraduates to gain information on SSI. Because biology courses can cover several SSI throughout a semester (Freeman et al., 2019), it might be useful for researchers to understand the sources students are using to gain their information on SSI. For this study, information sources we understood broadly by looking at categories of sources (e.g., news, social media), but future research could benefit from a more fine-grained analysis of information sources.

Conclusions

For this study, I looked at the connection between undergraduates' acceptance of SSI and the sources they used to gather information on SSI. Overall, undergraduates had different rates of acceptance of human evolution and pesticides based on their information sources. Within the sample, there were seven distinct groups of undergraduates that differed based on their acceptance of SSI. Within each group, their information sources varied across SSI, which highlights the extensiveness of information available to students. When comparing groups, information sources overlapped between high and low acceptance groups, with some sources being academic resources. This brings to the forefront the importance for instructors to build discourse within the classroom to allow students the opportunity to engage with different views on SSI and actively work on understanding those differing views. By allowing students to engage in this discourse, instructors can help students to improve their skills to develop complex arguments in real-world situations, which can ultimately help improve students' scientific literacy.

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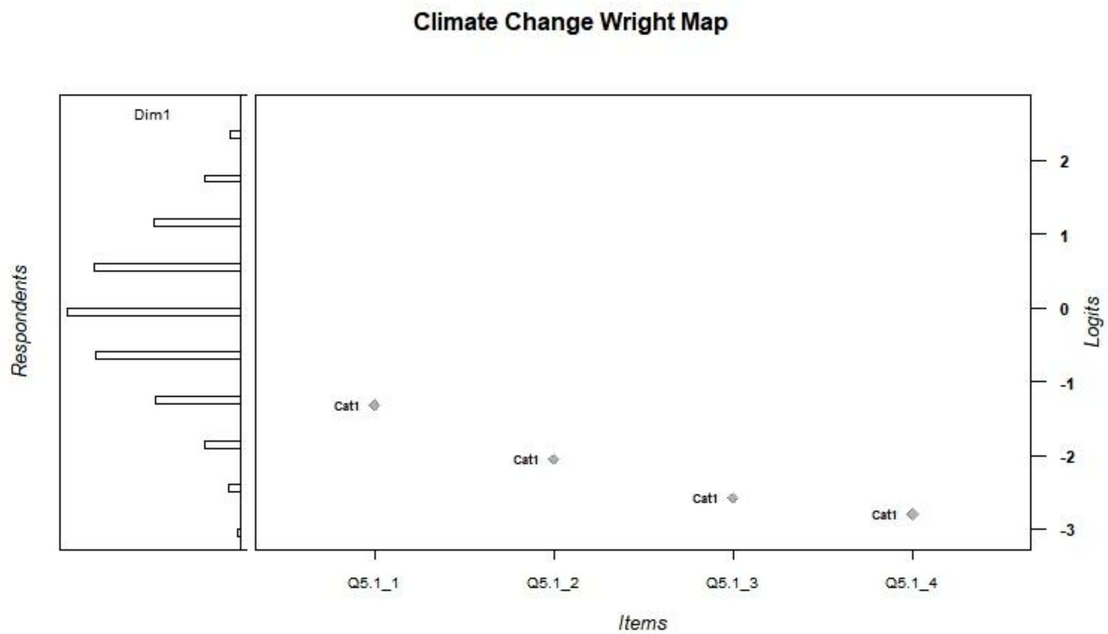
APPENDCIES

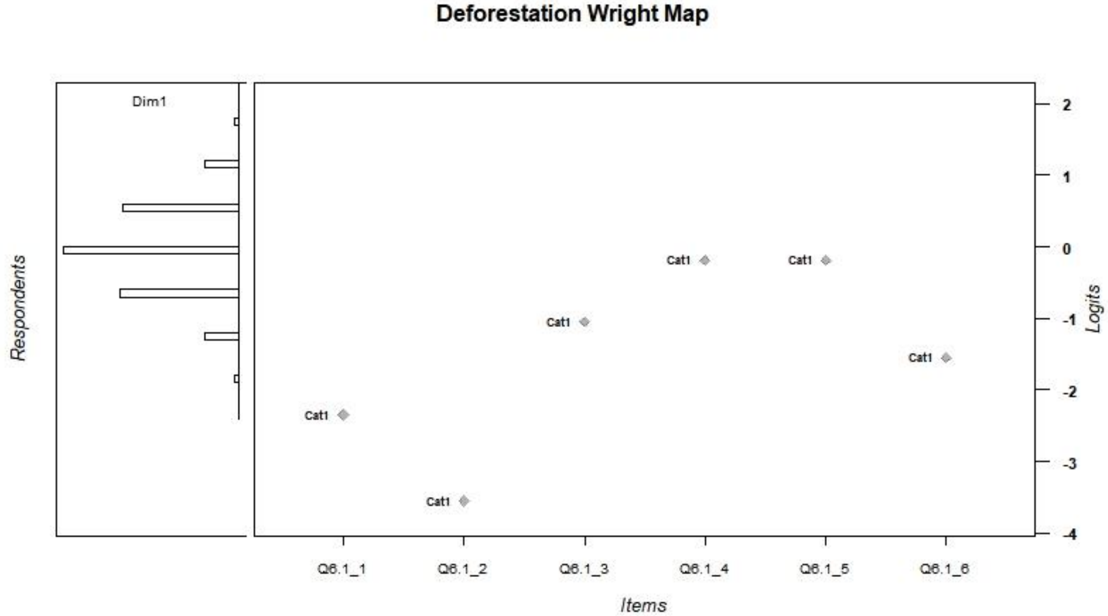
Appendix 3A: Rasch Analysis Fit Statistics and Wright Maps



Climate Change

	parameter	Outfit	Outfit_t	Outfit_p	Outfit_pholm	Infit	Infit_t	Infit_p	Infit_pholm
1	Q5.1_1	1.170885	0.900181	0.368024	1	1.094984	0.575514	0.564944	1
2	Q5.1_2	0.975152	-0.15047	0.880395	1	0.97974	-0.03519	0.971924	1
3	Q5.1_3	0.791386	-0.7558	0.449771	1	0.927083	-0.15214	0.879077	1
4	Q5.1_4	1.153311	0.329464	0.741805	1	1.067902	0.272134	0.785519	1

Q5.1_1: Global climate change is a natural occurrence.
Q5.1_2: Global climate change is caused by humans.
Q5.1_3: Global climate change is a natural occurrence that has been amplified by humans. (Removed)
Q5.1_4: Global climate change is not happening.

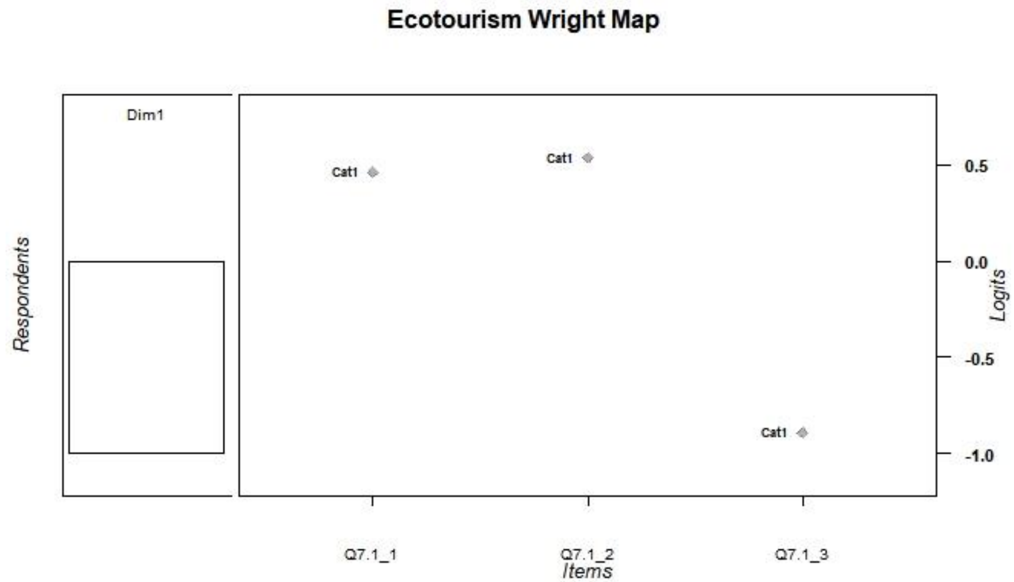


Deforestation

	parameter	Outfit	Outfit_t	Outfit_p	Outfit_pholm	Infit	Infit_t	Infit_p	Infit_pholm
1	Q6.1_1	0.892395	-0.28782	0.773485	1	0.990052	0.066226	0.947198	1
2	Q6.1_2	0.852382	-0.08695	0.930708	1	0.996857	0.206727	0.836223	1
3	Q6.1_3	1.007873	0.064474	0.948593	1	1.015165	0.137716	0.890465	1
4	Q6.1_4	1.018201	0.210148	0.833552	1	1.01416	0.173182	0.862508	1
5	Q6.1_5	1.007636	0.077956	0.937863	1	1.006663	0.07856	0.937382	1
6	Q6.1_6	0.985796	-0.04656	0.962864	1	1.0001	0.051984	0.958541	1

Q6.1_1: Removing native trees and other native plants from an area impacts human health.
Q6.1_2: Removing native trees and other native plants impacts the health of the environment.
Q6.1_3: Removing native trees and other native plants from an area only impacts the area where the plants were removed.
Q6.1_4: If native trees and other native plants are replaced, an area will return to its original habitat.
Q6.1_5: If native trees and other native plants are replaced, an area will never return to its original habitat.

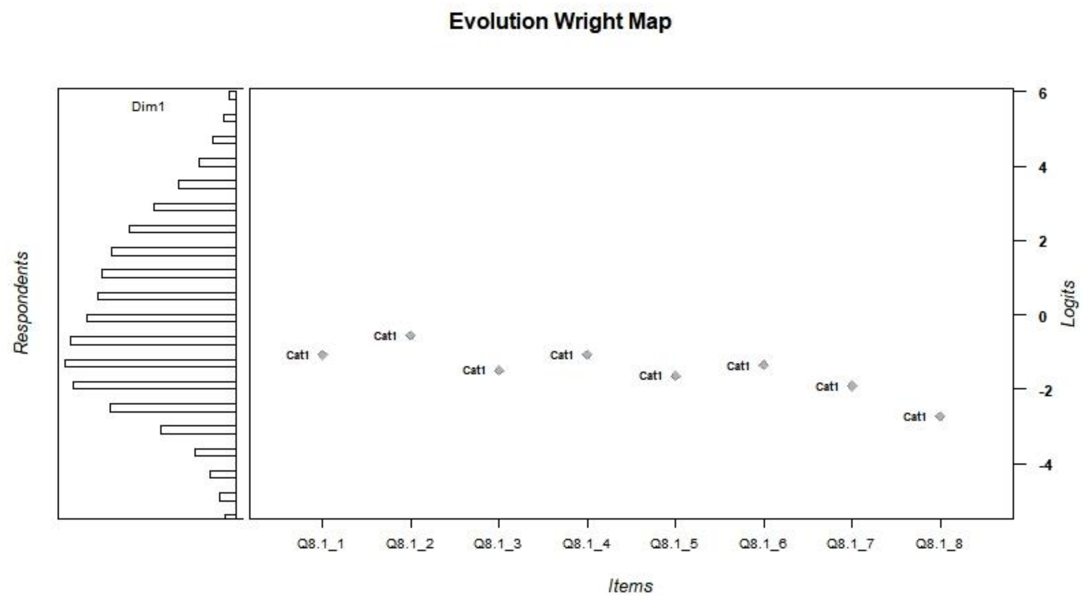
Q6.1_6: Habitats are always changing so it is pointless to replant native trees and other native plants.



Ecotourism

	parameter	Outfit	Outfit_t	Outfit_p	Outfit_pholm	Infit	Infit_t	Infit_p	Infit_pholm
1	Q7.1_1	1	0.020684	0.983498	1	1	0.020684	0.983498	1
2	Q7.1_2	1	0.024086	0.980784	1	1	0.024086	0.980784	1
3	Q7.1_3	1	0.041384	0.96699	1	1	0.041384	0.96699	1

Q7.1_1: Ecotourism is bad because it exploits and destroys habitats.
Q7.1_2: Ecotourism is good because it provides income for people and awareness for the habitat and organisms that live there.
Q7.1_3: Ecotourism is neither good nor bad because it provides some benefit and harm to the habitat and people.

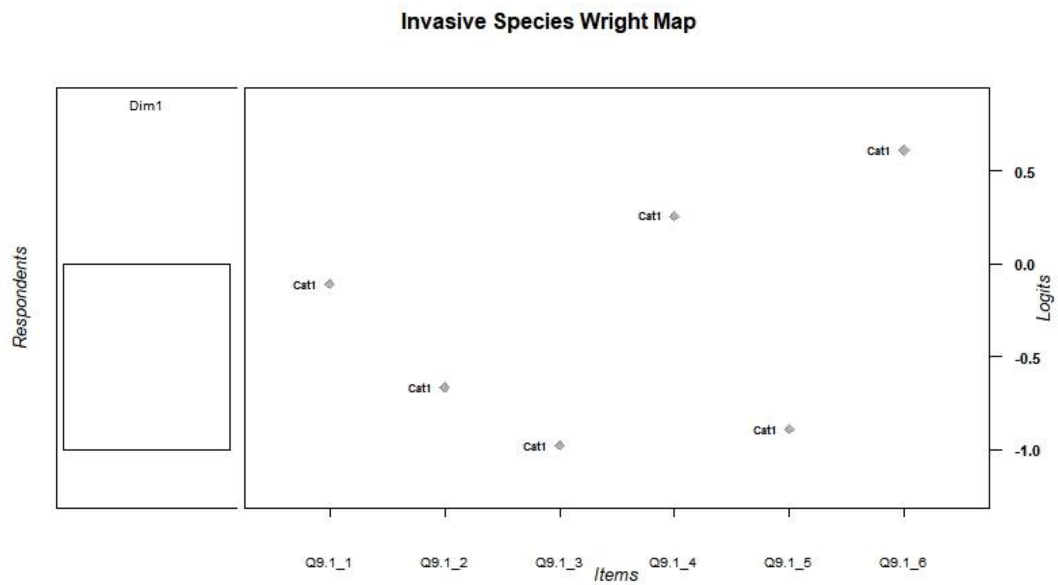


Human Evolution

	parameter	Outfit	Outfit_t	Outfit_p	Outfit_pholm	Infit	Infit_t	Infit_p	Infit_pholm
1	Q8.1_1	0.680363	-2.02287	0.043086	0.215431	0.882725	-0.63519	0.525307	1
2	Q8.1_2	0.883185	-0.75124	0.452509	1	0.964288	-0.16971	0.865241	1
3	Q8.1_3	0.936168	-0.40908	0.682483	1	1.167842	0.86965	0.384492	1
4	Q8.1_4	0.581999	-2.70432	0.006844	0.041066	0.810052	-1.07446	0.282616	1
5	Q8.1_5	0.72493	-1.66021	0.096872	0.387489	0.992326	-0.01626	0.98703	1
6	Q8.1_6	0.884832	-0.71231	0.476274	1	1.135606	0.716075	0.473945	1
7	Q8.1_7	0.426876	-3.68764	0.000226	0.001584	0.73655	-1.42295	0.154752	1
8	Q8.1_8	2.841388	4.370833	1.24E-05	9.90E-05	1.335624	1.268758	0.204527	1

Q8.1_1: There is reliable evidence to support the theory that describes how humans were derived from ancestral primates.
Q8.1_2: Although humans may adapt, humans have not/ do not evolve.

Q8.1_3: I think that the physical structures of humans are too complex to have evolved.
Q8.1_4: Humans do not evolve; they can only change their behavior.
Q8.1_5: The many characteristics that humans share with other primates (i.e., chimpanzees, gorillas) can best be explained by out sharing a common ancestor.
Q8.1_6: I think that humans and apes share an ancient ancestor.
Q8.1_7: I think humans evolve.
Q8.1_8: Physical variations in humans (i.e., eye color, skin color) were derived from the same processes that produce variation in other groups of organisms.

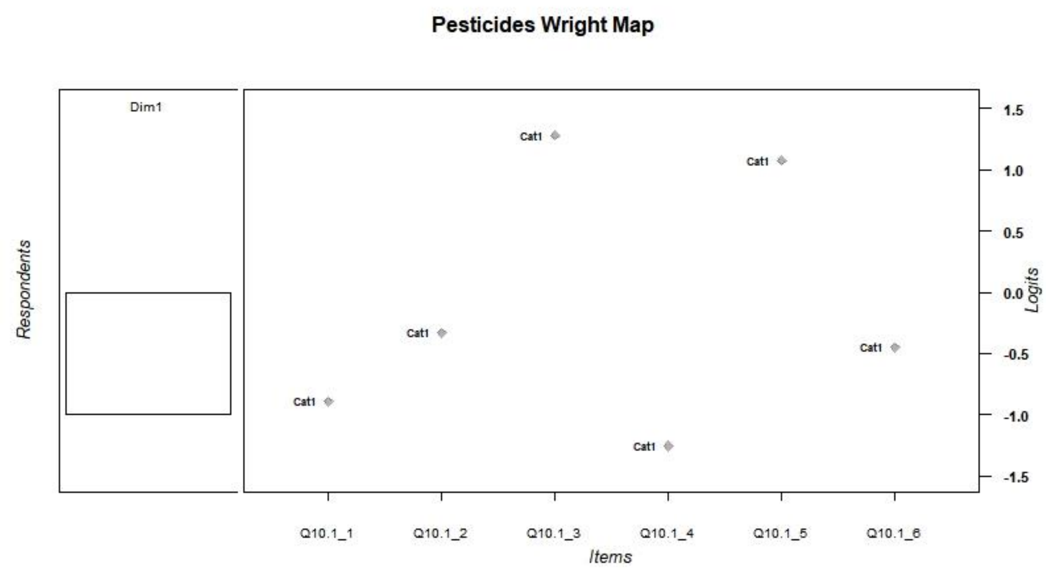


Invasive Species

	parameter	Outfit	Outfit_t	Outfit_p	Outfit_pholm	Infit	Infit_t	Infit_p	Infit_pholm
1	Q9.1_1	1	0.004911	0.996082	1	1	0.004911	0.996082	1
2	Q9.1_2	1	0.031011	0.975261	1	1	0.031011	0.975261	1
3	Q9.1_3	1	0.045873	0.963411	1	1	0.045873	0.963411	1
4	Q9.1_4	1	0.011535	0.990797	1	1	0.011535	0.990797	1

5	Q9.1_5	1	0.041384	0.96699	1	1	0.041384	0.96699	1
6	Q9.1_6	1	0.028144	0.977547	1	1	0.028144	0.977547	1

Q9.1_1: Species introduced to new places by humans need to be removed by humans from that new place.
Q9.1_2: Humans do not need to worry about removing species from new places.
Q9.1_3: As long as introduced species are not hurting the species that were already there, humans do not need to remove them from the new place.
Q9.1_4: Humans need to use any lethal or non-lethal tactics necessary to remove species introduced to new areas.
Q9.1_5: Humans need to only use non-lethal tactics to remove species introduced to new areas. (Removed)
Q9.1_6: Humans should not remove species introduced to new areas.

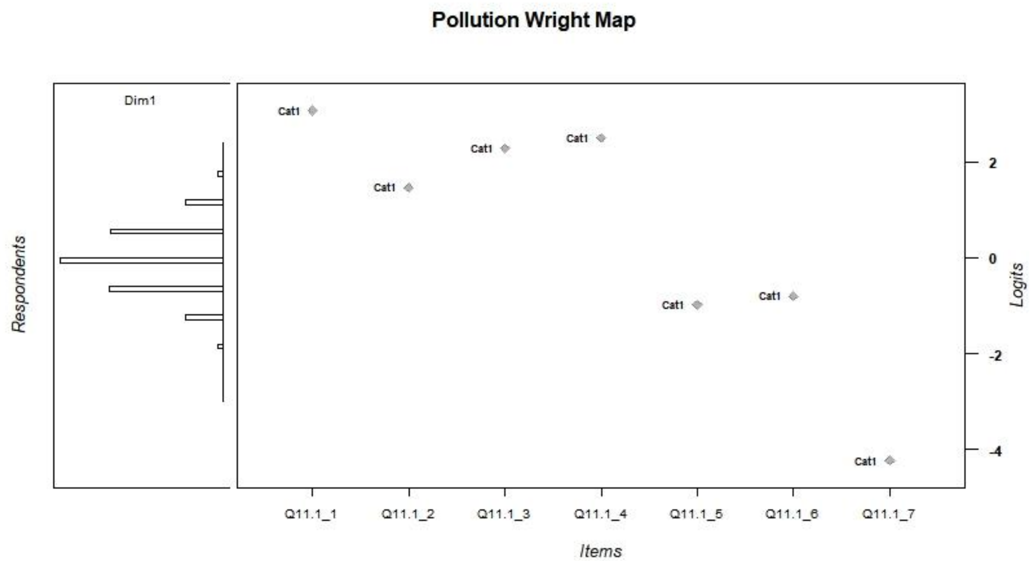


Pesticides

	parameter	Outfit	Outfit_t	Outfit_p	Outfit_pholm	Infit	Infit_t	Infit_p	Infit_pholm
1	Q10.1_1	1	0.041384	0.96699	1	1	0.041384	0.96699	1
2	Q10.1_2	1	0.014911	0.988103	1	1	0.014911	0.988103	1

3	Q10.1_3	1	0.061339	0.95109	1	1	0.061339	0.95109	1
4	Q10.1_4	1	0.060616	0.951665	1	1	0.060616	0.951665	1
5	Q10.1_5	1	0.050653	0.959602	1	1	0.050653	0.959602	1
6	Q10.1_6	1	0.020677	0.983503	1	1	0.020677	0.983503	1

Q10.1_1: Pesticides are harmful to the environment and should not be used.
Q10.1_2: Pesticides are not harmful to the environment and should be used.
Q10.1_3: Pesticides are harmful to the environment, but can be used for specific tasks.
Q10.1_4: Pesticides are harmful to human health.
Q10.1_5: Pesticides are beneficial to human health. (Removed)
Q10.1_6: Pesticides are harmful and beneficial to human health. (Removed)

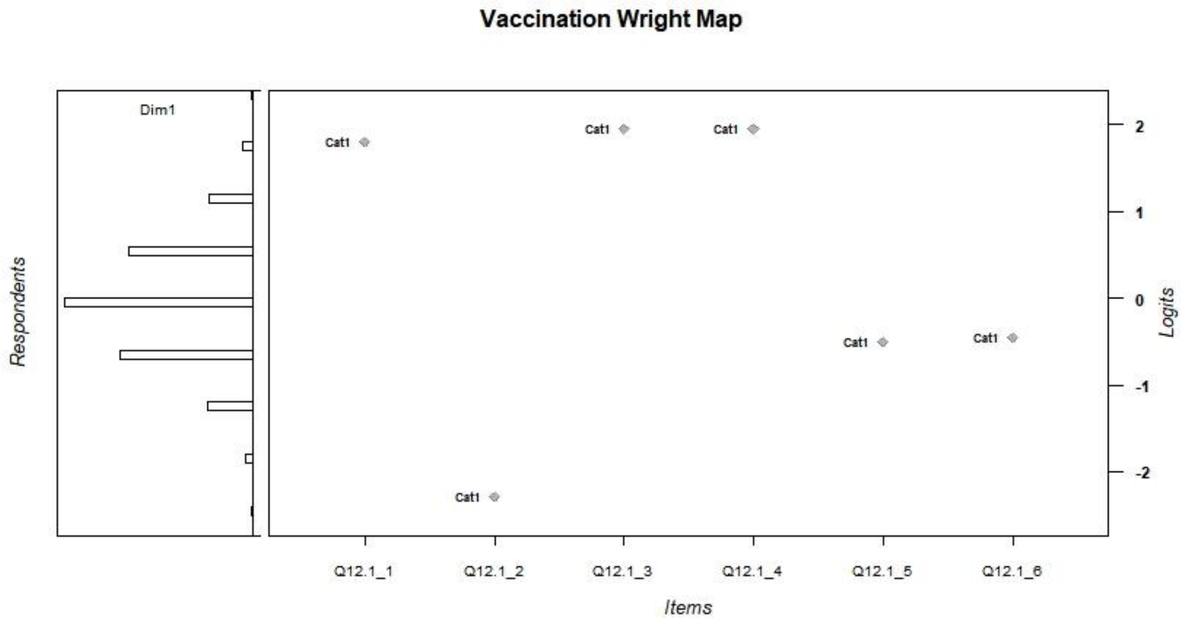


Pollution

	parameter	Outfit	Outfit_t	Outfit_p	Outfit_pholm	Infit	Infit_t	Infit_p	Infit_pholm
1	Q11.1_1	1.129316	0.347869	0.727939	1	1.048158	0.253247	0.800077	1
2	Q11.1_2	0.884368	-0.59511	0.551767	1	0.944099	-0.25837	0.796121	1

3	Q11.1_3	0.838075	-0.49219	0.622584	1	0.962942	-0.02828	0.977437	1
4	Q11.1_4	1.502703	1.204151	0.228531	1	1.096456	0.361814	0.717491	1
5	Q11.1_5	0.990147	-0.08595	0.931503	1	0.993297	-0.03594	0.971328	1
6	Q11.1_6	0.978647	-0.18895	0.850132	1	0.985408	-0.11609	0.907578	1
7	Q11.1_7	1.648501	0.762971	0.445481	1	1.023207	0.334023	0.738362	1

Q11.1_1: Pollution is a global problem.
Q11.1_2: Pollution only impacts urban areas.
Q11.1_3: Pollution is not a problem.
Q11.1_4: Fossil fuels create pollution.
Q11.1_5: Agriculture creates pollution.
Q11.1_6: Natural processes create pollution.
Q11.1_7: Humans create pollution.



Vaccinations

	parameter	Outfit	Outfit_t	Outfit_p	Outfit_pholm	Infit	Infit_t	Infit_p	Infit_pholm
1	Q12.1_1	1.000211	0.012271	0.990209	1	0.976017	-0.03709	0.970417	1
2	Q12.1_2	1.212792	0.631821	0.527504	1	1.027626	0.175311	0.860835	1
3	Q12.1_3	0.873007	-0.46881	0.639203	1	0.928424	-0.20675	0.836209	1
4	Q12.1_4	0.841714	-0.60639	0.544255	1	0.915585	-0.26138	0.793798	1
5	Q12.1_5	1.142054	1.364936	0.172273	1	1.109244	1.071483	0.283952	1
6	Q12.1_6	0.973958	-0.29449	0.768385	1	0.98547	-0.15401	0.877603	1

Q12.1_1: Vaccines are harmful to people and cause diseases.
Q12.1_2: Vaccines are beneficial to people and help reduce diseases.
Q12.1_3: Vaccines are not beneficial to people and do not cause diseases.
Q12.1_4: I will not get any vaccinations.

Q12.1_5: I will get all vaccinations recommended by health professionals.
Q12.1_6: I will pick and choose my vaccinations, regardless of recommendations from health professionals.

Appendix 3B: Survey Instrument for Socioscientific Acceptance

Informed Consent

Please confirm you have read and understand the consent document, which you can find at this link.

Please indicate your consent and eligibility by answering the following questions.

	Yes	No
I have read the informed consent document pertaining to the research.	O	O
The research procedures to be conducted are clear to me.	O	O
I confirm I am 18 years old or older.	O	O
I am aware of the potential risks of the study.	O	O

Please indicate your consent below.

By clicking below, I affirm that I freely and voluntarily choose to participate in this study. I understand I can withdraw from this study at any time without facing any consequences.

- O No, I do not consent.
- O Yes, I consent.

Demographics

How old are you? (If you prefer not to answer, please leave the field blank.)

[ ]

Please indicate your current college major.

[ ]

What is your parents' highest completed level of education? If you have more than one parent with different levels of education, choose the higher of the two.

- O Less than high school completed
- O High school diploma or GED
- O Some college but no degree

- Associates degree (for example: AA, AS)
- Bachelor's degree (for example: BA, AB, BS)
- Master's degree (for example: MA, MS, MEng, MEd, MSW, MBA)
- Higher than a Master's degree (for example: PhD, MD, JD)
- Decline to state

I most closely identify as:

- Man
- Woman
- Nonbinary
- Please describe your gender identity if the best option is not listed: ________
- Decline to state

Choose the race/ethnicity with which you most closely identify. (Select all that apply)

- Asian (East Asian, Southeast Asian, South Asian, West Asian, Middle Eastern)
- African American or Black
- Latinx or Hispanic
- American Indian, Native America, or Alaskan Native
- Native Hawaiian or Other Pacific Islander
- White
- Multiracial (please describe your multiple racial/ethnic identities) ________
- ________ Option not available, please describe:
- Decline to state

Are you an international student?

- Yes
- No
- Decline to state

Please select all that apply:

- East Asian (Chinese, Japanese, Mongolian, North or South Korean, Taiwanese)
- Southeast Asian (Cambodian, Laotian, Myanmari/Burmese, Malaysian, Bruneian, Indonesian, Thai, Timorese, Vietnamese, Bruneian, Singaporean)
- South Asian (Afghan, Bangali, Indian, Maldivian, Nepali, Pakistani, Sri Lankan)
- West Asian/Middle Eastern (Armenian, Azerbaijani, Bahraini, Cypriot, Georgian, Iranian, Iraqi, Israeli, Jordanian, Kuwaiti, Lebanese, Omani, Palestinian, Qatari, Saudi Arabian, Syrian, Turkish, Emirati, Yemeni)
- Filipino
- ______ Option not available, please describe:
- Decline to state

Religiosity

I most closely identify as:

- Buddhist
- Christian
- Hindu
- Jewish
- Muslim
- I don't identify with a religion
- ______ Option not available, please describe:
- Decline to state

Do you identify as Evangelical Christian?

- Yes
- No
- I'm not sure
- Decline to state

With what denomination of Christianity do you most closely identify?

- Catholic
- Jehovah's witness

- Orthodox
- Nondenominational
- Protestant
- Baptist
- The Church of Jesus Christ of Latter Day Saints
- [ ] Option not available, please describe:
- Decline to state

With what branch of Islam do you identify?

- Shia
- Sunni
- [ ] Option not available, please describe:
- Decline to state

I most closely identify as:

- Atheist (believes that God does not exist)
- Agnostic (does not have a definite belief about whether God exists or not)
- [ ] Option not available, please describe:
- Decline to state

With what branch of Judaism do you identify?

- Orthodox
- Conservative
- Reform
- Reconstructionist
- [ ] Option not available, please describe:

With what branch of Hinduism do you identify?

- Shaivism
- Vaishnava

- Shaktism
- Smarta
- [ ] Option not available, please describe:

With what branch of Buddhism do you identify?

- Mahayana
- Theravada
- Vajrayana
- [ ] Option not available, please describe:

Please indicate how much you agree or disagree with the following statements:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I attend religious services regularly (when they are available)	O	O	O	O	O
I believe in a God or Gods	O	O	O	O	O
I consider myself a religious person	O	O	O	O	O
I consider myself a spiritual person	O	O	O	O	O

Demographics 2

Please indicate your political identity.

- Extremely Liberal
- Liberal
- Slightly Liberal
- Moderate
- Slightly Conservative
- Conservative
- Extremely Conservative
- Decline to state

What is your best guess for the yearly income of your household?

- Less than $25,000
- $25,000-$49,999
- $50,000-$99,999
- $100,000 to $199,999
- $200,000 or higher
- Decline to state

How many people including yourself live in your household?

- 1
- 2
- 3
- 4
- 5
- 6 or more
- Decline to state

Where is your hometown located?

- Urban (city, town, suburb)
- Rural (the country)
- Decline to state

Please indicate the US state you live in.

Climate Change

Please select your level agreement to the following statements about global climate change.

	Disagree	Agree
Global climate change is a natural occurrence.	O	O
Global climate change is caused by humans.	O	O
Global climate change is not happening.	O	O

What is the main source you receive your information from on climate change?

- News (example: TV, Newspaper, Magazines)
- Social Media (example: Twitter, Facebook, Instagram)
- Academic Journals (example: Nature, Journal of Evolution)
- Direct Communication with People (example: Family, Friends)
- Other

Based on the previous question, please list the specific name of the source you receive your information from on climate change (example: Facebook). If your source is direct communication with people, please list your relationship with those people (example: mother, father, best friend).

Deforestation

Please select your level agreement to the following statements about deforestation.

	Disagree	Agree
Removing native trees and other native plants from an area impacts human health.	O	O
Removing native trees and other native plants impacts the health of the environment.	O	O
Removing native trees and other native plants from an area only impacts the area where the plants were removed.	O	O
If native trees and other native plants are replaced, an area will return to its original habitat.	O	O
If native trees and other native plants are replaced, an area will never return to its original habitat.	O	O
Habitats are always changing so it is pointless to replant native trees and other native plants.	O	O

What is the main source you receive your information from on deforestation?

- News (example: TV, Newspaper, Magazines)
- Social Media (example: Twitter, Facebook, Instagram)
- Academic Journals (example: Nature, Journal of Evolution)
- Direct Communication with People (example: Family, Friends)

- Other

Based on the previous question, please list the specific name of the source you receive your information from on deforestation (example: Facebook)? If your source is direct communication with people, please list your relationship with those people (example: mother, father, best friend).

Ecotourism

Please select your level agreement to the following statements about ecotourism.

	Disagree	Agree
Ecotourism is bad because it exploits and destroys habitats.	○	○
Ecotourism is good because it provides income for people and awareness for the habitat and organisms that live there.	○	○
Ecotourism is neither good nor bad because it provides some benefit and harm to the habitat and people.	○	○

What is the main source you receive your information from on ecotourism?

- News (example: TV, Newspaper, Magazines)
- Social Media (example: Twitter, Facebook, Instagram)
- Academic Journals (example: Nature, Journal of Evolution)
- Direct Communication with People (example: Family, Friends)
- Other

Based on the previous question, please list the specific name of the source you receive your information from on ecotourism (example: Facebook)? If your source is direct communication with people, please list your relationship with those people (example: mother, father, best friend).

Human Evolution

Please select your level agreement to the following statements about evolution.

	Disagree	Agree
There is reliable evidence to support the theory that describes how humans were derived from ancestral primates.	O	O
Although humans may adapt, humans have not/ do not evolve.	O	O
I think that the physical structures of humans are too complex to have evolved.	O	O
Humans do not evolve; they can only change their behavior.	O	O
The many characteristics that humans share with other primates (i.e., chimpanzees, gorillas) can best be explained by our sharing a common ancestor.	O	O
I think that humans and apes share an ancient ancestor.	O	O
I think humans evolve.	O	O
Physical variations in humans (i.e., eye color, skin color) were derived from the same processes that produce variation in other groups of organisms.	O	O

What is the main source you receive your information from on evolution?

- News (example: TV, Newspaper, Magazines)
- Social Media (example: Twitter, Facebook, Instagram)
- Academic Journals (example: Nature, Journal of Evolution)
- Direct Communication with People (example: Family, Friends)
- Other

Based on the previous question, please list the specific name of the source you receive your information from on evolution (example: Facebook). If your source is direct communication with people, please list your relationship with those people (example: mother, father, best friend).

Invasive Species

Please select your level agreement to the following statements about invasive species.

	Disagree	Agree
Species introduced to new places by humans need to be removed by humans from that new place.	O	O
Humans need to only use non-lethal tactics to remove species introduced to new areas.	O	O
As long as introduced species are not hurting the species that were already there, humans do not need to remove them from the new place.	O	O
Humans need to use any lethal or non-lethal tactics necessary to remove species introduced to new areas.	O	O
Humans should not remove species introduced to new areas.	O	O

What is the main source you receive your information from on invasive species?

- O News (example: TV, Newspaper, Magazines)
- O Social Media (example: Twitter, Facebook, Instagram)
- O Academic Journals (example: Nature, Journal of Evolution)
- O Direct Communication with People (example: Family, Friends)
- O Other

Based on the previous question, please list the specific name of the source you receive your information from on invasive species (example: Facebook)? If your source is direct communication with people, please list your relationship with those people (example: mother, father, best friend).

Pesticides

Please select your level agreement to the following statements about pesticides.

	Disagree	Agree
Pesticides are harmful to the environment and should not be used.	O	O
Pesticides are not harmful to the environment and should be used.	O	O
Pesticides are harmful to the environment and can be used for specific tasks.	O	O
Pesticides are harmful to human health.	O	O

	Disagree	Agree
Pesticides are beneficial to human health.	O	O

What is the main source you receive your information from on pesticides?

- News (example: TV, Newspaper, Magazines)
- Social Media (example: Twitter, Facebook, Instagram)
- Academic Journals (example: Nature, Journal of Evolution)
- Direct Communication with People (example: Family, Friends)
- Other

Based on the previous question, please list the specific name of the source you receive your information from on pesticides (example: Facebook)? If your source is direct communication with people, please list your relationship with those people (example: mother, father, best friend).

Pollution

Please select your level agreement to the following statements about pollution.

	Disagree	Agree
Pollution is a global problem.	O	O
Pollution only impacts urban areas.	O	O
Pollution is not a problem.	O	O
Fossil fuels create pollution.	O	O
Agriculture creates pollution.	O	O
Natural processes create pollution.	O	O
Humans create pollution.	O	O

What is the main source you receive your information from on pollution?

- News (example: TV, Newspaper, Magazines)
- Social Media (example: Twitter, Facebook, Instagram)
- Academic Journals (example: Nature, Journal of Evolution)
- Direct Communication with People (example: Family, Friends)
- Other

Based on the previous question, please list the specific name of the source you receive your information from on evolution (example: Facebook)? If your source is direct communication with people, please list your relationship with those people (example: mother, father, best friend).

Vaccination

Please select your level agreement to the following statements about vaccinations.

	Disagree	Agree
Vaccines prevent disease.	○	○
Vaccines are harmful to people.	○	○
Vaccines cause disease.	○	○
I will not get any vaccinations.	○	○
Vaccines are beneficial to people.	○	○
I will get all vaccinations recommended by health professionals.	○	○
I will pick and choose my vaccinations, regardless of recommendations from health professionals.	○	○

What is the main source you receive your information from on vaccinations?

- ○ News (example: TV, Newspaper, Magazines)
- ○ Social Media (example: Twitter, Facebook, Instagram)
- ○ Academic Journals (example: Nature, Journal of Evolution)
- ○ Direct Communication with People (example: Family, Friends)
- ○ Other

Based on the previous question, please list the specific name of the source you receive your information from on vaccinations (example: Facebook)? If your source is direct communication with people, please list your relationship with those people (example: mother, father, best friend).

Drawing

Would you like to be entered into a drawing for a $25 Amazon gift card?

- Yes
- No

Powered by Qualtrics

Appendix 3C: Demographic table for each SSI group

	1 (N=69)	2 (N=33)	3 (N=70)	4 (N=16)	5 (N=19)	6 (N=7)	7 (N=59)	Total (N=273)
Age								
Mean (SD)	20.1 (1.93)	22.7 (4.20)	19.5 (1.74)	21.0 (4.24)	19.4 (2.73)	20.6 (1.27)	21.4 (2.45)	20.5 (2.79)
Median (Min, Max)	20.0 (18.0, 27.0)	21.0 (18.0, 38.0)	19.0 (18.0, 23.0)	20.5 (18.0, 36.0)	19.0 (18.0, 30.0)	21.0 (18.0, 22.0)	21.0 (18.0, 30.0)	20.0 (12.0, 38.0)
Missing	1 (1.4%)	0 (0%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	1 (1.7%)	3 (1.1%)
Parents' Highest Degree								
Associates degree	2 (2.9%)	2 (6.1%)	3 (4.3%)	1 (6.3%)	1 (5.3%)	1 (14.3%)	7 (11.9%)	17 (6.2%)
Bachelor's degree	25 (36.2%)	6 (18.2%)	22 (31.4%)	4 (25.0%)	3 (15.8%)	2 (28.6%)	17 (28.8%)	79 (28.9%)
High school diploma or GED	12 (17.4%)	4 (12.1%)	9 (12.9%)	2 (12.5%)	1 (5.3%)	0 (0%)	4 (6.8%)	32 (11.7%)
Higher than a Master's degree	11 (15.9%)	0 (0%)	7 (10.0%)	1 (6.3%)	3 (15.8%)	0 (0%)	1 (1.7%)	23 (8.4%)
Less than high school completed	1 (1.4%)	0 (0%)	3 (4.3%)	2 (12.5%)	0 (0%)	0 (0%)	2 (3.4%)	8 (2.9%)
Master's degree	9 (13.0%)	12 (36.4%)	16 (22.9%)	3 (18.8%)	7 (36.8%)	0 (0%)	15 (25.4%)	62 (22.7%)
Some college but no degree	9 (13.0%)	9 (27.3%)	9 (12.9%)	3 (18.8%)	4 (21.1%)	4 (57.1%)	12 (20.3%)	50 (18.3%)
Decline to state	0 (0%)	0 (0%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	1 (1.7%)	2 (0.7%)
Gender Identity								
Decline to state	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1.7%)	2 (0.7%)
Man	22 (31.9%)	8 (24.2%)	18 (25.7%)	3 (18.8%)	7 (36.8%)	0 (0%)	14 (23.7%)	72 (26.4%)

Nonbinary	2 (2.9%)	0 (0%)	1 (1.4%)	0 (0%)	1 (5.3%)	0 (0%)	0 (0%)	4 (1.5%)
Woman	44 (63.8%)	23 (69.7%)	50 (71.4%)	13 (81.3%)	11 (57.9%)	6 (85.7%)	44 (74.6%)	191 (70.0%)
Please describe your gender identity if the best option is not listed:	0 (0%)	2 (6.1%)	1 (1.4%)	0 (0%)	0 (0%)	1 (14.3%)	0 (0%)	4 (1.5%)
Race/Ethnicity								
African American or Black	5 (7.2%)	9 (27.3%)	6 (8.6%)	1 (6.3%)	0 (0%)	0 (0%)	10 (16.9%)	31 (11.4%)
Asian	6 (8.7%)	1 (3.0%)	8 (11.4%)	3 (18.8%)	2 (10.5%)	0 (0%)	4 (6.8%)	24 (8.8%)
Asian, Latinx or Hispanic, White	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.4%)
Asian, Multiracial	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.4%)
Latinx or Hispanic	5 (7.2%)	1 (3.0%)	14 (20.0%)	2 (12.5%)	1 (5.3%)	0 (0%)	6 (10.2%)	29 (10.6%)
Multiracial	2 (2.9%)	3 (9.1%)	0 (0%)	0 (0%)	0 (0%)	1 (14.3%)	0 (0%)	6 (2.2%)
White	49 (71.0%)	17 (51.5%)	33 (47.1%)	9 (56.3%)	15 (78.9%)	6 (85.7%)	31 (52.5%)	160 (58.6%)
Decline to state	0 (0%)	1 (3.0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1.7%)	2 (0.7%)
Latinx or Hispanic, Multiracial	0 (0%)	1 (3.0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.4%)
African American or Black, Latinx or Hispanic	0 (0%)	0 (0%)	2 (2.9%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (0.7%)
Asian, Latinx or Hispanic, White, Multiracial	0 (0%)	0 (0%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.4%)
Asian, White	0 (0%)	0 (0%)	1 (1.4%)	1 (6.3%)	1 (5.3%)	0 (0%)	0 (0%)	3 (1.1%)
Latinx or Hispanic, White	0 (0%)	0 (0%)	4 (5.7%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (1.5%)

African American or Black, Latinx or Hispanic, Multiracial	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (3.4%)	2 (0.7%)
African American or Black, White	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1.7%)	1 (0.4%)
American Indian, Native America, or Alaskan Native	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1.7%)	1 (0.4%)
Asian, African American or Black	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1.7%)	1 (0.4%)
Option not available, please describe:	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (3.4%)	2 (0.7%)
Missing	0 (0%)	0 (0%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.4%)
Asian Ethnicity								
East Asian	1 (1.4%)	0 (0%)	4 (5.7%)	1 (6.3%)	1 (5.3%)	0 (0%)	0 (0%)	7 (2.6%)
Filipino	3 (4.3%)	0 (0%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (1.5%)
South Asian	2 (2.9%)	1 (3.0%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	2 (3.4%)	6 (2.2%)
West Asian/Middle Eastern	2 (2.9%)	0 (0%)	2 (2.9%)	1 (6.3%)	0 (0%)	0 (0%)	1 (1.7%)	6 (2.2%)
Southeast Asian	0 (0%)	0 (0%)	2 (2.9%)	2 (12.5%)	1 (5.3%)	0 (0%)	1 (1.7%)	6 (2.2%)
East, Filipino	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (5.3%)	0 (0%)	0 (0%)	1 (0.4%)
Option not available, please describe:	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1.7%)	1 (0.4%)
Missing	61 (88.4%)	32 (97.0%)	60 (85.7%)	12 (75.0%)	16 (84.2%)	7 (100%)	54 (91.5%)	242 (88.6%)
Religious Identity								
Christian	35 (50.7%)	23 (69.7%)	43 (61.4%)	12 (75.0%)	11 (57.9%)	6 (85.7%)	51 (86.4%)	181 (66.3%)

Decline to state	1 (1.4%)	2 (6.1%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	2 (3.4%)	6 (2.2%)
I don't identify with a religion	25 (36.2%)	5 (15.2%)	19 (27.1%)	1 (6.3%)	7 (36.8%)	0 (0%)	1 (1.7%)	58 (21.2%)
Jewish	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (14.3%)	0 (0%)	2 (0.7%)
Muslim	3 (4.3%)	0 (0%)	1 (1.4%)	1 (6.3%)	0 (0%)	0 (0%)	2 (3.4%)	7 (2.6%)
Option not available, please describe:	4 (5.8%)	1 (3.0%)	4 (5.7%)	1 (6.3%)	1 (5.3%)	0 (0%)	3 (5.1%)	14 (5.1%)
Buddhist	0 (0%)	1 (3.0%)	0 (0%)	1 (6.3%)	0 (0%)	0 (0%)	0 (0%)	2 (0.7%)
Hindu	0 (0%)	1 (3.0%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (0.7%)
Missing	0 (0%)	0 (0%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.4%)
Evangelical Christian Status								
I'm not sure	4 (5.8%)	5 (15.2%)	8 (11.4%)	1 (6.3%)	2 (10.5%)	1 (14.3%)	8 (13.6%)	29 (10.6%)
No	29 (42.0%)	14 (42.4%)	28 (40.0%)	11 (68.8%)	8 (42.1%)	4 (57.1%)	26 (44.1%)	120 (44.0%)
Yes	2 (2.9%)	4 (12.1%)	5 (7.1%)	0 (0%)	1 (5.3%)	1 (14.3%)	14 (23.7%)	27 (9.9%)
Decline to state	0 (0%)	0 (0%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	3 (5.1%)	4 (1.5%)
Missing	34 (49.3%)	10 (30.3%)	28 (40.0%)	4 (25.0%)	8 (42.1%)	1 (14.3%)	8 (13.6%)	93 (34.1%)
Christian Denomination								
Baptist	4 (5.8%)	10 (30.3%)	9 (12.9%)	2 (12.5%)	1 (5.3%)	4 (57.1%)	17 (28.8%)	47 (17.2%)
Catholic	7 (10.1%)	3 (9.1%)	4 (5.7%)	3 (18.8%)	0 (0%)	1 (14.3%)	1 (1.7%)	19 (7.0%)
Nondenominational	4 (5.8%)	4 (12.1%)	6 (8.6%)	0 (0%)	0 (0%)	0 (0%)	11 (18.6%)	25 (9.2%)

Option not available, please describe:	3 (4.3%)	3 (9.1%)	2 (2.9%)	1 (6.3%)	1 (5.3%)	0 (0%)	11 (18.6%)	21 (7.7%)
Orthodox	2 (2.9%)	0 (0%)	1 (1.4%)	0 (0%)	0 (0%)	1 (14.3%)	2 (3.4%)	6 (2.2%)
The Church of Jesus Christ of Latter Day Saints	15 (21.7%)	1 (3.0%)	20 (28.6%)	6 (37.5%)	9 (47.4%)	0 (0%)	3 (5.1%)	54 (19.8%)
Decline to state	0 (0%)	2 (6.1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1.7%)	3 (1.1%)
Protestant	0 (0%)	0 (0%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	5 (8.5%)	6 (2.2%)
Missing	34 (49.3%)	10 (30.3%)	27 (38.6%)	4 (25.0%)	8 (42.1%)	1 (14.3%)	8 (13.6%)	92 (33.7%)
Muslim Denomination								
Shia	2 (2.9%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (0.7%)
Sunni	1 (1.4%)	0 (0%)	1 (1.4%)	1 (6.3%)	0 (0%)	0 (0%)	2 (3.4%)	5 (1.8%)
Missing	66 (95.7%)	33 (100%)	69 (98.6%)	15 (93.8%)	19 (100%)	7 (100%)	57 (96.6%)	266 (97.4%)
Non-Religious Identity								
Agnostic	15 (21.7%)	2 (6.1%)	13 (18.6%)	0 (0%)	5 (26.3%)	0 (0%)	0 (0%)	35 (12.8%)
Atheist	6 (8.7%)	0 (0%)	3 (4.3%)	0 (0%)	1 (5.3%)	0 (0%)	0 (0%)	10 (3.7%)
Decline to state	3 (4.3%)	1 (3.0%)	3 (4.3%)	0 (0%)	0 (0%)	0 (0%)	1 (1.7%)	8 (2.9%)
Option not available, please describe:	0 (0%)	2 (6.1%)	0 (0%)	1 (6.3%)	1 (5.3%)	0 (0%)	0 (0%)	4 (1.5%)
Missing	45 (65.2%)	28 (84.8%)	51 (72.9%)	15 (93.8%)	12 (63.2%)	7 (100%)	58 (98.3%)	216 (79.1%)
Jewish Denomination								
Reform	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.4%)

Orthodox	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (14.3%)	0 (0%)	1 (0.4%)
Missing	68 (98.6%)	33 (100%)	70 (100%)	16 (100%)	19 (100%)	6 (85.7%)	59 (100%)	271 (99.3%)
Buddhist Denomination								
Shaivism	0 (0%)	1 (3.0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.4%)
Option not available, please describe:	0 (0%)	0 (0%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.4%)
Missing	69 (100%)	32 (97.0%)	69 (98.6%)	16 (100%)	19 (100%)	7 (100%)	59 (100%)	271 (99.3%)
Hindu Denomination								
Mahayana	0 (0%)	1 (3.0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.4%)
Option not available, please describe:	0 (0%)	0 (0%)	0 (0%)	1 (6.3%)	0 (0%)	0 (0%)	0 (0%)	1 (0.4%)
Missing	69 (100%)	32 (97.0%)	70 (100%)	15 (93.8%)	19 (100%)	7 (100%)	59 (100%)	271 (99.3%)
Political Identity								
Conservative	8 (11.6%)	9 (27.3%)	6 (8.6%)	4 (25.0%)	1 (5.3%)	2 (28.6%)	14 (23.7%)	44 (16.1%)
Decline to state	6 (8.7%)	9 (27.3%)	5 (7.1%)	3 (18.8%)	0 (0%)	0 (0%)	10 (16.9%)	33 (12.1%)
Extremely Conservative	1 (1.4%)	1 (3.0%)	0 (0%)	0 (0%)	1 (5.3%)	4 (57.1%)	5 (8.5%)	12 (4.4%)
Extremely Liberal	8 (11.6%)	0 (0%)	3 (4.3%)	0 (0%)	1 (5.3%)	0 (0%)	1 (1.7%)	13 (4.8%)
Liberal	22 (31.9%)	2 (6.1%)	21 (30.0%)	0 (0%)	6 (31.6%)	0 (0%)	6 (10.2%)	57 (20.9%)
Moderate	13 (18.8%)	8 (24.2%)	21 (30.0%)	8 (50.0%)	4 (21.1%)	1 (14.3%)	17 (28.8%)	72 (26.4%)
Slightly Conservative	7 (10.1%)	1 (3.0%)	8 (11.4%)	1 (6.3%)	2 (10.5%)	0 (0%)	3 (5.1%)	22 (8.1%)
Slightly Liberal	4 (5.8%)	3 (9.1%)	6 (8.6%)	0 (0%)	4 (21.1%)	0 (0%)	3 (5.1%)	20 (7.3%)

Household Income								
$100,000-$199,999	22 (31.9%)	8 (24.2%)	16 (22.9%)	2 (12.5%)	5 (26.3%)	2 (28.6%)	12 (20.3%)	67 (24.5%)
$200,000 or higher	6 (8.7%)	1 (3.0%)	10 (14.3%)	0 (0%)	2 (10.5%)	1 (14.3%)	4 (6.8%)	24 (8.8%)
$25,000-$49,999	11 (15.9%)	9 (27.3%)	16 (22.9%)	6 (37.5%)	1 (5.3%)	1 (14.3%)	9 (15.3%)	53 (19.4%)
$50,000-$99,999	10 (14.5%)	4 (12.1%)	12 (17.1%)	5 (31.3%)	6 (31.6%)	2 (28.6%)	21 (35.6%)	60 (22.0%)
Decline to state	8 (11.6%)	5 (15.2%)	3 (4.3%)	2 (12.5%)	2 (10.5%)	1 (14.3%)	9 (15.3%)	30 (11.0%)
Less than $25,000	12 (17.4%)	6 (18.2%)	13 (18.6%)	1 (6.3%)	3 (15.8%)	0 (0%)	4 (6.8%)	39 (14.3%)
Individuals in Household								
1	10 (14.5%)	4 (12.1%)	5 (7.1%)	1 (6.3%)	2 (10.5%)	0 (0%)	2 (3.4%)	24 (8.8%)
2	5 (7.2%)	5 (15.2%)	5 (7.1%)	0 (0%)	3 (15.8%)	0 (0%)	13 (22.0%)	31 (11.4%)
3	12 (17.4%)	9 (27.3%)	14 (20.0%)	4 (25.0%)	4 (21.1%)	2 (28.6%)	4 (6.8%)	49 (17.9%)
4	13 (18.8%)	10 (30.3%)	19 (27.1%)	1 (6.3%)	3 (15.8%)	2 (28.6%)	21 (35.6%)	69 (25.3%)
5	10 (14.5%)	4 (12.1%)	14 (20.0%)	4 (25.0%)	2 (10.5%)	1 (14.3%)	12 (20.3%)	47 (17.2%)
6 or more	19 (27.5%)	1 (3.0%)	13 (18.6%)	6 (37.5%)	4 (21.1%)	2 (28.6%)	7 (11.9%)	52 (19.0%)
Decline to state	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (5.3%)	0 (0%)	0 (0%)	1 (0.4%)
Hometown Location								
Rural	20 (29.0%)	8 (24.2%)	7 (10.0%)	5 (31.3%)	3 (15.8%)	5 (71.4%)	15 (25.4%)	63 (23.1%)
Urban	49 (71.0%)	25 (75.8%)	63 (90.0%)	11 (68.8%)	16 (84.2%)	2 (28.6%)	44 (74.6%)	210 (76.9%)

Appendix 3D: Counts and percentages for the number of information sources selected by participants within each SSI group

Socioscientific Issues	1 (N=69)	2 (N=33)	3 (N=70)	4 (N=16)	5 (N=19)	6 (N=7)	7 (N=59)	Total (N=273)
Climate Change								
Academic Journals	14 (20.3%)	2 (6.1%)	7 (10.0%)	1 (6.3%)	2 (10.5%)	0 (0%)	3 (5.1%)	29 (10.6%)
Direct Communication	7 (10.1%)	4 (12.1%)	10 (14.3%)	1 (6.3%)	3 (15.8%)	0 (0%)	9 (15.3%)	34 (12.5%)
News	22 (31.9%)	11 (33.3%)	29 (41.4%)	6 (37.5%)	4 (21.1%)	4 (57.1%)	18 (30.5%)	94 (34.4%)
Other	6 (8.7%)	2 (6.1%)	4 (5.7%)	2 (12.5%)	6 (31.6%)	0 (0%)	1 (1.7%)	21 (7.7%)
Social Media	20 (29.0%)	14 (42.4%)	20 (28.6%)	6 (37.5%)	4 (21.1%)	3 (42.9%)	28 (47.5%)	95 (34.8%)
Deforestation								
Academic Journals	6 (8.7%)	2 (6.1%)	10 (14.3%)	2 (12.5%)	4 (21.1%)	0 (0%)	6 (10.2%)	30 (11.0%)
Direct Communication	12 (17.4%)	5 (15.2%)	16 (22.9%)	2 (12.5%)	6 (31.6%)	0 (0%)	4 (6.8%)	45 (16.5%)
News	23 (33.3%)	7 (21.2%)	21 (30.0%)	6 (37.5%)	3 (15.8%)	4 (57.1%)	19 (32.2%)	83 (30.4%)
Other	5 (7.2%)	3 (9.1%)	7 (10.0%)	1 (6.3%)	2 (10.5%)	0 (0%)	6 (10.2%)	24 (8.8%)
Social Media	23 (33.3%)	16 (48.5%)	16 (22.9%)	5 (31.3%)	4 (21.1%)	3 (42.9%)	24 (40.7%)	91 (33.3%)
Ecotourism								
Academic Journals	2 (2.9%)	3 (9.1%)	7 (10.0%)	0 (0%)	1 (5.3%)	0 (0%)	4 (6.8%)	17 (6.2%)
Direct Communication	13 (18.8%)	4 (12.1%)	8 (11.4%)	1 (6.3%)	9 (47.4%)	2 (28.6%)	12 (20.3%)	49 (17.9%)
News	11 (15.9%)	4 (12.1%)	13 (18.6%)	5 (31.3%)	1 (5.3%)	2 (28.6%)	19 (32.2%)	55 (20.1%)

Other	19 (27.5%)	5 (15.2%)	19 (27.1%)	6 (37.5%)	2 (10.5%)	0 (0%)	10 (16.9%)	61 (22.3%)
Social Media	24 (34.8%)	17 (51.5%)	23 (32.9%)	4 (25.0%)	6 (31.6%)	3 (42.9%)	14 (23.7%)	91 (33.3%)
Human Evolution								
Academic Journals	28 (40.6%)	8 (24.2%)	22 (31.4%)	4 (25.0%)	3 (15.8%)	1 (14.3%)	8 (13.6%)	74 (27.1%)
Direct Communication	19 (27.5%)	7 (21.2%)	22 (31.4%)	5 (31.3%)	10 (52.6%)	1 (14.3%)	15 (25.4%)	79 (28.9%)
News	3 (4.3%)	3 (9.1%)	6 (8.6%)	2 (12.5%)	0 (0%)	3 (42.9%)	9 (15.3%)	26 (9.5%)
Other	14 (20.3%)	6 (18.2%)	16 (22.9%)	3 (18.8%)	5 (26.3%)	0 (0%)	18 (30.5%)	62 (22.7%)
Social Media	5 (7.2%)	8 (24.2%)	2 (2.9%)	2 (12.5%)	0 (0%)	2 (28.6%)	8 (13.6%)	27 (9.9%)
Missing	0 (0%)	1 (3.0%)	2 (2.9%)	0 (0%)	1 (5.3%)	0 (0%)	1 (1.7%)	5 (1.8%)
Invasive Species								
Academic Journals	12 (17.4%)	4 (12.1%)	12 (17.1%)	2 (12.5%)	1 (5.3%)	2 (28.6%)	9 (15.3%)	42 (15.4%)
Direct Communication	8 (11.6%)	5 (15.2%)	16 (22.9%)	2 (12.5%)	7 (36.8%)	0 (0%)	5 (8.5%)	43 (15.8%)
News	17 (24.6%)	6 (18.2%)	13 (18.6%)	5 (31.3%)	4 (21.1%)	2 (28.6%)	16 (27.1%)	63 (23.1%)
Other	18 (26.1%)	8 (24.2%)	15 (21.4%)	5 (31.3%)	6 (31.6%)	0 (0%)	16 (27.1%)	68 (24.9%)
Social Media	12 (17.4%)	9 (27.3%)	12 (17.1%)	2 (12.5%)	1 (5.3%)	3 (42.9%)	12 (20.3%)	51 (18.7%)
Missing	2 (2.9%)	1 (3.0%)	2 (2.9%)	0 (0%)	0 (0%)	0 (0%)	1 (1.7%)	6 (2.2%)
Pesticides								
Academic Journals	13 (18.8%)	6 (18.2%)	16 (22.9%)	1 (6.3%)	2 (10.5%)	2 (28.6%)	7 (11.9%)	47 (17.2%)
Direct Communication	14 (20.3%)	4 (12.1%)	14 (20.0%)	7 (43.8%)	8 (42.1%)	1 (14.3%)	10 (16.9%)	58 (21.2%)

News	14 (20.3%)	5 (15.2%)	14 (20.0%)	4 (25.0%)	5 (26.3%)	2 (28.6%)	15 (25.4%)	59 (21.6%)
Other	13 (18.8%)	6 (18.2%)	17 (24.3%)	2 (12.5%)	3 (15.8%)	0 (0%)	12 (20.3%)	53 (19.4%)
Social Media	13 (18.8%)	11 (33.3%)	6 (8.6%)	2 (12.5%)	1 (5.3%)	2 (28.6%)	13 (22.0%)	48 (17.6%)
Missing	2 (2.9%)	1 (3.0%)	3 (4.3%)	0 (0%)	0 (0%)	0 (0%)	2 (3.4%)	8 (2.9%)
Pollution								
Academic Journals	15 (21.7%)	3 (9.1%)	11 (15.7%)	0 (0%)	3 (15.8%)	1 (14.3%)	5 (8.5%)	38 (13.9%)
Direct Communication	12 (17.4%)	3 (9.1%)	9 (12.9%)	2 (12.5%)	5 (26.3%)	0 (0%)	6 (10.2%)	37 (13.6%)
News	19 (27.5%)	8 (24.2%)	17 (24.3%)	7 (43.8%)	5 (26.3%)	1 (14.3%)	22 (37.3%)	79 (28.9%)
Other	13 (18.8%)	7 (21.2%)	14 (20.0%)	4 (25.0%)	4 (21.1%)	0 (0%)	9 (15.3%)	51 (18.7%)
Social Media	9 (13.0%)	11 (33.3%)	14 (20.0%)	3 (18.8%)	1 (5.3%)	5 (71.4%)	15 (25.4%)	58 (21.2%)
Missing	1 (1.4%)	1 (3.0%)	5 (7.1%)	0 (0%)	1 (5.3%)	0 (0%)	2 (3.4%)	10 (3.7%)
Vaccinations								
Academic Journals	15 (21.7%)	3 (9.1%)	23 (32.9%)	1 (6.3%)	2 (10.5%)	2 (28.6%)	7 (11.9%)	53 (19.4%)
Direct Communication	19 (27.5%)	7 (21.2%)	13 (18.6%)	5 (31.3%)	7 (36.8%)	1 (14.3%)	16 (27.1%)	68 (24.9%)
News	16 (23.2%)	7 (21.2%)	14 (20.0%)	5 (31.3%)	6 (31.6%)	1 (14.3%)	14 (23.7%)	63 (23.1%)
Other	9 (13.0%)	8 (24.2%)	11 (15.7%)	3 (18.8%)	4 (21.1%)	0 (0%)	13 (22.0%)	48 (17.6%)
Social Media	7 (10.1%)	6 (18.2%)	7 (10.0%)	1 (6.3%)	0 (0%)	3 (42.9%)	5 (8.5%)	29 (10.6%)
Missing	3 (4.3%)	2 (6.1%)	2 (2.9%)	1 (6.3%)	0 (0%)	0 (0%)	4 (6.8%)	12 (4.4%)

CHAPTER FOUR: STUDY TWO

(Manuscript will be submitted to the Journal of Research in Science Teaching)

Introduction

A major objective of current STEM education reform efforts at all levels (Kindergarten through Undergraduate) is to create classroom environments that allow students to take an active role in developing their conceptual understanding (Freeman et al., 2014; Lombardi et al., 2021). This is in contrast to passive forms of learning, such as lecture (Jiménez-Aleixandre et al., 2000). This active role within the classroom should encourage students to participate in scientific practices, such as argumentation from evidence and effective science communication, related to the content (Brookfield & Preskill, 1999). To promote discussion within classrooms, one pedagogical practice that is commonly utilized is collaborative or cooperative small-group learning (Slavin, 1996). Although these forms of structured small-group learning have demonstrated positive student outcomes on achievement, reasoning ability, and motivation (Johnson & Johnson, 2009; Slavin, 1996), the effectiveness of interactions relies on many complicated factors (Chang & Brickman, 2018). This includes group composition, student values and behaviors, and the community factors (Chai et al., 2019).

Within science education, socioscientific issues (SSI) interventions often utilize small collaborative groups as a context to promote scientific literacy across students by providing them opportunities to discuss problems that lack a clear or singular path to a solution (Sadler & Zeidler, 2009). Because SSI are ill-structured problems, solutions based purely on the science are not always clear cut and can require students to utilize personal beliefs when constructing an argument for a particular solution (Sadler &

Zeidler, 2005). This reliance on beliefs in arguments may cause tension for students within the classroom because students develop differing solutions that may all seem valid (Lee et al., 2020). Since SSI interventions often encourage students to develop complex reasoning skills through small group discussion, it is important to capture group dynamics during SSI interventions to better understand how learning is taking place in these complex contexts.

In science education, research methods on small group learning often focus on individuals within a group or parts of an entire small group discussion (e.g., discourse analysis). In addition, small group dynamics are not static but evolve over time within a single class period and across a course unit. Recent advances in social network theory provide a potential methodological lens through which to overcome some of these limitations (Chai et al., 2019). Because group discussion is interactive in nature, social network theory may be applied to better understand the dynamic structure of these interactions. Network theory focuses on the connections (ties) between individual actors (nodes) within a network, as well as the characteristics of actors themselves (Borgatti & Ofem, 2010).

This scholarship addresses network antecedents and outcomes associated with whole network characteristics as well as an actor's position within the network of a small collaborative learning group (Borgatti et al., 2009; Borgatti & Ofem, 2010). A method utilized across a broad variety of disciplines to capture these network characteristics is social network analysis (SNA) that can represent data through sociograms of whole groups. By utilizing SNA, it is possible to track the formation of small group networks in classrooms, interactions between actors, as well as compare network interactions across the class to provide mechanistic explanations for positive student outcomes during small group collaborative learning about SSI (Grunspan et al., 2014).

Background

For this study, I draw from literature on small groups' collaborative learning in the classroom, socioscientific issues in science education, and social network theory to help frame small group discussion of socioscientific issues. The following section builds the argument for the importance of each of these components.

Small Groups in the Classroom

Within the science classroom, active learning practices encourage students to be at the center of their learning experience by allowing them to develop their own knowledge of a concept (Bonwell & Eison, 1991). As noted earlier, an active learning practice that has been utilized within the classroom is to divide larger classrooms into small collaborative groups. The motivation for this context of active learning draws upon social constructivism to frame student learning. Social constructivism theorizes that learning happens through the process of individual students constructing their knowledge through interactions in their social environment (Palincsar, 1998; Vygotsky, 1978). Learning is social and as such, small groups provide a context in which learning can occur through social interactions between peers.

In practice, small group learning can be defined as either cooperative or collaborative (Slavin, 1996; Davidson & Major, 2014). Cooperative learning has been operationalized by groups of students working together on a shared task with each student needing to contribute to the group discussion in order to complete the task (Felder & Brent, 2007). Cooperative learning uses five elements for productive group work in the classroom to differentiate itself from collaborative learning: 1) positive interdependence of students to achieve a learning task, 2) face-to-face promotive interaction between students, 3) individual accountability/personal responsibility of students to complete the learning task, 4) development of interpersonal and small-group skills, and 5) promotion of group processing (Johnson & Johnson, 1990).

Collaborative learning is more broadly defined and less restrictive. Panitz (1999) states collaborative learning, "is a personal philosophy, not just a classroom technique. In all situations where people come together in groups, it suggests a way of dealing with people which respects and highlights individual group members' abilities and contributions. There is a sharing of authority and acceptance of responsibility among group members for the group's actions. The underlying premise of collaborative learning is based upon consensus building through cooperation by group members, in contrast to competition in which individuals best other group members." (pp. 3-4). When implemented in the classroom, Bruffee (1999) mentions four initial steps needed to establish productive collaborative group work (i.e., composition of small consensus groups, designing of a learning task, plenary discussion to unpack small consensus group discussions, representation of larger relevant knowledge communities).

Between cooperative and collaborative learning, one main difference is that cooperative learning provides students with more structured group roles that are implemented and regulated by the instructor whereas collaborative learning allows students to navigate the group work in unstructured group roles (Bruffee, 1999). While cooperative and collaborative learning can have very structured implementation, Cohen defines cooperative learning as, "students working together in a group small enough that everyone can participate on a collective task that has been clearly assigned. Moreover, students are expected to carry out their task without direct and immediate supervision of the teacher" (1994, p. 3). With this definition, Cohen (1994) highlights they are providing a broad view of cooperative learning that spans across cooperative and collaborative learning. Despite Cohen's definition, differentiating and operationalizing these two types of small group learning is still debated in the literature.

Whether cooperative or collaborative, students working in small groups have demonstrated improvement in critical outcomes such as participation and learning (Bromme et al., 2010; Freeman et al., 2014; Pollock et al., 2011; Ryan, 2000). However, this improvement can vary depending on group composition (Webb, 1982; Bennett et al., 2010). When considering group composition, students hold many different identities that influence their ideas, which then impact how they may work together in a group to a achieve a learning goal. Identities such as gender (Springer et al., 1999), race (Antonio et al., 2004; Springer et al., 1999), personality (French & Kottke, 2014; Humphrey et al., 2011; Flanagan & Addy, 2019), and political identity (Clark, 2018) can all impact small group learning. Also, small group discussion is impacted by the amount of time groups have been working together (Armstrong, 2008, Soetanto & MacDonald, 2017) and the accuracy of information being presented by a student (Cavagnetto et al., 2022). Therefore, small group interventions can be undermined if instructors are not mindful of the demographics of group composition and the interpersonal interactions that engenders.

Socioscientific issues

It is not just the student demographics that can impact small group learning, but the nature of the learning task itself. For example, the more complex the learning task, the more difficult it may be for small student groups to achieve critical learning objectives. One such complex learning goal of education is to improve scientific literacy (American Association for the Advancement of Science, 1993, 2011; National Academies of Sciences, Engineering, and Medicine, 2016; National Research Council, 1996). The complexity of science literacy as a learning objective within the context of socioscientific issues is discussed further.

Although there is consensus within the science education community to improve scientific literacy, definitions can differ. Roberts (2007) provides views that sit on the ends of a continuum for scientific literacy, Vision I and Vision II. Vision I scientific literacy is defined as, "rooted in the products and processes of science, has historically been the starting point for defining SL, which has then been exemplified by reaching out to situations or contexts in which science can be seen to have a role" (Roberts, 2007, p. 730). Vision II scientific literacy states that, "students learn how the discourse of resolving issues and making decisions differs from and complements the explanatory discourse of science itself" (Roberts & Bybee, 2014, p. 546). When comparing both definitions, the difference between them is a focused on moving science into discussions within the context of society (Vision I) versus moving society into science discussion (Vision II). Therefore, Vision I scientific literacy does not consider the influence of society within science education and views science knowledge as being passed to others by experts in the science community (Liu, 2009), and Vision II does acknowledge society's role within science and encourages students to engage in creating personal decisions for issues within society (Sadler & Zeidler, 2009). In addition to Vision I and Vision II, Aikenhead (2007) adds another view, Vision III, that incorporates a cultural aspect to scientific literacy to help expand scientific literacy outside of a Eurocentric view of science.

Within the science classroom, a particular context that has been utilized to improve science literacy across all three visions is socioscientific issues (Kolstø, 2001; Sadler, 2011; Zeidler, 2016; Zeidler & Nichols, 2009; Zeidler & Sadler, 2011). Socioscientific issues (SSI) are, potentially controversial, ill-structured issues within society that require science knowledge to develop solutions (Sadler, 2004). Because SSI are ill-structured, this provides students the opportunity to build complex arguments on potential solutions for these issues, rather than having clear-cut answers (e.g., facts).

Owens et al. (2017) discuss three phases within the SSI instructional context that engage students in creation and evaluation of arguments: encounter the issue, study the science behind the issue and engage in reasoning about potential solutions, and synthesize key ideas and practices. For the encounter the issue phase, students gain an awareness of the SSI, which allows them to develop questions and find relevant science content surrounding the issue. When students study and engage in reasoning, an avenue is created by the SSI for students to explore underlying social components that tie back into their scientific knowledge gained while encountering the issue. Finally, while synthesizing key ideas and practices, students are given opportunities to reflection on science ideas, science practices, and socioscientific reasoning (SSR) practices utilized during the development of their arguments (Sadler et al., 2017).

SSR consists of four practices: 1) recognition of the complexity in the multiple, dynamic interactions of factors within SSI; 2) using different perspectives to create solutions when addressing SSI; 3) valuing when new information is discovered to add to the ongoing inquiry on SSI; and 4) being skeptical when another individual presents information that may be potentially biased (Sadler et al., 2007). When using SSR, students are required to continually integrate new knowledge into arguments as it becomes available to them to develop a potential solution of an SSI, which allows for them to reflect on the change in their own perspectives (Sadler, 2004; Sadler et al., 2007, Zeidler, 2014). By exposing students to this ill-structured nature, SSI are allowing them to experience a messy and iterative process of decision-making, more commonly seen in science, rather than a stepwise, linear process of scientific decision making often shown within textbooks (Duncan et al. 2011).

Due to the complexity, lack of clear solutions, dynamic shifting of claims, and sometimes socially controversial nature, SSI can create a divide between students' personal arguments in the classroom (Zeidler & Sadler, 2007). This divide between personal arguments can create an environment where students evoke emotions and not just the science when discussing their claims (Zeidler & Sadler, 2004). By evoking emotions, socioscientific argumentation creates both pros and cons for learning in small groups. On one hand, socioscientific argumentation is evoking emotion because they are relevant to the students, which creates motivation to participate in discussion and promotes learning (Zeidler & Sadler, 2007). On the other hand, socioscientific argumentation can expose differences in students' morals, which can create negative student interactions within the small group (Mayhew & Engberg, 2010). Therefore, it is important to understand the tensions that may exist between students when discussing SSI. Lee et al. (2020) found four phenomena (i.e., intolerance of uncertainty, scientisim, sense of rivalry, and reaching an expedient and easy consensus) when looking at potential sociocultural tensions for students when discussing SSI that highlighted the complexity students and teachers face when implementing SSI discussion into the classroom. Because these sociocultural tensions exist within SSI discussion, it is important to understand SSI discussion from a socially constructed perspective. Therefore, researchers need to utilized methodology that can capture students' socially constructed discussion in small groups to help provide a deeper understanding on SSI within the classroom.

Social Network Theory

Because they encourage discussion between students, small groups create a network of discourse, which allows researchers to use social network theory to gain an understanding of the group structure and dynamic interactions (Wagner & Gonzalez-Howard, 2018). A network is made up of nodes (e.g., people) and ties (e.g., connections between people) (Borgatti & Ofem, 2010). Within small groups, these nodes and ties can represent students talking to each other about a particular topic such as SSI. These ties can have varying degrees of strength (i.e., strength of ties) which is often calculated as the frequency of interaction between actors, such as number of talk turns between students (Chai et al, 2019). These ties can also have direction to capture which student is talking to whom in the small group and which speaking interactions are reciprocal (Molm, 2010). This method can provide insight into students' interactions in the group during a learning task.

In addition to connections between students, social network theory is concerned with placement and connection of individual nodes (e.g., a student) within a network. When looking at a student's place in the small group network, researchers can utilize measures such as degree centrality of an individual in the group (Freeman, 1978). For small groups in the classroom, centrality measures can be used to show which student(s) are central to the discussion by looking at the number of connections that go to and from each of them. Understanding students' centrality can provide an understanding of the influence each student has on the overall discussion (Hanneman & Riddle, 2014), which may provide useful insight into whether or not a particular student is dominating a group conversation. The methods section discusses how these metrics are calculated in more detail below.

To gain an overall understanding of how the group network is functioning, researchers can use density to see how connected all students are in the group (Carolan, 2014). For small groups, where the number of interactions between students is important, density is calculated by taking the sum of the weight of the ties present in the network and dividing them by the total possible ties (Hanneman & Riddle, 2014). The purpose for highlighting the difference in interactions between students may be to show if conversation was evenly spread out amongst students or siloed to a couple students. By utilizing social network theory to understand discourse, researchers can compare these social network measures across groups to track differences between small group interactions, as well as the change in individual small group interactions over time (Wagner & Gonzalez-Howard, 2018).

Within this study, I aimed to understand how small group dynamics develop and are sustained over time when discussing and SSI, as well as how group dynamics impact the construction of group answers. To help gain an understanding of group dynamics, I used a combination of social network analysis and epistemic analysis (Gašević et al., 2019). As discussed above, social network analysis (SNA) looks at the underlying structure of a network by focusing on the interactions between individuals (e.g., students talking to each other) in a network (e.g., cooperative small group) to calculate standardized measures that can be compared across networks. Epistemic network analysis (ENA) is used to understand connections between elements (i.e., qualitative codes) within an epistemic frame (Shaffer et al., 2009) from which standardized measure can also be calculated and compared across networks. An epistemic frame is defined as, "a pattern of associations among knowledge, skills, habits of mind, and other cognitive elements that characterizes communities of practice, or groups of people who share similar ways of framing, investigating, and solving complex problems" (Siebert-Evenstone et al., 2017, p. 125). By using a combination of SNA and ENA methods, I was able to capture the flow of information within a small group and the impact the social structure of the group has on that information flow during specific class periods, as well as across a semester.

Research Questions

For this study, my overarching research question is: how do cooperative small group conversations about SSI develop over a semester? More specifically, I looked at:

1) Does group structure impact the development of the group engagement?
    a) If so, what factors (e.g., political affiliation, religious affiliation, gender, race, ethnicity, assigned role) of group structure impact group engagement?
2) How do students' interactions change over time?

Methods

Data Collection

In the Spring of 2021, I collected video and audio data on thirteen cooperative small groups in an introductory biology course for majors. Groups were created by the instructor and were based on student's declared major. Groups interacted in Zoom breakout rooms, where groups would work together on a Google Doc to answer four to five questions based within a biology case study and had up to an hour to answer the questions. Each member in the group had a designated role (i.e., reader, typer, facilitator, checker, harmonizer). The roles were created by the instructors but were assigned to group members by the group during the case study session. Because roles were assigned by the group, it is possible group members occupied the same role throughout the semester, even though they were encouraged by the instructor to occupy different roles. Groups were also asked to fill out a demographic survey that asked about their race/ethnicity, religious and political affiliation, hometown location, first-generation status, and age. For this analysis, I selected three groups by first removing groups that had missing demographic data and then using a random numbers generator to select from the remaining groups.

Data Analysis

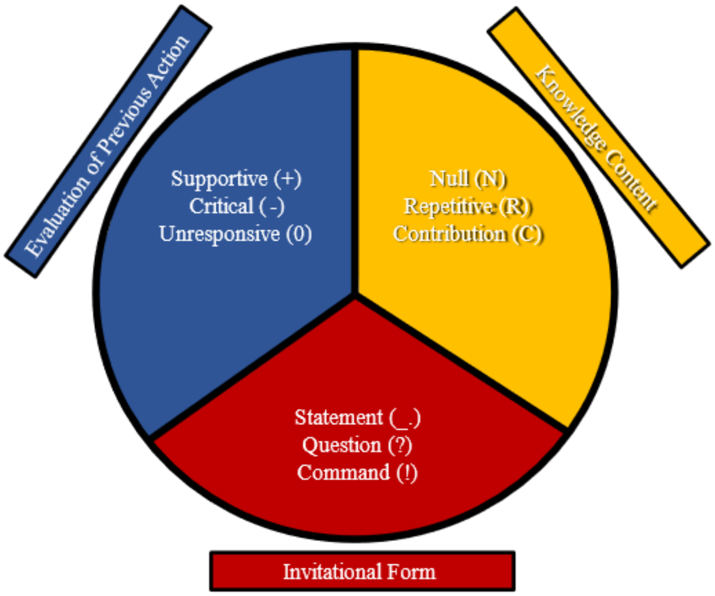
Phase One: Coding Transcripts

For this study, data analysis was divided into three phases. The first phase consisted of coding the transcripts of the verbal interactions between individuals within the small groups. The transcripts were created using Otter.ai and were paired with group videos during coding. To code the transcripts, I used Chiu's (2000) framework that captures group problem-solving processes (Figure 4.1). Chiu's framework utilized three dimensions, which each contain three codes, that capture students' individual actions during group problem-solving: invitational form (statement, question, command), knowledge content (null, repetitive, contribution), and evaluation of previous action (supportive, critical, unresponsive). Invitational form was used to understand how individuals invited others to participate in the conversation by categorizing utterances into a declarative statement, command demanding a response, or a question seeking a response. Knowledge content looked at the disciplinary content being presented by an individual as it relates to the task the group is working on by categorizing utterances into null (i.e., presenting information not relating to the prompt), contribution (i.e., presenting new information related to the prompt), or repetition (presenting previously stated information related to the prompt). Lastly, evaluation of previous action categorized utterances into supportive (i.e., supports the current direction of discussion in group problem-solving), critical (i.e., challenges the current direction of discussion in group problem-solving), or unresponsive (i.e., ignores the current direction of discussion in group problem-solving) to provide an understanding of how the individual assessed the previous utterance.

While coding the transcripts using this framework, I also noted the directionality of interactions between students by creating a code that show who initiated the interaction and who the interaction was directed towards (i.e., Student 1 → Student 2). By capturing directionality, I was able to track how information is flowing between individuals within the network.

Figure 4.1

Coding framework used to determine the small group problem-solving processes during an SSI task



Phase Two: Social Network Analysis

For the SNA, I used the number of talk-turns students had between each other as the connections (edges). For the actors (nodes), I used the total number of talk-turns students were involved in to represent the percent of total conversation involvement of the student. For each group discussion (12 discussions per group), I calculated density, reciprocity, degree centralization, and strength of ties. Density represents the number of connections present within a social network divide by the total potential connections in the network, which allows for an overall understand of connections being made by students. Reciprocity is used to measure the extent students return each other's interactions when prompted. Within SNA, centrality refers to a group of measures that understands how central an actor is within a network and is calculated for each individual within the network. For this study, I used a normalized degree centralization, which is used to understand the variation between centrality scores in a network to gain a group level perspective. By utilizing a normalized measure of centralization, I was able to account for differing numbers of students throughout the semester, which will allow for comparison across time. For each individual student, I calculated their strength of ties within the group to help understand who in the group is taking a central role. To visualize group interactions, I created a sociogram for each group at each time point (3 groups x 12 timepoints = 36 sociograms).

Phase Three: Epistemic Network Analysis

To better understand what information is flowing through the groups, I conducted epistemic network analysis. Epistemic network analysis (ENA) is similar to SNA in that it is utilizing graph theory to understand connections between nodes, but instead of the nodes representing students, they represent codes that were created from a qualitative analysis of the content of the talk turns (Shaffer, 2006). To create the boundaries of a network in ENA, Shaffer et al. (2016) uses groups of sentences related by context called stanzas (Gee, 2011). For my epistemic frames, I used each weekly group conversation as one epistemic frame (3 groups x 12 weeks = 36 epistemic frames). For my stanzas, I used a moving stanza window method, which highlights a set number of lines in a transcript and then iteratively moves down the transcript by replacing the beginning line in the stanza with the next line below the stanza until the transcript has been completely coded (Siebert-Evenstone et al., 2017). To further conceptualize this idea, a transcript that consists of ten lines and has moving stanza windows of two lines would beginning the analysis with lines 1 and 2, then followed by lines 2 and 3, and repeated until lines 9 and

10. My moving stanza window consisted of two lines (i.e., two talk-turns). Since I am looking at the connection between the current talk-turn and the talk-turn directly before it (e.g., Evaluation of Previous Action codes) using a window larger than two lines creates co-occurrences between codes that are not linked. For each stanza, I used the codes produced for group problem-solving from Phase One of this data analysis. To further help understand group conversation development, I created epistemic networks for each group with co-occurrences between group problem-solving codes.

Results

Group Demographics

For Group 1, students ranged in age from 18 to 20. Four of the five students were White women (Heather, Marylin, Megan, Sarah) and the remaining student was a Black man (Lewis). Four of the students identified as Christian (Heather, Lewis, Marylin, Sarah) and one declined to state their religion (Megan). Three of the students indicated that they had a conservative political identity (Lewis, Marylin, Megan) and the remaining two had a moderate (Heather) or declined to state (Sarah). One of the students was a first-generation student (Sarah). Finally, three students had hometowns located in an urban area (Lewis, Marylin, Sarah) and two were in a rural area (Heather, Megan).

In Group 2, students ranged in age from 18-35. Three of the five students were women (Anna, April, Bailey) and the remaining two were men (Darius, Dean). Two of the students were White (Anna, Darius), one student was Asian (April), one student was Black (Bailey), and one student was Multiracial (Dean). Three students stated they were Christian (Anna, April, Darius) and two students stated they did not identify with a religion (Bailey, Dean). Three students indicated they have a conservative political identity (Anna, April, Darius), one identified as moderate (Bailey), and one identified as slightly liberal (Dean). One student was a first-generation student (Darius). Four students had hometowns in an urban area (Anna, April, Bailey, Dean) and one was in a rural area (Darius).

Lastly, Group 8 had students that ranged in age from 18-20. Three students were women (Abigail, Ashley, Nadia) and two were men (James, Ruben). Two students were Multiracial (James, Ruben), two students were White (Abigail, Ashley), and one student was Asian (Nadia). Three students identified as Christian (Abigail, James, Ruben), one identified as Muslim (Nadia), and one did not identify with a religion (Ashley). Two students had a liberal political identity (Nadia, Ruben), one had a slightly liberal identity (James), one had a moderate identity (Abigail), and one declined to state (Ashley). Two students were first-generation (Abigail, James). Four students had hometowns in an urban area (Abigail, Ashley, Nadia, Ruben) and one was in a rural area (James). See Table 4.1 for more detail on demographics.

Table 4.1

Demographics for each student within the small groups

Name (Group)	Age	Gender	Race/ Ethnicity	Religion (Denomination)	Parents Education	Political Identity	Hometown
Heather (1)	18	Woman	White	Christian (Baptist)	Associates	Moderate	Rural
Lewis (1)	20	Man	African American or Black	Christian	Some college but no degree	Conservative	Urban
Marylin (1)	19	Woman	White	Christian (Catholic)	Master's degree	Conservative	Urban
Megan (1)	20	Woman	White	Decline to state	Bachelor's degree	Conservative	Rural
Sarah (1)	19	Woman	White	Christian (Catholic)	Less than high school completed	Decline to state	Urban
Anna (2)	18	Woman	White	Christian (Protestant)	Bachelor's	Conservative	Urban

Table 4.1 (continued)

April (2)	35	Woman	Asian	Christian (Non-denominational)	Higher than a Master's	Conservative	Urban
Bailey (2)	20	Woman	African American or Black	No Religion (Spiritual Relationship with God)	Master's	Moderate	Urban
Darius (2)	18	Man	White	Christian (Baptist)	High school diploma or GED	Conservative	Rural
Dean (2)	23	Man	Multiracial (Black & White)	No Religion (Agnostic)	Bachelor's	Slightly Liberal	Urban
Abigail (8)	20	Woman	White	Christian (Catholic)	High school diploma or GED	Moderate	Urban
Ashley (8)	18	Woman	White	No Religion	Higher than a Master's	Decline to state	Urban
James (8)	20	Man	Multiracial (Black & White)	Christian (Non-denominational)	High school diploma or GED	Slightly Liberal	Rural
Nadia (8)	19	Woman	Asian	Muslim (Sunni)	Master's	Liberal	Urban
Ruben (8)	18	Man	Multiracial (Hispanic & White)	Christian (Catholic)	Master's	Liberal	Urban

Social Network Analysis

Group 1

When looking across the semester, there is some fluctuation in the SNA measures for Group 1, but, overall, they seem to be fairly stable (Figure 4.2) For the group-level measures of reciprocity and density, the overall trend was that the measures increased from Week 1 to Week 6 and began to decline until the end of the semester. For centralization, there was an initial increase and then it dropped down after Week 3 until the end of the semester, with Week 9 being an exception and centralization increased. These trends indicate that as the semester developed, students in Group 1 talked back and forth to each other and conversation was more evenly distributed, until the middle of the semester when less connections were being made and conversation became more centralized.

When looking at the students individually, two students (Marylin and Sarah) consistently had the highest strength of ties scores (Figure 4.3), meaning they were talking the most in the group. Two of the students (Heather and Lewis) had constantly low strength throughout the semester (Figure 4.3), indicating they were not as vocal during conversation. The final student in the group (Megan) had a higher fluctuation of strength (Figure 4.3). Megan began the semester being a more vocal member of the group, but quickly moved out of a central role. As the semester advanced, Megan became a more central actor and eventually become the most vocal individual during Week 6. This was then followed by Megan moving to a less vocal role the following week, which continued for the rest of the semester.

Figure 4.2

Group level SNA measures for Group 1 across the semester

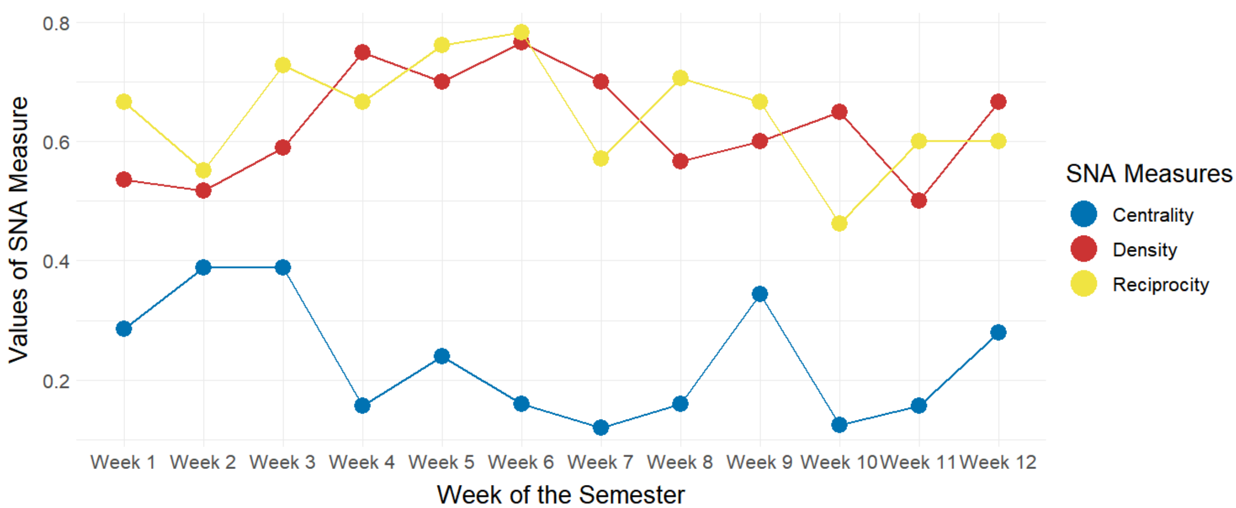
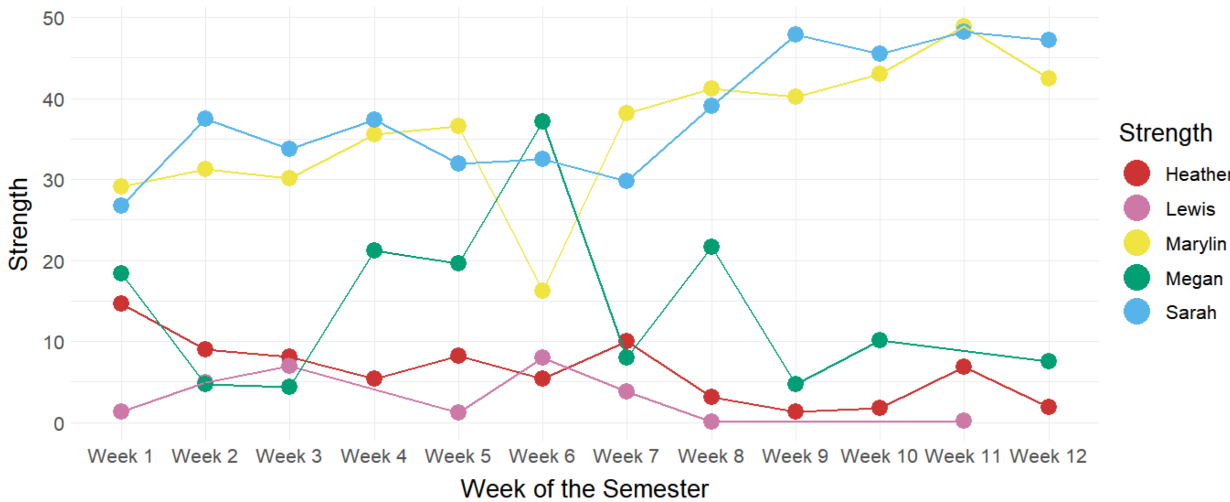


Figure 4.3

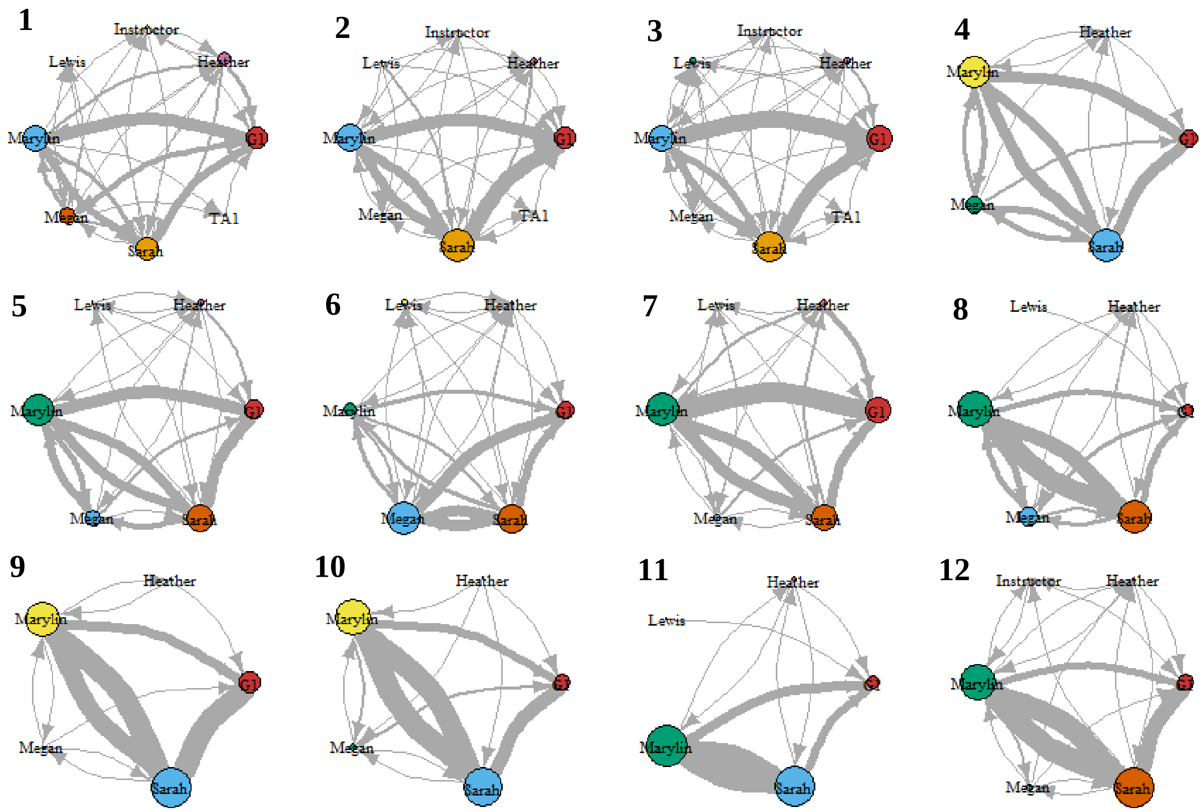
Strength measures for each individual in the small group for Group 1 across the twelve weeks of the semester



When looking at the sociograms for Group 1 (Figure 4.4), it is apparent that the group began the semester with the conversation being spread between individuals but over time became a conversation that was mainly between Marylin and Sarah. Also, there became fewer questions asked to the group as whole (e.g., What do you all think?) as the semester progressed, which further shows that Marylin and Sarah were having conversations that were exclusive to them. This highlights that despite assigned roles within the group, Marylin and Sarah were leading and developing the conversation for the group. As mentioned above, Week 6 was particularly interesting because Megan became the most central individual within the group. This central role may have been aided by her assigned role in the group, facilitator, which placed her in a position to help drive the conversation forward. Another potential reason for Megan's central role in the group was the group was having a difficult time hearing Morgan that day because

Figure 4.4

Sociograms for Group 1 across the semester



Notes. Circles are nodes. Nodes represent students, instructor, whole group, and teaching assistants. Size of circles indicates the percentage of interactions for each node. Lines represent interactions. Arrows represent direction of interactions. Width of lines indicates the percentage of interactions between nodes. Bolded numbers represent the week of the semester.

Morgan was using her phone and the audio was poor. This may have opened up space for Megan to become more integrated into the conversation. Although Heather was present for all group discussions, she never moved into a central role. Lewis was absent for five of the twelve group discussions, which may have impacted him moving into a more central role.

Group 2

In Group 2, the SNA measures were relatively stable with the middle and end of the semester having some fluctuation (Figure 4.5). For density, it had spikes on Week 6 and 10 but was consistent for most of the weeks. Reciprocity stayed consistent until the end of the semester when it dropped to its lowest after previously reaching its highest measure. Centrality had more fluctuation than density and reciprocity, with centrality slow declining until Week 6, increased until Week 8, decreased after Week 9, and consistently increased for the rest of the semester. This drop in density and reciprocity with the increase in centrality at the end of the semester indicates that fewer students in the group were driving the conversation. In contrast, students were having more evenly spread conversation between the majority of the group in Week 6 and 10.

Generally, Dean and April had the highest strength of ties throughout the semester. Bailey always had the lowest strength in the group (Figure 4.6). For Darius, he had lower strength in Week 1, 2, 3, 7, 8, and 9 and relatively higher strength during Week, 4, 5, and 6 (Figure 6). Also, Darius was absent for the last three weeks of class. Overall, Anna steadily increased in strength throughout the semester (Figure 4.6).

Figure 4.5

Group level SNA measures for Group 2 across the semester

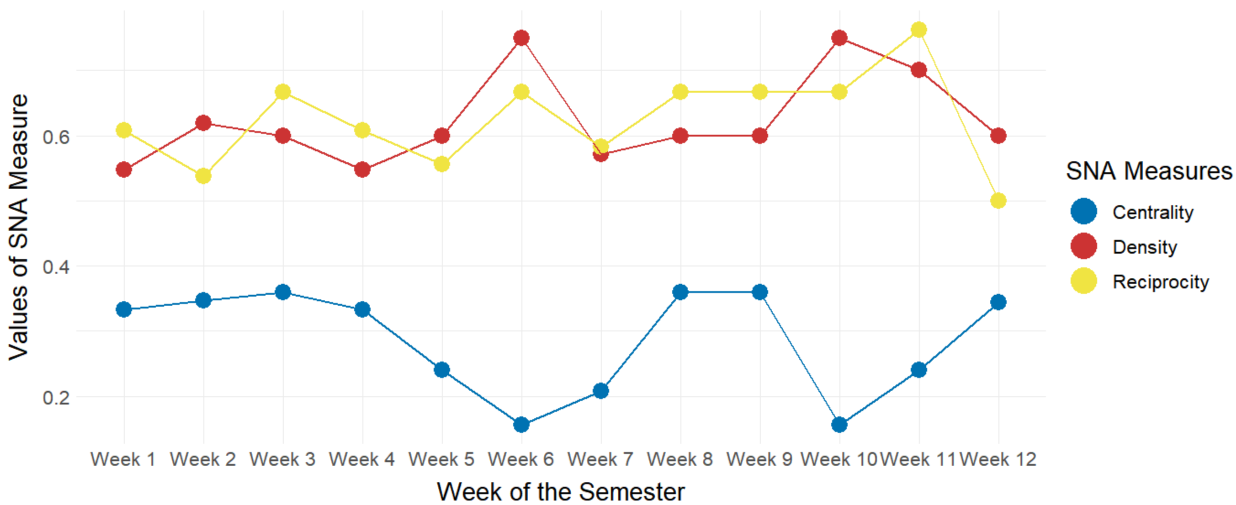
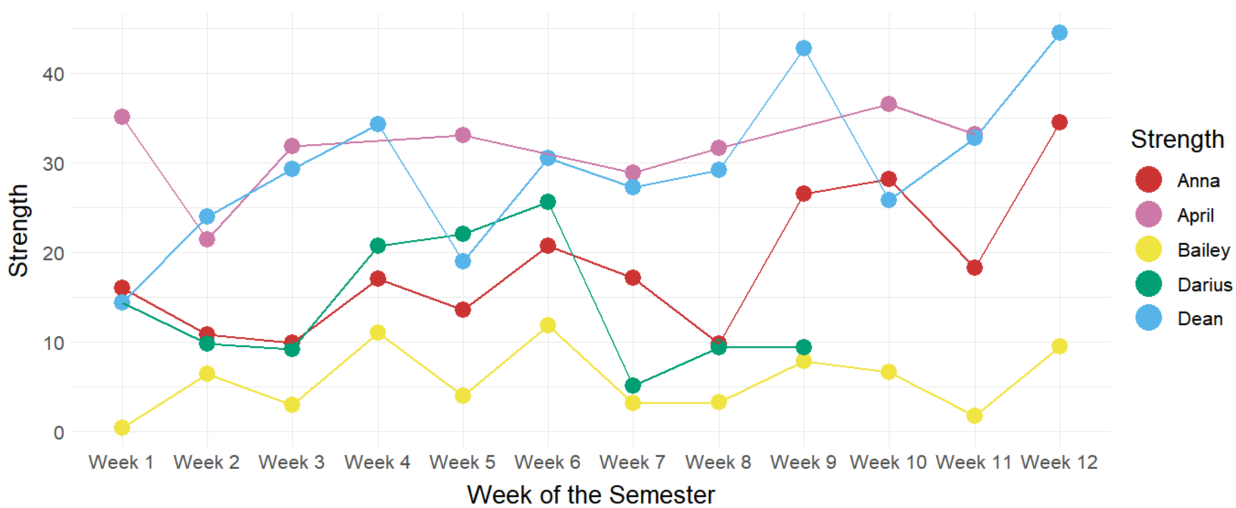


Figure 4.6

Strength measures for each individual in the small group for Group 2 across the twelve weeks of the semester



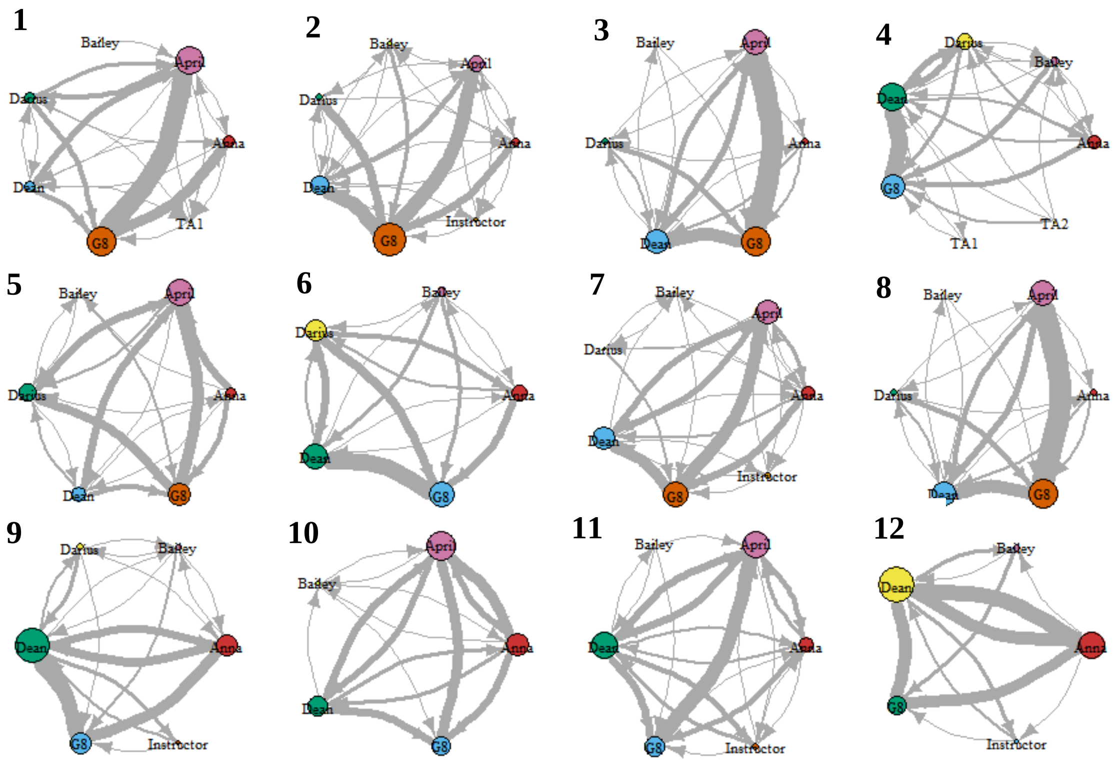
When looking closer at the strength of each individual, there is a pattern of Dean taking the most central role in the group when April is gone but taking a less central role when April is there. When looking at the sociograms for Group 2 (Figure 4.7), April seems to drive the conversation for the group during the first week by mostly addressing the group as a whole, rather than an individual. In Week 2 and 3, April is still playing a large part in the conversation, but Dean has begun to also play a larger role. Both Dean and April are still building the conversation by addressing the group as a whole. During Week 4, April is absent from the group and Dean drives most of the conversation with Darius having some increase in his participation. Dean is still utilizing addressing the whole group to aid the conversation, while most of Darius' contribution to the conversation is directed at Dean.

In Week 5, April returned to the group and filled the most central role in the group with the majority of her discourse addressing the group as a whole. In contrast to previous weeks, the conversation seemed to be less focused on addressing the group as a whole and more to directed conversation between students, although most of the conversation was directed towards April. During Week 8, April was absent from the group. Dean took the most central role in the group, followed by Darius and Anna. Dean and Anna relied on asking questions of the group as a whole, while Darius had a higher percent of conversation directed at individuals. For Week 8 and 9, April and Dean were the most central in the conversation with both of them relying heavily on addressing the group to keep moving conversation forward, although Week 8 had a higher proportion of talk between April and Dean. In the following week, Dean and Anna had central roles, with Dean having the most central role. Dean and Anna drove almost all of the conversation and a majority of conversation being directed toward the group as a whole, although Dean and Anna had a fairly high proportion of talk between each other. During this week, April was absent.

For Week 10 and 11, most of the conversation was between April, Dean, and Anna. For both weeks, April still addressed the group as a whole to help move conversation forward, where as Dean and Anna were more likely to address April. Finally, the conversation in Week 12 was mainly between Dean and Anna. Despite being present for every group discussion, Bailey played a very decentralized role in the group. Throughout the semester, April played a very central role when she was present in the group with most of the conversation being driven by and directed at her. When April was not present, Dean seemed to fill her role throughout the semester and Anna began to share this role with Dean towards the end of the semester.

Figure 4.7

Sociograms for Group 2 across the semester



Notes. Circles are nodes. Nodes represent students, instructor, whole group, and teaching assistants. Size of circles indicates the percentage of interactions for each node. Lines represent interactions. Arrows represent direction of interactions. Width of lines indicates the percentage of interactions between nodes. Bolded numbers represent the week of the semester.

Group 8

Across the semester, Group 8 had a lot of fluctuation in SNA measures (Figure 4.8). Until the middle of the semester (Week 1-6), density, reciprocity, and centrality consistently fluctuated up and down. As the semester moved into the final weeks (Week

7-12), reciprocity and centrality become more stable and gradually increased until Week 11. For density, it steadily decreased after Week 8 until Week 10, where it steadily increased until the end of the semester. This fluctuation in earlier weeks followed by a more stable incline in measures highlights the group structure became more defined as the semester developed. When looking at individuals, the strength of ties also has fluctuation throughout the year (Figure 4.9). At the beginning and end of the semester, Nadia, Ruben, and Abigail have the highest strength of ties. In Week 6 and 8, James has high strength, whereas Abigail has low strength. Throughout the semester, Ashley has low strength of ties.

Figure 4.8

Group level SNA measures for Group 8 across the semester

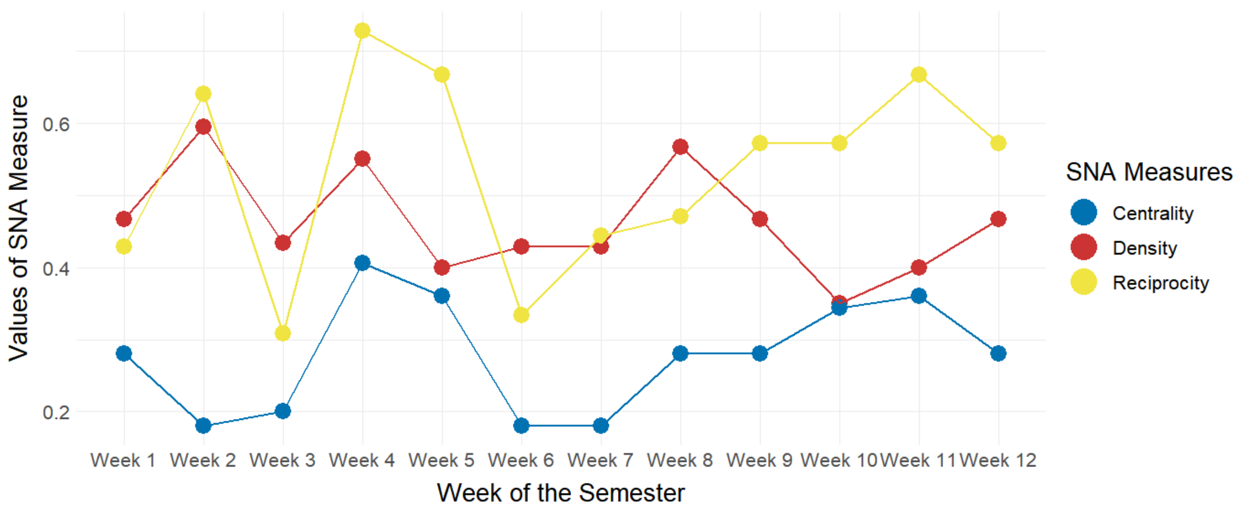
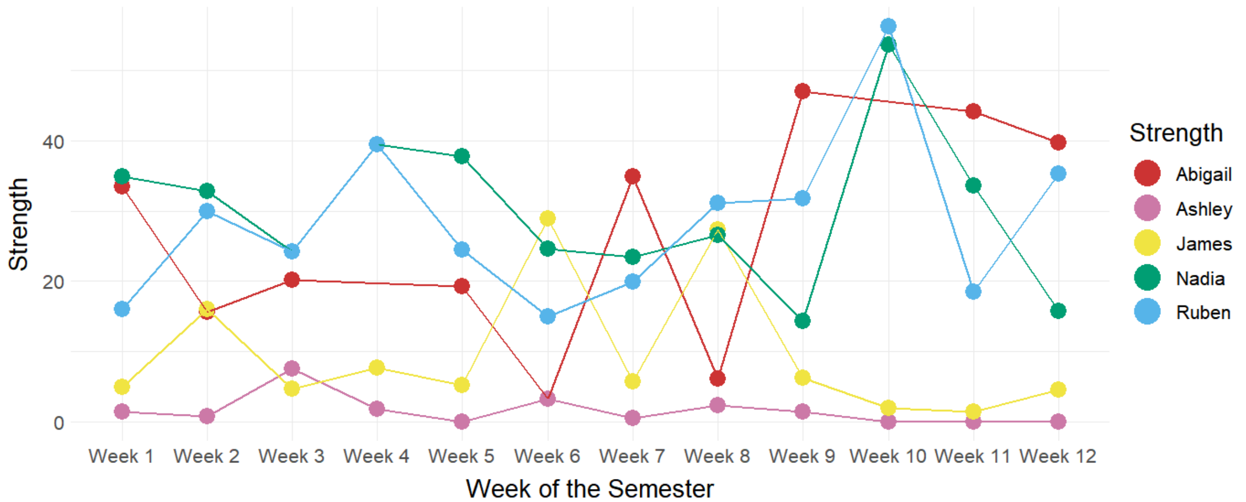


Figure 4.9

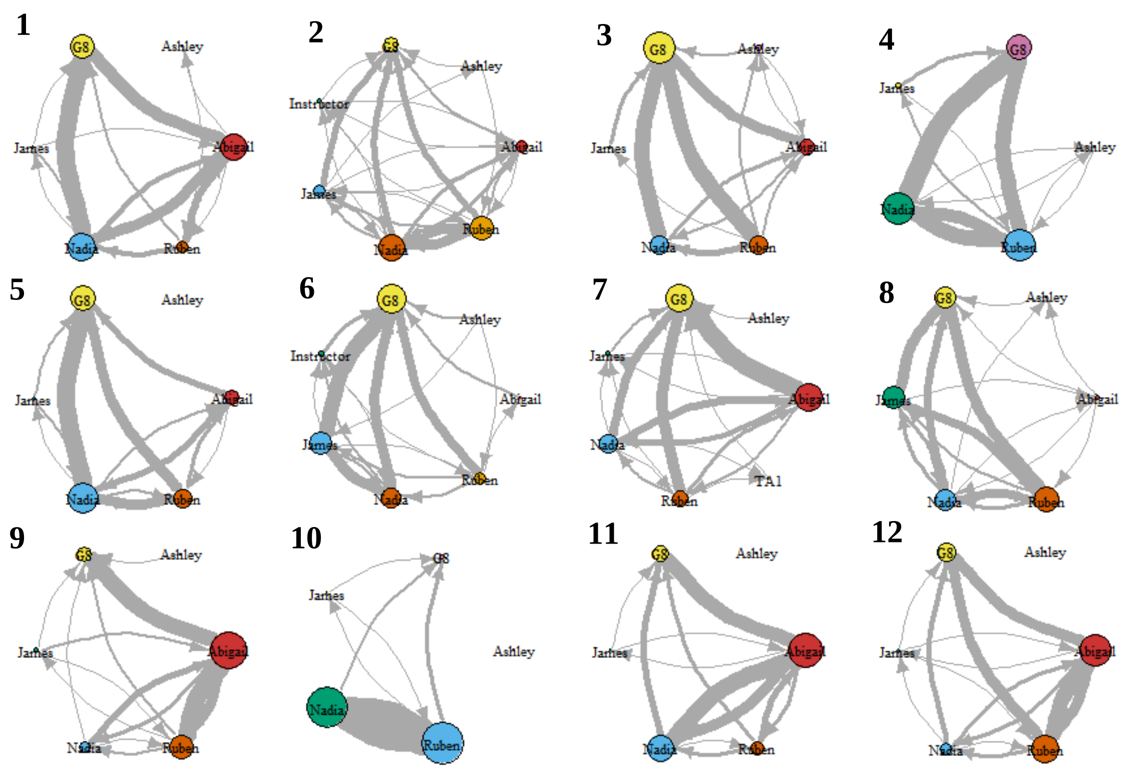
Strength measures for each individual in the small group for Group 8 across the twelve weeks of the semester



Within the sociograms for Group 8 (Figure 4.10), there was less conversation directed toward the group as whole and conversation became more siloed between two students as the weeks progressed. Generally, conversation in Group 8 also seemed to be influenced by the roles assigned for each week, in particular students who were assigned the reader or typer role were more central in the group. For Week 1, Nadia and Abigail were driving the conversation with most of the talk being directed towards the group as a whole, although Abigail had more talk that was directed toward an individual (Nadia and Ruben). During Week 2, the conversation was much more distributed across students in the group. Nadia and Ruben had central roles during the conversation and most of their conversation was between each other. In the following week, conversation was almost exclusively directed to the group as a whole for all students with little of the conversation moving directly between students. Week 4 consisted of Nadia and Ruben having a conversation between each other, even though they directed a large amount of their discourse to the group. This could highlight that Nadia and Ruben were responding back to each other when questions or statements were posed to the group. Despite their being a

Figure 4.10

Sociograms for Group 8 across the semester



Notes. Circles are nodes. Nodes represent students, instructor, whole group, and teaching assistants. Size of circles indicates the percentage of interactions for each node. Lines represent interactions. Arrows represent direction of interactions. Width of lines indicates the percentage of interactions between nodes. Bolded numbers represent the week of the semester.

large amount of discourse directed to the group, James and Ashley engaged very little with the discourse. Abigail was absent during this week.

For Week 5, Nadia had the most central role within the group with the majority of her discourse being directed to the group as a whole. Ashley was present but did not talk during the discussion. In Week 6, Nadia still had a central role in the group, but James had the most central role within the group with the majority of his talk going to the group as a whole. For Nadia, a large portion of her discourse was directed toward James, which may mean that James was initiating conversation and Nadia was responding to it. Week 7 had Abigail playing a the most central role in the group by directing her discourse to the group as a whole. Despite Nadia and Ruben having similar amounts and patterns of discourse, Nadia had more back and forth exchanges with Abigail during the conversation. During Week 8, Ruben occupied the most central role and had most of his discourse directed towards the group as a whole. For the next most central individuals (Nadia and James), their discourse was evenly distributed between Ruben and the group as a whole.

In Week 9, Abigail played a very central role with conversation from her being directed toward the group as a whole and Ruben. During this conversation, Abigail had the overwhelming majority of talk directed to the group as a whole. For talk directly between students, Abigail and Ruben had the majority of the talk only between them. For Week 10, Nadia and Ruben had a conversation that was almost exclusively between themselves and had very little talk directed out to the group as a whole. Abigail was absent during this week. Week 10 was a conversation that was primarily between Nadia and Abigail, although Abigail did have a large portion of her discourse directed towards the group as a whole. Finally, Week 12 had Abigail and Ruben in central roles in the group with the majority of conversation happening between them. They both had large portions of discourse directed at the group as a whole, but it seems as though they responded primarily to each other. For the last three weeks, Ashley was present but did not participate in the discussion at all.

As mentioned above, the assigned roles students had in the group impacted their participation within the conversation (Table 4.2). The majority of students who had a central role within the group were assigned to the reader (8 of 12 weeks) and typer (11 of 12 weeks). Regardless of her role, Ashley never had a central role within the group. When looking closer at the impact of the roles, Nadia and Ruben seem to be able to play central roles regardless of their role. For Abigail, she only had a central role if she was in the typer role and was never assigned the reader role. As the semester progressed, James became a central role when he was in the typer or reader role.

Table 4.2

Roles of Students for Group 8 across the semester

Week	Roles				
	Reader	Typer	Facilitator	Checker	Harmonizer
1	**Nadia**	**Abigail**	James	Ashley	Ruben
2	James	**Nadia**	Abigail	**Ruben**	Ashley
3	**Ruben**	Ashley	Abigail	**Nadia**	James
4	**Nadia***	**Ruben**	Ashley	**Nadia***	James
5	**Ruben**	**Nadia**	James	Abigail	Ashley
6	Ashley	**James**	Abigail	**Nadia**	Ruben
7	Ruben	**Abigail**	**Nadia**	Ashley	James
8	**James**	**Ruben**	Abigail	Ashley	Nadia

Table 4.2 (continued)

9	Ashley	**Abigail**	Nadia	James	**Ruben**
10	**Ruben**	**Nadia***	**Nadia***	James	Ashley
11	**Nadia**	**Abigail**	James	Ashley	Ruben
12	**Ruben**	**Abigail**	James	Nadia	Ashley

Note. Bold indicates students with the top two strength scores.

* Same student had two roles with the group

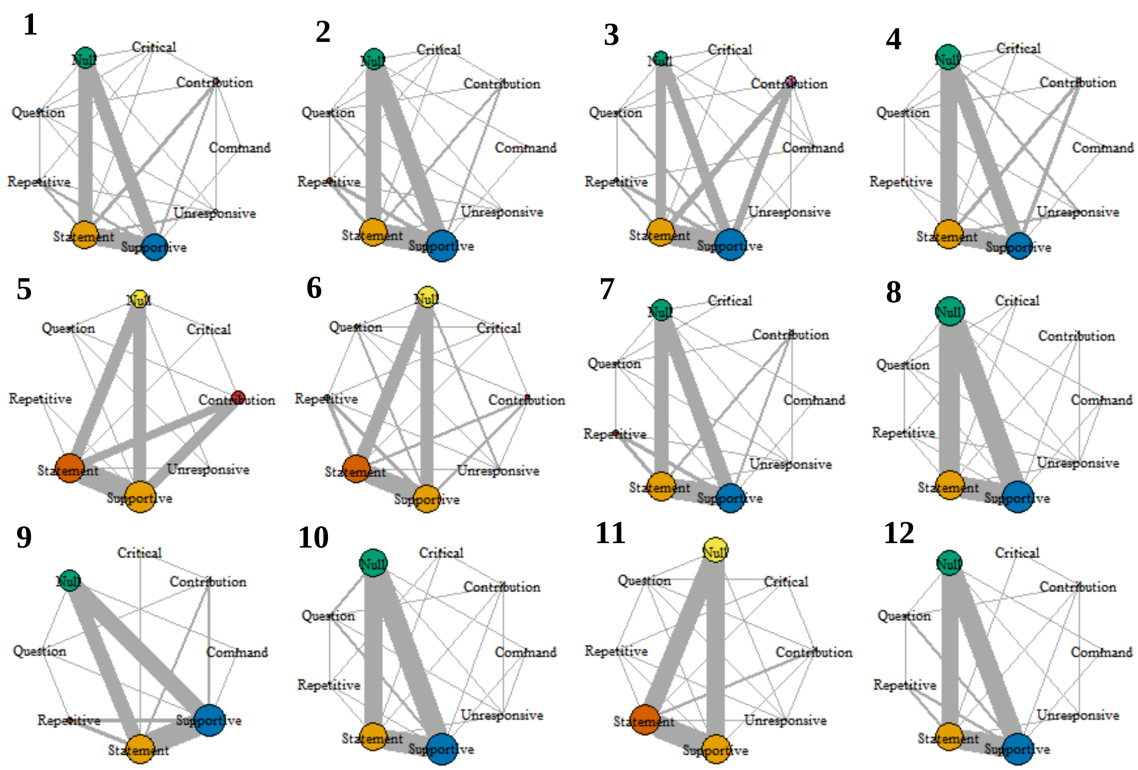
Group Dynamics

Group 1

The group dynamics seen across the conversations in Group 1 were individuals making supportive statements that did not offer content related to the prompt, regardless of the prompt (Figure 4.11). This pattern of group dynamics could mean that students are having off-topic conversations during the majority of the class period. It might also mean that students are quickly accepting information that is presented in the group, as opposed to presenting new information to build on the current information in the conversation. When focusing on individual weeks, Group 1 had a relatively higher proportion of contributed knowledge in Week 3 and 5. With the increase in contributed knowledge, the group built up their group answers during the conversation, rather than agreeing on information right away. Despite the increased contributed knowledge, the sociograms for Group 1 (Figure 4.4) highlight that the conversation is being dominated by Marylin and Sarah at Week 3 and 5, so potentially these increased contributions are not reflecting the whole groups ideas.

Figure 4.11

Group dynamics networks for Group 1 across the semester



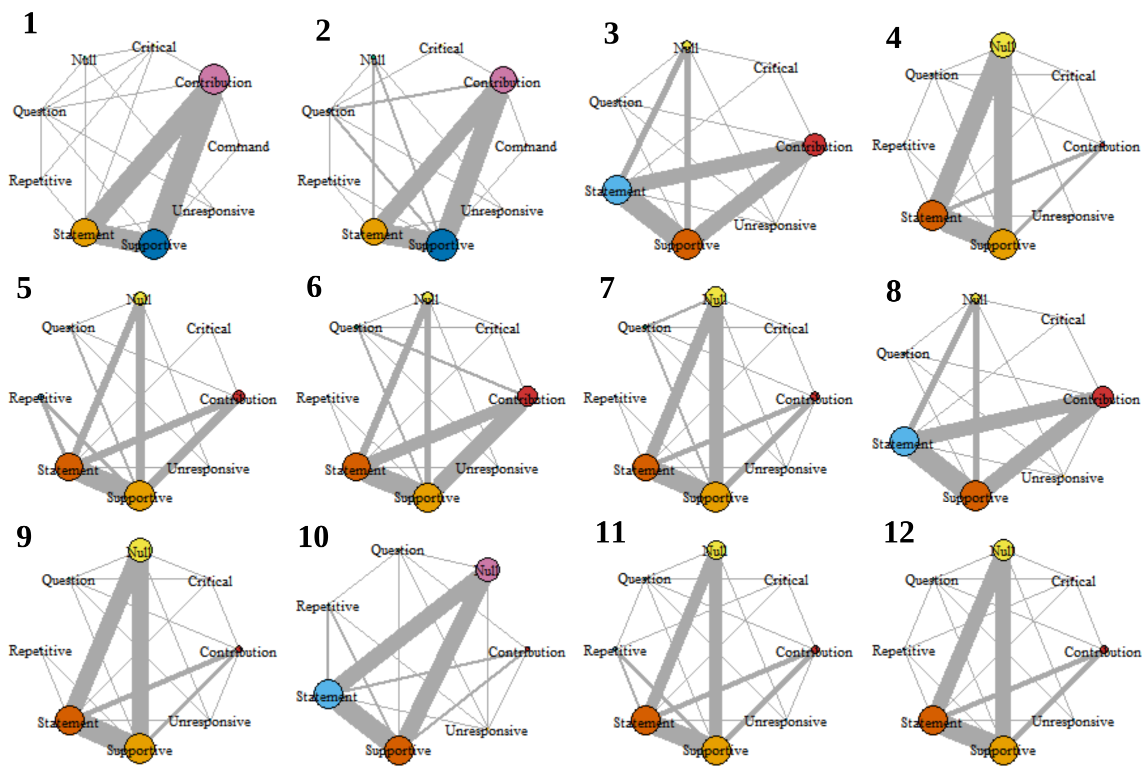
Notes. Circles are nodes. Nodes represent group dynamic codes. Size of circles indicates the percentage of interactions for each node. Lines represent interactions. Width of lines indicates the percentage of interactions between nodes. Bolded numbers represent the week of the semester.

Group 2

In Group 2, conversation started as supportive statements that contributed knowledge, then slowly transitioned to having more supportive statements that did not contribute knowledge and finished as supportive statements that did not contribute knowledge (Figure 4.12). When comparing the group dynamic networks to the sociograms (Figure 4.7), conversation became less directed towards the group as a whole as the contribution of knowledge decreased.

Figure 4.12

Group dynamics networks for Group 2 across the semester



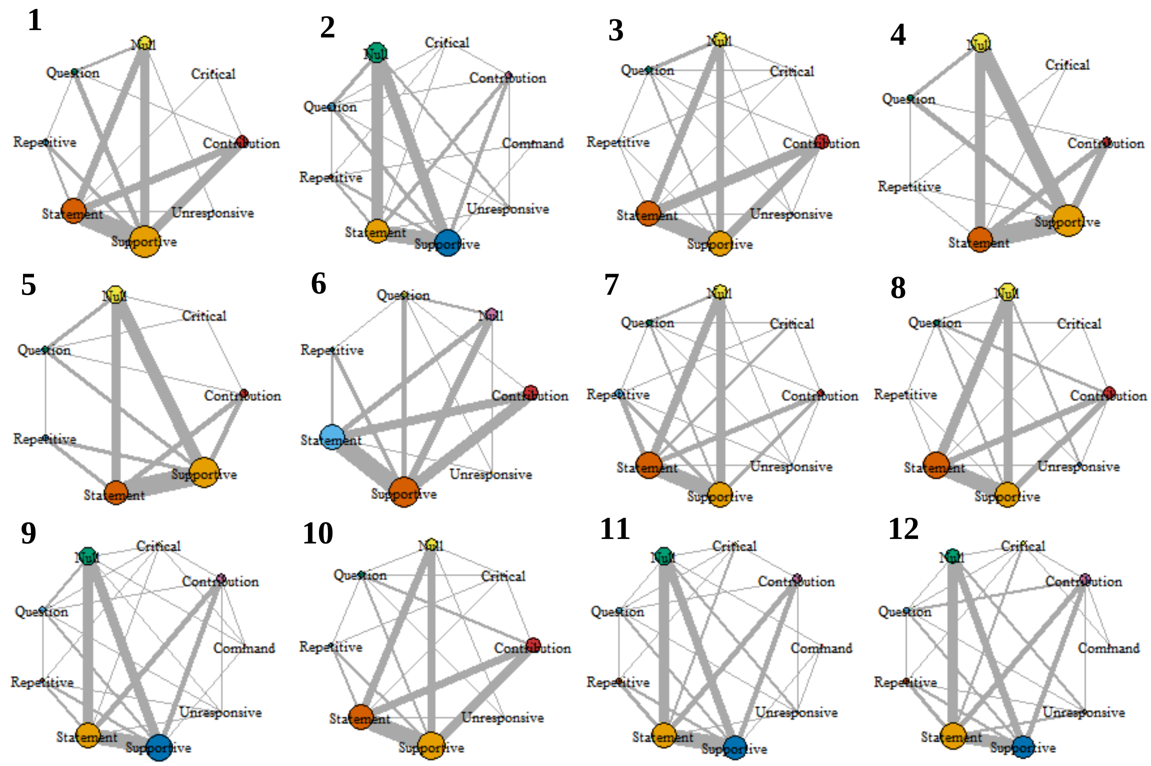
Notes. Circles are nodes. Nodes represent group dynamic codes. Size of circles indicates the percentage of interactions for each node. Lines represent interactions. Width of lines indicates the percentage of interactions between nodes. Bolded numbers represent the week of the semester.

Group 8

Throughout the semester, Group 8 mostly utilized supportive statements during conversation, but the contribution of knowledge varied (Figure 4.13). Generally, conversation had similar proportions of talk-turns that contributed and did not contribute knowledge. This pattern could indicate that the students were actively contributing knowledge to the conversation (e.g., Pheromones are chemoreceptors.) while also providing verbal support of the knowledge (e.g., yup), which highlights a collaborative process of developing the group answer. Group 8 tended to utilize questions more at the beginning of the semester when more conversation was being directed towards the group as a whole (Figure 4.10). Despite conversation becoming more centralized towards the end of the semester (Figure 4.10), the group still had a variety of group dynamics throughout the conversation. This may show that even though most of the conversation was happening between two students, those students were still building upon each other's knowledge to create the group answers. From the sociograms (Figure 4.10), the last four weeks were dominated by Abigail, Nadia, and Ruben and, therefore, the group answers would reflect these students' knowledge, regardless of if conversation was building knowledge.

Figure 4.13

Group dynamics networks for Group 8 across the semester



Notes. Circles are nodes. Nodes represent group dynamic codes. Size of circles indicates the percentage of interactions for each node. Lines represent interactions. Width of lines indicates the percentage of interactions between nodes. Bolded numbers represent the week of the semester.

Discussion

For this study, I looked at the longitudinal change in students' interactions within small groups across an entire semester. Despite having the same amount of time, roles, and tasks, small group dynamics showed high variation across groups. There were some general trends across groups, however. In general, small groups tended to become less collaborative towards the end of the semester, which could indicate that group dynamics became established over time. In general, at the beginning of the semester, most members had reciprocal interactions during discussions, but as the semester progressed, the discussions became siloed between two primarily students. As discussions became more siloed, group members tended to direct talk-turns less to the group and more towards specific individuals.

When looking individually at groups, the dynamics within Group 1 were consistent throughout the entire semester with individuals providing supportive statements that did not relate to the task. These statements indicate that the group quickly agreed on ideas that were presented during the task or individuals were having off-task conversation. This is further emphasized by two students (Marylin and Sarah) driving the conversation throughout the entire semester. For Group 1, this highlights that the group's collaborative answer was potentially developed by only one or two students.

Group 2 began the semester with more contributions of new knowledge to the conversation and contributed less knowledge as the semester progressed, but always utilized supportive statements. This pattern might suggest that the students started the semester sharing ideas amongst the group but gradually began to look to particular individuals for answers. For instance, Group 2 also had two students (April and Dean) who drove the conversation throughout the semester by addressing the group as a whole. This highlights that these two students were seen as the "experts" in the group.

Group 8 was the most dynamic of the groups by consistently utilizing more invitational forms and knowledge contributions. This dynamic nature is also shown by the fluctuation in which student had the most central role in the group during the semester., This centrality was, in part, influenced by the assigned roles. This combination of group dynamics and interaction may highlight that the assigned roles helped to distribute group discussion by allowing certain students to have space to state their ideas.

Implications for Instruction

When looking across groups, the variation in group dynamics may indicate that instructors need to consistently check in on groups to help ensure that all students are participating. This has been highlighted in prior research (e.g., Johnson & Johnson, 2003). Although it has been highlighted as important aspect of group work, instructors may not know what productive talk looks like within small groups and their role in helping encourage productive talk (Khong et al., 2019). From this study, instructors may benefit from observing students during the beginning weeks of group work to see which students may be dominating the discussion and then intervene into the group discussion to help assign new roles or bolster the voices of quieter students. By doing this, instructors can positively disrupt the established dynamics of the group to provide space for all students to state their ideas. Also, this disruption of group dynamics may be especially important at the end of the semester, as all of the groups in this study become less collaborative towards the end of the semester.

The topic being discussed did not seem to have an effect on small group discussion. Within each weekly task, the students were given a question that looked at the connection between the topic and society and asked the group to create a collaborative answer. When working through these questions, students did not seem to have differing opinions on the solution to the issue because they often used supportive statements that did not contribute new knowledge (e.g., yup) to move the discussion forward. The lack of difference between students' opinions is in contrast to previous studies that have utilized SSI interventions in the classroom, which showed students challenged each other's claims when developing a collaborative solution and had to reach a group consensus for how to move forward in the discussion. (e.g., Ottander & Simon, 2021; Solli et al., 2019). The contradictory findings in this study could be because of the amount of time and required detail for the task. Previous SSI interventions have dedicated weeks to one SSI (Albe, 2008; Furberg & Ludvigsen, 2008; Sadler, 2011), whereas our interventions were only for one class period (~50 minutes) and the SSI changed each week. Therefore, students may have thought it would be easier to agree to the solutions presented in the group and set aside their actual solutions because they knew a new topic would be discussed the following week. Although this approach of SSI intervention may not seem as in depth as prior interventions, it may be more reflective of how SSI are implemented in the classroom. This is because of time constraints when several topics are needed to be covered in the course, such an introductory biology course.

Also, since the groups tended to have one or two students driving the conversation, students may have felt that their ideas were in the minority and did not feel comfortable sharing them. In the SSI literature, researchers often utilize small groups in the classroom when implementing SSI interventions to encourage discussion between students (e.g., Chung et al., 2016; Lee et al., 2012; Owens et al., 2021; Sadler, 2004), but this study may indicate that more attention needs to be given to small group discussion during the intervention to ensure all students ideas are being incorporated into the collective answer. This may be especially true for longitudinal studies on students' discussion on SSI, since this study saw a drop in student collaboration at the end of a semester.

Implications for Research

The dynamic nature of small groups can be challenging to capture as a researcher and is further complicated when looking at longitudinal data (Kozlowski & Chao, 2018). Within this study, the combination of social network analysis (SNA) and epistemic network analysis (ENA) provided a lens to effectively capture longitudinal small group dynamics related to learning. SNA provided an understanding of the interactions between students during a single class period (the sociograms) and the change in those interactions across and entire semester (combination of sociograms and group-level SNA measures). By allowing researchers to track changes for a small group across a semester, SNA can help provide insight into how group structure impacts student discussion on SSI as well as learning. This could allow researchers to use SNA to locate potentially important shifts in student conversation that can then be looked at with a more fine-grained analysis (e.g., discourse analysis, ENA) to understand the content of student conversation.

Even though SNA was able to provide insight into how students were interacting, it did not provide an understanding as to what was the nature of those interactions. This gap was filled by ENA, specifically for understanding the dynamics of group discussion. ENA offers the opportunity to understand the connection between disciplinary content codes, rather than isolated incidents (e.g., counts of individual codes). This then allows researchers to track the development of the content of a conversation within a class period. Utilizing ENA across an entire semester can help researchers identify learning tasks that may or may not be eliciting productive student discussion and allow for the task to be modified (Wagner & González-Howard, 2018). This longitudinal analysis also provides a more detailed view of intervention design because it captured in-the-moment discourse to determine student learning during interventions, instead relying on pre-post testing alone.

While a more qualitative approach was taken when discussing the groups in this study, SNA and ENA also provide an opportunity to quantitatively understand longitudinal change within groups (Borgatti & Ofem, 2010; Shaffer et al., 2016). By using quantitative measures to track longitudinal change, it can allow researchers to have standardized measures across groups, which also allows for comparison between groups (Quintane et al., 2014). Having the ability to effectively and efficiently compare several small groups within classrooms can help researchers gain a detailed view of student interactions and add a unique understanding on a process of active learning.

Conclusions

In this study, small group discussion on SSI was followed for 12 weeks to understand the impact group structure has on student engagement and the longitudinal change in student interactions. Group interactions varied across the semester, with groups tending to become less collaborative toward the end of the semester. For group dynamics, all groups used supportive statements to move conversation forward, but the contribution of new knowledge to the conversation varied by group and week of the semester. For instruction, these results highlight 1) the potential need for instructors to continually check in with groups to ensure that all students are contributing to group discussion, 2) group dynamics can be consistent throughout a semester, regardless of SSI topic being discussed, and 3) SSI interventions need to give more attention to student interactions when implementing small groups. Lastly, the use of SNA and ENA to understand small group dynamics can help provide researchers with new insights into students’ interactions within active learning environments.

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CHAPTER 5: CONCLUSIONS

Students engage with science information from multiple sources on a daily basis, much of this information is not without controversy when situated in a social sphere. Socoscientific issues (SSI) are social issues that are potentially controversial and require some scientific knowledge to explain (Driver, Newton, & Osborne, 2000; Sadler, 2004; Zeidler & Nichols, 2009). Because SSI are situated in the broader society, they offer students an opportunity to develop skills in creating arguments for complex real-world issues. Even though they offer this opportunity, SSI argumentation can be influenced by students' personal belief on an SSI and not just factual scientific information (Carter & Wiles, 2014). This can make it difficult to decipher between scientific information and information based on personal believes.

Within education, researchers have designed several SSI interventions to help students develop arguments around SSI (Dawson & Carson, 2020; Dawson & Venville, 2013; Lee et al., 2013; Leung & Cheng, 2020; Yoon, 2011). For these interventions, researchers have drawn upon active learning strategies to encourage discussion between students. One particular practice that has been often utilized is small groups. While small groups have been shown to increase student learning (Freeman et al., 2014), this effectiveness relies on numerous factors that influence students' interactions (Chang & Brickman, 2018; Chai et al., 2019). Since the effectiveness of small groups can be impacted by a multitude of factors, it is important to use a methodology that can effectively capture and track group dynamics within a single class period and across multiple class periods. Social network analysis provides a flexible methodology that can allow researchers to understand the dynamic interactional nature of small groups (Carolan, 2013).

For Chapter Two, a systematic literature review on the use of social network analysis (SNA) to understand discourse within educational contexts was conducted to understand the following research questions: 1) what is the frequency distribution of the number of studies across time, across journal, and across education research disciplinary sub-type (RQ1), 2) what was the study type in terms of methodological approach (RQ2), 3) what type of educational environment was the data collected in (RQ3), 4) did the authors utilize other analyses in addition to SNA and how did this analysis complement or supplement the social network analysis (RQ4), 5) what SNA measures were used in this study to better understand discourse structure (RQ5)? The review showed that SNA is relatively recent methodology used in education research with the first paper being published in 2002 and has sparse usage in discourse studies. Articles that have developed SNA methods are specific to understanding discourse, which encourages the methods use in other discourse studies. The majority of articles collected online data, with few studies collecting in-person data. Because online courses are becoming more common, SNA provides a useful lens to understand the dynamics of students' interactions to help improve teaching practices. The lack of in-person studies draws attention to the need for these studies to help further the efficacy of the use of SNA methodologies in the classroom. Finally, the work demonstrated the flexibility of SNA as a methodology because researchers were able to use it for both quantitative and qualitative data.

In Chapter Three, a cross-sectional survey was conducted to answer the following research questions: 1) how do demographics relate to individuals' acceptance of socioscientific issues, 2) how are information sources related to individuals' acceptance of socioscientific issues, 3) how are information sources of SSI and SSI-Acceptance clusters affiliated to each other? This study found seven distinct groups of undergraduates that differed on their acceptance of SSI but had similar demographics. For most of the information sources, students' acceptance rates did not differ, except for human evolution and pesticide use. When comparing information sources used by each group, there were differences in the type of information sources used to gather information about SSI. Interestingly, similar information sources (i.e., social media, academic resources) were utilized by both high and low acceptance groups, which could indicate students are receiving siloed information from some sources. This highlights the need for instructors to utilize discourse within their classroom to allow students to interact with different informational sources on SSI and encourage engagement with differing views.

Finally, Chapter Four used a combination of social network analysis and epistemic analysis to understand longitudinal changes of small group interactions across twelve weeks. Specifically, this study answered these research questions: 1) Does group structure impact the development of the group engagement, 1a) If so, what factors (i.e., political affiliation, religious affiliation, gender, race, sexual orientation, ethnicity, assigned role) of group structure impact group engagement, 2) how do students' interactions change over time? Within this study, small group dynamics varied across groups, even though groups were provided with the same amount of time, roles, and tasks. There was less collaboration between students towards the end of the semester with discussion being usually isolated between two students. This variation in group dynamics and lower collaboration indicates that instructors may need to continually check in with groups to ensure that all students are contributing to the discussion. For this study, the particular SSI topic being discussed did not seem to have an effect on group dynamics, which could have been due to the amount of time spent on each topic (~50 mins). Students may have simply agreed with each other, rather than sharing their true thoughts, because the topics would not be discussed across multiple weeks. While this study did not see an effect of SSI on group dynamics, prior research has seen students' opinions differ in small groups (e.g., Ottander & Simon, 2021; Solli et al., 2019). Within SSI literature, small groups are often utilized to encourage discussion between students, but this study highlights that attention needs to be given to ensuring all students are contributing to group answers. If students are not contributing to group answers, the SSI interventions may not be having their intended effect on student learning.

Overall, this dissertation shows the flexibility of SNA as a methodology by using it across multiple research designs (i.e., cross-sectional survey, multiple case studies), highlighting prior research that analyzed qualitative and quantitative data, and within different research areas (information sources and SSI acceptance, small group dynamics). Drawing on this flexibility, this dissertation also helped to further methodological considerations on data collection related to small group dynamics. It is difficult to capture longitudinal change within small groups because of methodological limitations (Kozlowski & Chao, 2018), however, this dissertation, specifically Chapter Four, was able to gain understanding of multiple small groups across a twelve-week period at the group and individual level. From this, future research can build from this dissertation to further unravel the complex nature of small groups to help improve their implementation within the classroom.

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